Stopped Vehicle Hazards – Avoidance, Detection and Response (SHADAR)

Improving responses to stopped vehicle incidents

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D6.1 Improving responses to stopped vehicle incidents

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Executive summary

The project "SHADAR" (Stopped vehicle Hazards – Avoidance, Detection, And Response) addresses the objective of "Preventing collisions with stopped vehicles in a live traffic lane". Stopped vehicles on the highway network present a significant hazard with an impact on safety and the economy.

The SHADAR project aims to help reduce the risk of collisions with stopped vehicles on highway networks by improving the detection, reporting and management of these hazards. This is accomplished by establishing and sharing knowledge on current effective practices, and by researching potential improvements that can advance the current state of practice. This research proceeds in three inter-related strands – on detection and reporting technology, road user behaviour, and response from national road managers. The project identifies the state-of-the-art and then researches possible improvements.

This report is the output from SHADAR work package (WP) 6 which builds on previous SHADAR work packages, 2 (detection and response), 3 (response), 4 (road user behaviours) and 5 (detection improvement) to investigate and identify practical means of improving National Road Authorities‘ (NRA) and road managers‘ responses to stopped vehicle incidents.

After analysis we further considered 3 topics with potential to bring advancements in response:

- Human behaviours
- Fusion of data from multiple different sources, providing new information and allowing increased automation for operational response
- Connected vehicles and devices as a channel for NRA response

Methodology

The methodology applied outputs and activities from existing work by SHADAR:

WP2 – current detection technology

WP3 – barriers and enablers to an effective response, inputs into the Traffic Management Centre (TMC), road user behaviours and workshops previously conducted with National Road Authorities (NRA) and stakeholders

WP4 – driver understanding of road requirements and reporting when faced with a stopped vehicle

WP5 – the fusion of data from multiple sources and its presentation to operational staff

The link between people, processes and systems as explored in WP3 was used to support the development of scenarios and to understand further the impact on the TMC of the fusion of data or newer forms of data such as Waze and social media.

We elaborated a series of six scenarios, featuring different environmental conditions and combinations of technology or information inputs, to test what the NRA would consider useful and to understand what the barriers to acceptance of particular data inputs would be.

Semi-structured interviews were conducted with four NRAs based on the information from the WPs, the link between people process and systems and the developed scenarios, to support thinking about the pragmatic needs and potential interventions that could be applied to support improved NRA response.

Recommendations

Potential solutions and related considerations were identified for each sub-topic. Each would require tailoring for the context and current starting point of any single national road authority.

For **road user behaviours** the key requirement was a better understanding of what to do when faced with a stopped vehicle in a live lane situation. Education through campaigns and augmented driver learning could improve knowledge on how to report a stop and how to react to a stop. Delays between emergency calls and TMC contact also suggest potential for review and improvement of the processes and steps involved.

The input and use of **fused data** from potential new sources into the TMC led to much discussion and NRA suggestions on how best to incorporate such data to support fast and effective response. Crucial is the level of trust in the information that was being received, particularly from social media or apps such as Waze. Having multiple data sources could support confidence in the type of incident and response needed. Conversely there is concern that an operator may become overloaded with too much information which could impact effective response. Confidence levels determined by the data fusion regime can be used to help prioritise alerts for operational users. Studies of the experience of successfully importing new technologies into a TMC highlighted the need for involvement at the outset of the operators in the TMC in the design and implementation of new technologies and ways of working. Fused data integrated in the traffic management system also brings potential for performance assessment, both on technology and related response.

Connected vehicles and devices can provide an additional channel to disseminate information as part of the NRA response, but it is important that in-car information reaching road user via private organisations does not conflict with what they see from the road authority's own channels including roadside signs and signals. Consistency will support trust by the driver and should encourage helpful behaviours such as compliance with NRA advice. Specific cooperation patterns for public-private cooperation have been proposed, although these are likely to require ongoing funded effort to provide any benefit.

A separate idea at an earlier stage of readiness is standardised data communication between emergency responders and vehicles involved in incidents. Benefit has been suggested by research and the first standard has been produced, though given the early stage of the specifications further research seems required to confirm value and viability.

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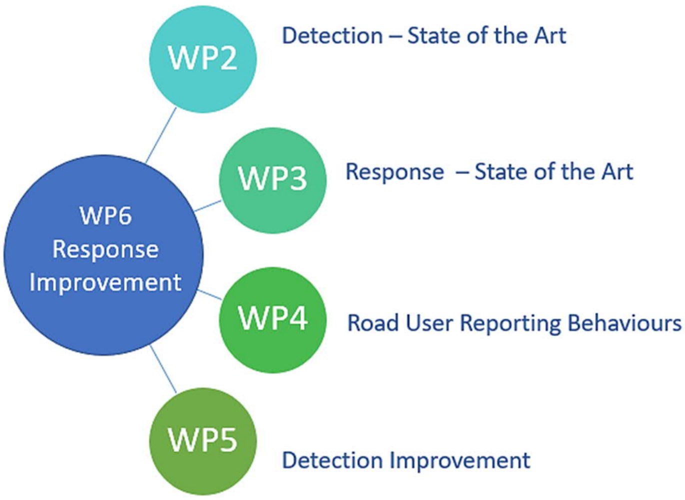
1 Introduction

1.1 Background

The project 'SHADAR' (Stopped Vehicle Hazards – Avoidance, Detection and Response) addresses the objective of 'Preventing collisions with stopped vehicles in a live traffic lane' as defined in the Description of Research Needs for Safe Smart Highways. Stopped vehicles on the highway network presents a significant hazard with impact on safety and the economy. The SHADAR project aims to help reduce the risk of collisions with stopped vehicles on highway networks by improving detection, reporting and management of these events.

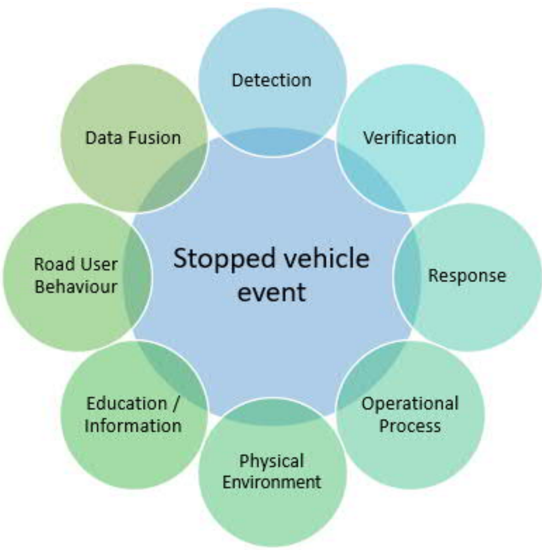
This report is the output from SHADAR Work Package (WP) 6 on response improvement, which is influenced by results of other WPs as illustrated in figure 1.1.

Figure 1-1: SHADAR Work Packages influencing WP6



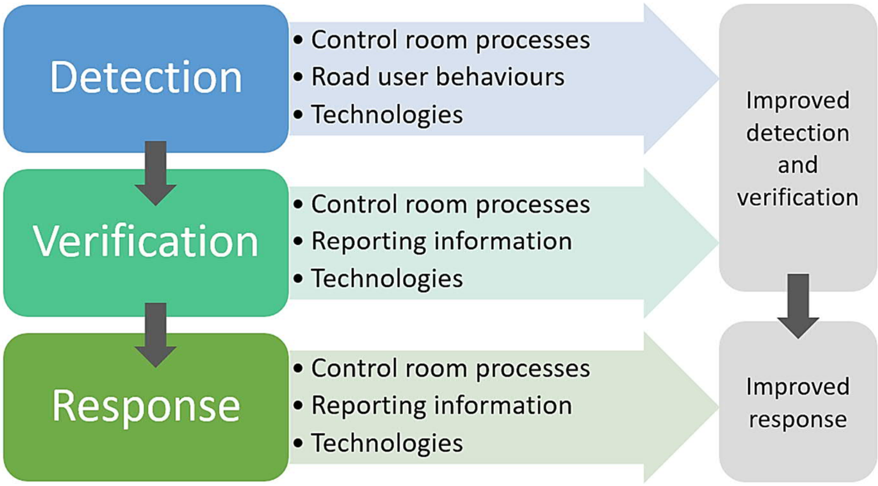
The work conducted delivered an understanding of the various factors involved in avoidance, detection and response discussed in this report, as shown in Figure 1.2.

Figure 1-2: Factors influencing potential stopped vehicle collisions



At a macro level, three inter-related strands inform this WP, detection and verification of the incident followed by the decision by the NRA to respond. Detection and verification are key to response time and response improvement. These strands are supported by associated technologies, road user behaviours, and NRA processes, procedures and decision making (Fig. 1.3).

Figure 1-3: WP6 aspects informing improved response



1.2 Purpose and structure

The objective of WP6 is to investigate and identify practical means of improving National Road Authorities (NRA) and road managers responses to stopped vehicle incidents. We further consider 3 topics with potential to bring advancements in response:

1. Human behaviours (section 3.1).
2. Exploiting fusion of data from multiple different sources, providing new information and allowing increased automation for operational response (sections 3.2 - 3.4).
3. Connected vehicles and devices within NRA response (section 4).

This report identifies current and future potential best practices and provides recommendations for improved stopped vehicle response. WP6 builds upon the findings of WP3, which considered the factors which support or hinder the response to stopped vehicles, to identify opportunities to improve the response. In addition to the findings of WP3 we refer to Work Packages 2, 4 and 5, to consider how improvements in detection and influencing driver behaviour could support the control room's response.

Response is informed by being able to detect that there is potentially a stopped vehicle in a live lane and then verifying the event to a level of confidence where the NRA will decide to respond according to their processes and procedures. To improve response, the detection and verification aspects need to be better informed to enhance the speed and appropriateness of the response. These areas are reviewed in this document as the stepping stones to response improvement.

1.3 Information from other work packages

Information from the following SHADAR WPs were utilised to support WP6 objectives and inform WP6:

- WP2 (detection and reporting) researched the state-of-the-art in stopped vehicle detection and reporting. The work considered current detection and verification methods and technologies, and the reporting of alerts to operational staff and/or automated response systems. Key detection methods identified three categories.
  - Firstly, human sight and included reporting by bystanders via roadside phone, mobile call, information posted on social media and navigation applications, and police, traffic officers and road inspectors.
  - Secondly, fixed sensors (roadside or in-road), such as induction loops, cameras, radar, and LiDAR (Light Detection and Ranging).
  - Thirdly, vehicle-based sensors, such as floating vehicle data, Cooperative ITS, and eCall. [Ref. 1].
- WP 3 (response) focused on understanding the factors which support or hinder response to stopped vehicles. It considered the inputs, outputs, and processes, and how this impacts effective response through a literature review and primary research. The research identified that control rooms respond to stopped vehicle by reacting to information they receive from technologies such as queue detection, radar, and external sources such as police, traffic officers on the ground and/or the public [Ref. 2].
- WP 4 (road user behaviour) investigated the reaction and behaviour of car drivers when faced with a stopped vehicle in a live lane on the highway network. It also sought to understand where drivers get their information about incidents on the highway and identify suggestions for improvement in this respect. WP4 applied virtual reality simulations which highlighted the variable responses to how drivers would behave and their knowledge of who they would contact to report a stopped vehicle in a live lane. The majority of participants confirmed not knowing which number to call or organization to alert, with the default option being to call the police. A second set of virtual reality simulations (concurrent with the research in this report) explored the effects of different methods of providing warning information, and provided conclusions [Ref. 3] for NRA information provision which for completeness are also summarized in the conclusion of the present report.
- WP 5 (detection improvement) investigated real-time detection of stopped vehicles and the fusion of data from multiple sources to improve detection and response. The WP identified options for improving the time to detect, the reliability of detection, the kinds of information that can be gathered and reported, and how it is reported to traffic operators and policy makers [Ref. 4]. The WP considered potential improvements using RADAR, eCall and other connected vehicle sources, drones, human reporting, the fusion of multiple sources, and how the outputs could be presented to traffic operators and technology managers. The use of data fusion in WP5 was explored further in interviews with NRAs as part of WP6 and is discussed in section 3.

Appendix A identifies further potential work items that were not taken up and has been included to help guide future work.

2 Methodology

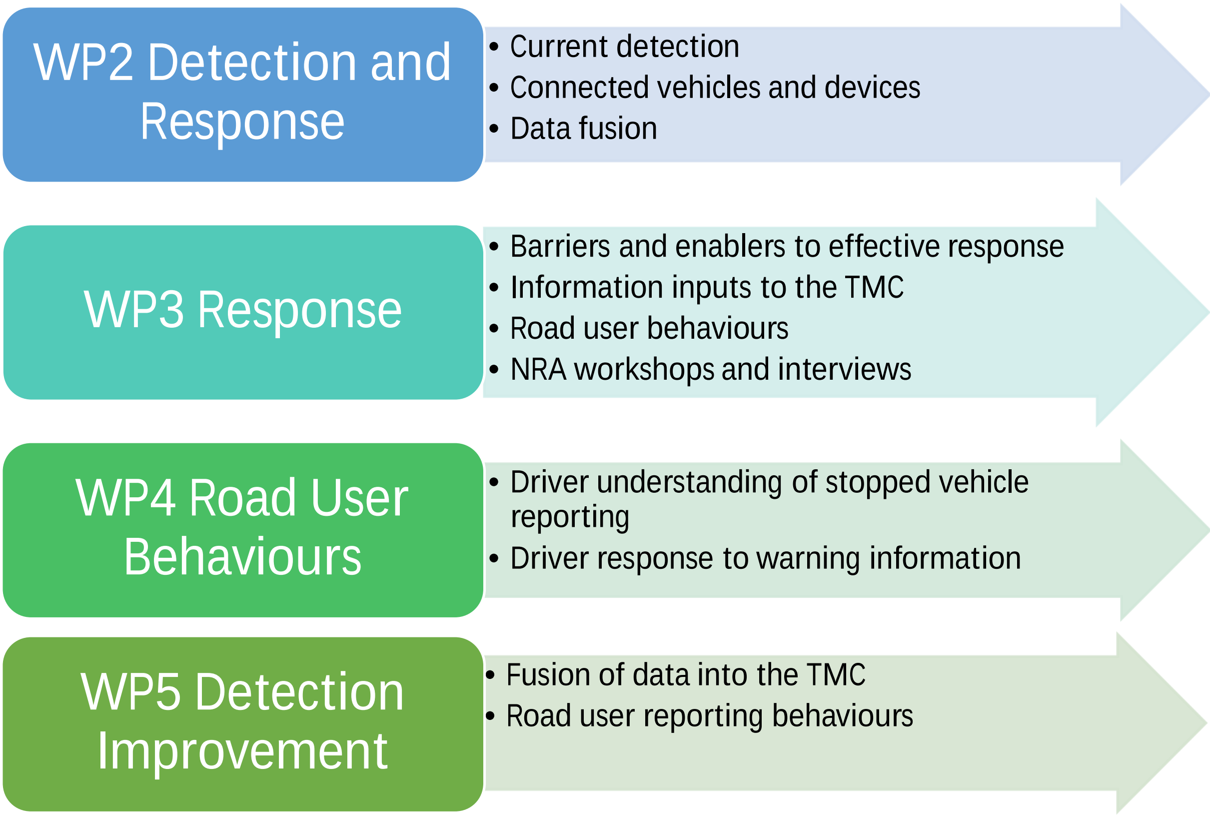
To inform the methodology, the following inputs were used:

- Other SHADAR work packages
- People, process and system review to inform interviews
- Scenarios developed to support the NRA interviews
- Results of relevant recent research
- Semi-structured interviews with NRAs

2.1.1 Use of other SHADAR WPs

To elicit greater understanding and to test ideas around the objective of improved response times including the identified sub-tasks (behaviour, fusion, connectivity – section 1.2), relevant information and activities carried out in WPs 2, 3, 4 and 5 were utilised, as shown in Figure 2.1:

Figure 2-1: Information from WPs used to inform WP6

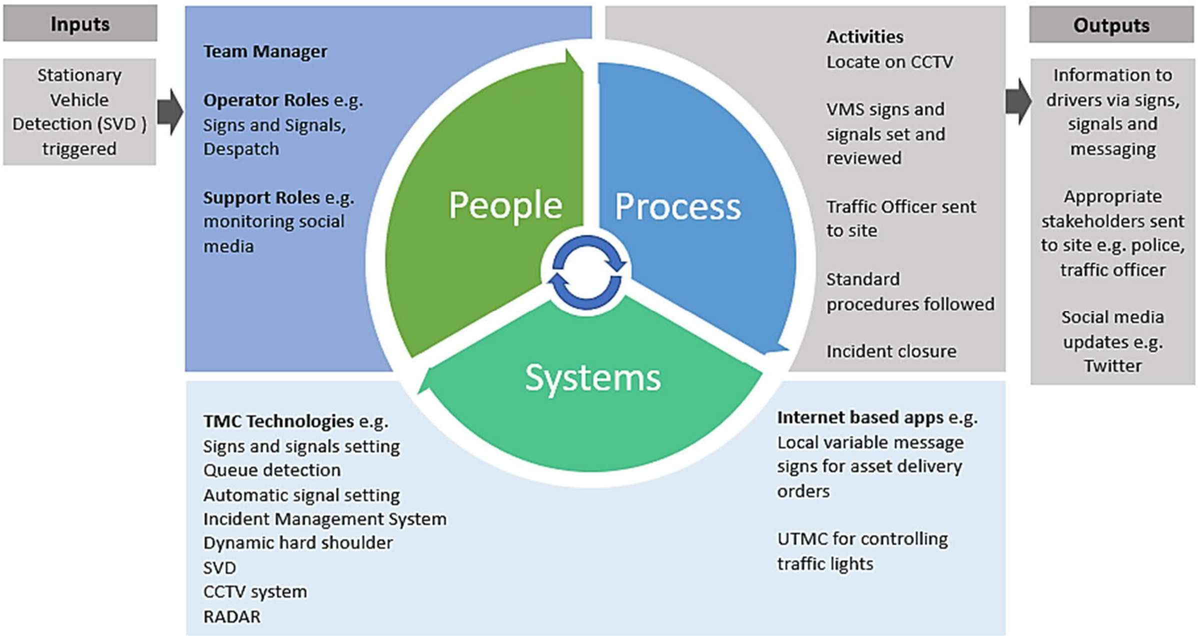


2.1.2 People, process, systems

WP3 [Ref. 5] explored the link and relationships between the people, process and systems that are required to deliver an effective response when a stopped vehicle is detected. This link was used in the semi-structured interviews with the NRAs to support exploration of the scenarios described in table 2.1 and provoke additional discussion with the NRAs.

Figure 2.2 provides a high level example of a stopped vehicle alert input into the TMC, and the people, process and systems involved.

Figure 2-2: Link analysis – relationships between people, processes and systems



2.1.3 NRA semi-structured interviews on operational response

From the information and activities carried out in other WPs, a baseline question set was identified to use in semi-structured interviews with NRAs. These were conducted to inform potential ways of improving response from the NRA's perspective. These interviews included material from WP5 and were compiled to ensure the previously identified three sub-tasks were addressed. The interviews were conducted either via video conferencing or face-to-face, with NRA stakeholders who had a strategic interest and operational involvement in managing stopped vehicles in live lanes.

Key themes explored in the interviews around improved response were:

- Road user responses
- The usefulness of different forms of data
- The impact of fusing different forms of data to improve detection, verification and response useful over and above current practices
- Presentation of user interface (UI) information to understand what information may be useful to TMC to see in order to inform response (WP5.6) [Ref. 4]
- Impact of increased automation and data on control room response (WP5.6) [Ref. 4]

The interviews were held between 9th June and 22nd July 2022 with four NRAs:

- National Highways (NH)
- Transport Scotland (TS)
- Rijkswaterstaat (RWS)
- Transport Infrastructure Ireland (TII)

The NRA roles interviewed were:

- Operations Centre Managers
- Senior Operations Manager
- Motorway Operations Manager
- National Technology Relationship Managers
- Design and Maintenance of Road Infrastructure
- Intelligent Transport Lead
- Business Architect - Traffic Management Systems

Each of the NRAs have different geographic, roadside and TMC technologies, operational processes and cultures which inform how they are currently able to detect, verify and respond and which inform potential future requirements. Table 3.1 details the scenarios and responses of the different NRAs.

2.1.4 Stopped vehicle scenarios

The semi-structured interviews used supporting material from WP5 to present six different scenarios and user interface mock-ups to support stakeholder understanding and elicit discussion [Ref. 4]. The six scenarios covered different environmental situations, each with differing forms and volumes of information to support TMC operator understanding. Table 2.1 describes these scenarios and the information received into the TMC:

Table 2.1: Scenario descriptions

No.	Scenario Description	Input to TMC
1	Incident on rural road. No available roadside technology. Multiple low-level reports leading to a high confidence rate	Manual eCall activation Waze activation (type: hazard) Waze activation (type: accident minor)
2	Major road breakdown	RADAR Automatic eCall (providing vehicle details e.g. electric car)
3	Major road, multiple collisions, no RADAR in the area. Escalating levels of information into control room	Traffic detectors activate traffic slow-down (low likelihood, low impact event) Manual eCall received (now medium likelihood, low impact event Then multiple Waze events stating hazard on road, accident major (now high likelihood, high impact event)
4	Critical incident, multiple collisions	RADAR alert 3 automatic eCall activations (including vehicle details) Multiple manual eCall activations Multiple Waze activations

5	Breakdown at night. Rural area. Severe weather e.g., snow. CCTV unavailable	Waze report of an accident
6	Waze alert in RADAR area. RADAR does not activate	Traffic detectors activate traffic slowdown (low likelihood, low impact event Waze alert – accident (medium likelihood) RADAR does not alert

Appendix B provides a copy of the questions used to support the discussions; the images and screenshots are available as a separate appenix of D5.1 [Ref. 6].

2.1.5 In-vehicle technology as a response channel

We studied the relevant research project SOCRATES$^{2.0}$ [Ref 8], conducted further discussions within the TM2.0 organisation, and held 9 interviews with national and regional roads authorities. The scope of these discussions was wider than the SHADAR project; the relevant aspects for stopped vehicle traffic management are given in section 4 of this report.

Late in the project we became aware of the forthcoming CEN specification on post-eCall incident support communciations. This was too late for inclusion in any interviews, but we include a brief analysis of the July 2022 draft specification.

2.1.6 Methodology challenges

Understanding the challenges and limitations the study team encountered when understanding and testing potential improvements to the NRAs response included factors outside of the research team's control. These included:

- The number of European-wide NRAs available for interview. Four NRAs were open to participation. This meant that some factors such as the variety of NRA practices and procedures, particular environmental aspects such as long tunnels and varying road technologies could not be fully explored. Our conclusions are drawn from a relatively small sample size.
- Obtaining suitable participants for each aspect of the conversation was also challenging given NRA staff time constraints and some difficulty identifying the correct personnel.

3 Interview findings and analysis

This section reports the results of analysis of relevant parts of other SHADAR work packages and the semi-structured interviews. It considers the role of the road user in reporting a stopped vehicle, the impact of different forms of data coming into the control room: how they are presented and their influence on NRA response.

3.1 Road user behaviours

Key to a speedy response to a stopped vehicle by the NRA is the timely detection and verification of the incident. As the road user is likely to have the initial primary knowledge that an incident has taken place, being able to get the person to report accurately and swiftly is an important first step to improved response.

The WPs and interviews highlighted some essential issues with road users and their responses to a stopped vehicle. This included understanding how and to whom to report the incident. WP4 (road user behaviour) identified some factors that act as barriers to road users reporting an incident:

- Individuals may consider it too dangerous on motorways to stop and use their mobile to report something
- Most of the participants in WP 4 did not know which number to call or which organisation to alert when seeing a stopped vehicle on the road, the majority would alert the police rather than the NRA
- Not everyone knows about the eCall function, or if they do know, are unsure about how it works
- Lack of knowledge about how to react in a situation when encountering a vehicle which has stopped in a live lane

WP5 [Ref. 4] suggest that public behaviour for alerting police or road authorities is not uniform. Awareness of how to act when a stopped vehicle/incident is encountered seems low and diverse. It was advocated that road authorities, governments or traffic safety organisations could contribute further by making the appropriate information more publicly available.

The semi-structured interviews also confirmed that from an NRA perspective drivers may have limited understanding about who to report an incident to. There may also be a lack of understanding that the driver of the stopped vehicle could be reinforcing a potential hazard by not moving to a place of safety. The NRAs advised that reporting of a hazard by a passer-by could be problematic for improving response due to:

- Misinformation being supplied to the traffic operator by misreading a situation. For example, a person laying down beside the road whilst awaiting a pick-up truck can be misread by a passer-by as someone dead.
- Delay between reporting and passing the incident whilst the driver finds a safe spot to stop and call
- Lack of accurate or misleading location information including road, motorway and junction numbers and direction of travel leading to increased delay in response.
- Lack of knowledge regarding road terminology which could impeded effective response, such as being able to differentiate lanes, whether the stopped vehicle was on a verge,

hard shoulder or emergency bay or understanding the purpose of markers on the side of a highway.

As the calls generally go to a call centre or highways customer care line rather than direct to a highways control room there is an additional delay in the control room receiving knowledge of a potential incident. One NRA advised that if a road user/passer-by calls their customer care line, it will be logged in the call centre and gets processed through the system and onwards to the traffic control room via email. However, it was noted that it may take ‘hours’ before that logged call arrives and that there is no direct link between the public and the traffic control room other than via social media such as Twitter. Another NRA noted that police will forward report logs of unconfirmed incidents but the length of time it takes to reach the TMC can be between 15 – 60 minutes depending on how busy the police are. The reports received from the police by the NRA use grid references to identify locations, but these are not natively supported by NRA systems thus making location of the incident difficult and adding delay to response.

3.2 Data fusion, increased automation and data in the TMC

Table 3.1 describes six scenarios and differing types of data available to the TMC, presented to the NRAs at the interviews. The table informs the different NRA responses and provides recommendations from the interviews with the NRAs when considering the fusion of different data sources into the TMC.

Table 3.1: NRA comments and recommendations re TMC fused data

Scenario	Data input to control centre	NRA Comment	NRA Recommendations
1. Incident on rural road. No available roadside technology. Multiple low-level reports leading to a high confidence rate	Manual eCall activation Waze activation (type: hazard) Waze activation (type: accident minor)	Manual eCall activation will go to the police. The speed of the information log getting to the NRA control room depends on how busy the police are. Could be immediate or between 15 minutes to 1 hour later. Issue with automated eCall is that it provides grid reference and NRA requires road names and junction numbers to identify location to speed response. Uncertainty around the accuracy of eCall information Concern that different sources of information may provide differing information so trust in the data may become an issue. Prioritising of information – more likely to trust and respond to several calls from the public via mobile than a single unconfirmed call	Provide ability to convert grid references automatically to road/junction descriptors. Trust in the information is key when introducing new sources of data so testing is key to understanding confidence levels that allow for decision making by the operator.
		Interest in both Waze and manual eCall activation. An automated unverified link would need to have confidence and a level of trust that the information was accurate and not subject to human error. Data fusion in this scenario is of interest and would reduce operator workload and support a faster response, but only if there was confidence in the information provided Risk of incorrect assumption that 2 separate alerts refer to the same incident, potentially leading to premature closure of incident.	The fusion of data is only useful if a confidence level is applied that can support verification and response. Fused data needs to be able to differentiate between separate incidents.
		Fused manual eCall, and Waze activation (type hazard) would be most useful because they have a high probability/ high impact and would improve the verification process which supports faster response. Automation of data reduces the chance of incorrect data being entered in log files by the operator and adversely impacting verification and response. 10% false positives would be acceptable when looking at delivering an automatic alert. Overall preference for automatic alerts.	Consideration for probability and impact levels when considering types/levels of data to fuse. Agreement on acceptable levels of false positives when fusing data need to be considered.
		NRA already has Waze interchange. The traffic management system takes reliability and confidence from Waze and applies a threshold so only reliable/confident alerts reach the operator. Incident context determines the approach to priority in response e.g., rural vs managed motorway.	
2. Major road	RADAR	Provision of RADAR and eCall provide event details that enable an	

Scenario	Data input to control centre	NRA Comment	NRA Recommendations
breakdown	Automatic eCall (providing vehicle details e.g. electric car)	effective response i.e. jointly they would provide knowledge that an electric car had broken down and therefore an understanding of towing restrictions to inform the response.	
		Having both RADAR and automatic eCall would improve response. Currently rely on a report being phoned in or pick it up on CCTV (there is limited coverage and where there is full coverage NRA operator can only view one direction at a time so gaps to viewing network.	Increased trusted technologies would support improved and faster response. Currently looking at integrated RADAR and CCTV which can be overwritten manually by an operator to support improved detection and response
		Automated eCall is considered to indicate high probability of an incident so a response will commence immediately. eCall alerts are currently sent to the police who inform TMC via phone, eCalls should be received automatically by TMC to reduce response time. NRA does not use RADAR and has no immediate plans to adopt.	To improve response time, review number of steps between manual eCall activation and alert to the TMC.
		NRA does not use RADAR but has video analytics in part of their network. The automatic eCall is perceived by NRA for emergency services to respond to.	Understand from NRAs what data is suitable for fusion when aligned with their technologies and road user behaviours.
3. Major road, multiple collisions, no RADAR in the area. Escalating levels of information into control room	Traffic detectors activate traffic slow-down (low likelihood, low impact event) Manual eCall received (now medium likelihood, low impact event Then multiple Waze events stating hazard on road, accident major (now high likelihood, high impact event)	Scenario did not provoke much discussion. Systems detection of traffic slow down combined with manual eCall, and social media information would support detection of an incident prior to following processes to verify and send out appropriate response.	
		Currently only respond when an incident can be verified. If no CCTV then need trustworthy information so would deploy the police and road operating company to get to incident site as quickly as possible and verify. Would place warning signs on as a caution to drivers until incident confirmed. May be helpful if there were a few incidents at the same and there was a need to prioritize e.g. woman with child in vehicle on their own.	Information needs to be trusted. Could support prioritisation of response and resources if there were reports of multiple incidents
		CCTV not required – a traffic officer would be sent based on eCall activation alone. CCTV would support greater understanding of the situation and provide accurate location information allowing for matrix signs to be activated (all highways that have CCTV have matrix signs). Multiple Waze alerts in this scenario would support dispatch of a	Data should display increased urgency levels based on the information provided by the data to support effective response.

Scenario	Data input to control centre	NRA Comment	NRA Recommendations
		traffic officer.	
		NRA has no interest in eCall voice calls but sees potential the data to inform verification and response. Levels of impact already used within NRA - 4 defined levels relating to safety and traffic congestion impact which influence priority level. Multiple unconfirmed alerts of the same event could be considered confirmed which will support a faster verification and response	Evaluate the type and number of unconfirmed reports needed to be considered as confirming that an event can be confirmed as verified and a response is required.
4. Critical incident, multiple collisions	RADAR alert 3 automatic eCall activations (including vehicle details) Multiple manual eCall activations Multiple Waze activations	Issue with the number of alerts and reports. Waze not considered helpful because radar had already identified a problem. ECall would provide information which would be critical to the response. Previously experienced receipt of many duplicate logs with slightly differing information. These get responded to as one incident when they could indicate a number of different incidents close together	Consideration needs to be given to the source and how much information is presented into the control room and the potential to either add value or overload the operator or mis-inform of incident situation. Potential needed to suppress additional alerts in the area to avoid distracting operators
		Volume of information could become overload and distracting quite quickly and also having the time to respond e.g. to social media via Twitter. However, can help if it's an extended incident to receive updates but issue is how recent are the updates, potentially information is from someone who passed the incident 10 minutes earlier so different levels of accuracy	Consideration to timeliness of information and how to piece disparate pieces of information together to provide a timely, accurate picture to verify with confidence and deliver appropriate response.
		Level of information coming in to the TMC from this scenario would support multiple traffic officers, tow trucks and so forth being sent to the location. The TMC would advise the police to attend.	
		Where multiple sources are available it is important for the system to work out the implications e.g. the confidence in an alert, rather than throw multiple separate pieces of information at an operator and require the operator to work out the implications.	Data fusion system to not deliver multiple pieces of information to an operator which may result in overload, but to work out the implications and confidence levels in the data and provide a (potentially) single rather than multiple alerts so that appropriate response can be given.
5. Breakdown at night. Rural area. Bad weather e.g. snow. CCTV unavailable	Waze report of an accident	Currently don't use Waze. Unlikely to respond to a single Waze report, if a Waze report occurs then operator will try to use current technology or go via the police to see if there was any verifying information to support a response. Context of incident also important, for example, a Waze report of a school bus on fire then NRA would expect to see a number of reports coming in to support a response. Environmental conditions may impact response, for example if deep snow then they will likely prioritise a response over a similar situation where there is no snow.	Levels of confidence need to be considered balanced against the number of Waze reports occurring and the trust placed in those reports before serious consideration is given to using Waze as part of a response decision making tool

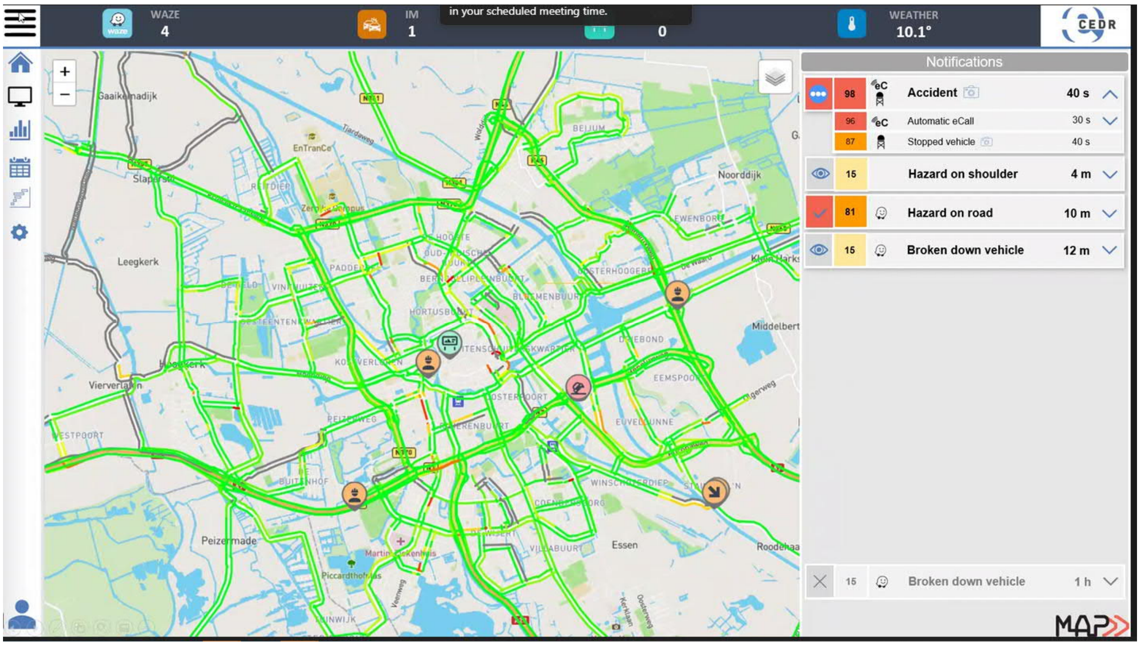
Scenario	Data input to control centre	NRA Comment	NRA Recommendations
		Would not ignore a Waze report but would look to verify by checking for congestion via their systems e.g., INRIX mobility data. Weather data important – currently manually check using nearest weather station (mainly for rural areas)	Due to the nature of national weather and rural environment, integration of granular weather data and road condition information useful to aid preparation for response support.
		Would not respond to a single Waze report alone. Would require multiple forms of evidence e.g., multiple Waze or other crowd sourced reports (e.g., Flitsmeisther/AmiGo by TomTom), a 112 call, floating car data. Potentially could increase hazard level due to environmental conditions.	Confirm type of data sources and volume of data source that would be needed to indicate TMC needs to detect, verify and respond. External conditions e.g. extreme cold, could inform the decision to provide a response on a single Waze report.
		Single Waze report treated as unconfirmed and further corroboration is sought e.g., traffic effects seen in Google data. Will not respond without additional confirmation.	Connected vehicle data has greater potential for corroborating unconfirmed reports and supporting faster verification and response.
6. Waze alert in RADAR area. RADAR does not activate	Traffic detectors activate traffic slowdown (low likelihood, low impact event Waze alert – accident (medium likelihood) RADAR does not alert	Currently NRA has to respond to a direct report, which Waze isn't considered to be, Waze is deemed an additional, unconfirmed piece of information and there needs to be trust in the data. Cannot see Waze being incorporated into the control room at this point in time.	Studies needed to confirm how reliable Waze is in the information it provides to improve confidence and trust in it as a tool for response decision making.
		If a Waze report was received but no RADAR alert, they would still check the CCTV or other systems to see if there was congestion build up. If had both a Waze and RADAR alert, they would prioritize the RADAR. If had both RADAR and Waze alerts, then this would provide more confidence when setting matrix signs.	Multiple data sources can support confidence in the type of messaging that's put out and help speed up detection and verification of the incident
		Single Waze alert would not support sending out a traffic officer. Combination of Waze alert and traffic detectors (traffic loop information) would support sending out resource.	Define the number of Waze alerts needed to deliver confidence that either verification or a response is required.
		NRA would not activate a response based on this scenario, would continue to monitor.	

3.3 User Interface (UI) dashboard

WP 5 [Ref. 4] explored future and upcoming methods for stopped vehicle detection to consider new practical means of real-time detection and reporting of stopped vehicles. The following images were used with the NRAs to support discussion around the usefulness of presenting information to operators to deliver improved detection, verification and response.

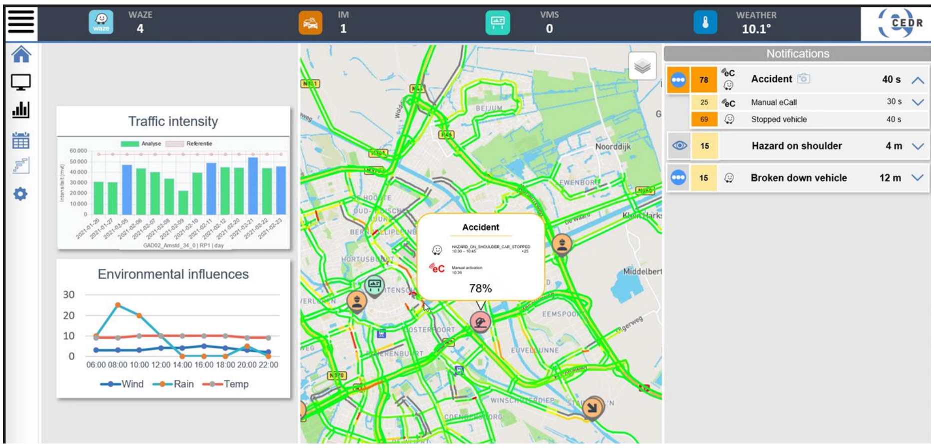
Figure 3.1 explores the grouping of events with colours (e.g., red, amber, yellow) to provide indication of confidence levels in the event and potential seriousness of the event. NRAs said that colour indication informing of importance / type of incident would be useful if accurate.

Figure 3-1: Geographic area and grouping of events



An NRA highlighted the importance of simplicity in the presentation of information so that the operator was not overloaded and could quickly see where they should focus their attention. Figure 3.2 shows additional information added to figure 3.1 above, and was considered to provide too much information, with the operator having to spend longer to understand what was being shown and in decoding the importance of the information. An NRA indicated that an operator should not need to spend more than 10 seconds trying to understand what they were looking at to inform an operator decision. The illustration of environmental influences (wind, rain, temperature) was considered unnecessary, making more difficult to focus on necessary information.

Figure 3-2: Geographic area with additional traffic and environmental information



The interviews also considered the usefulness of technology and operational performance dashboard reports. This is described in Appendix C as it is mostly outside the topic of response.

3.4 New technologies and the control room environment

The concept of data fusion and presentation of new or additional information into a TMC requires careful consideration if uptake is to be successful in achieving improved detection, verification and response times.

WP3 [Ref. 2] identified that when introducing new technologies, for their uptake to be successful, control room operators and stakeholders need to be engaged from the start with the integration of the technologies and how they support improvement in response time. Additionally, as the effectiveness of the control room is dependent upon the interaction between staff and technology, consideration should be given to how this knowledge is refreshed and sustained.

The research in WP3 also found that the impact of technology unavailability or failure, combined with other scenarios such as peak traffic or severe weather conditions, was a key technology risk, whilst developing a systems response for each variant would be challenging. With this in mind, the need for skilled and knowledgeable operators is imperative to dynamically determine a suitable response, thus highlighting a training need.

The interviews with the NRAs highlighted the concerns around aspects such as potential information overload and the need for confidence and trust in the information to support response decision making. It is also clear that each NRA has their own individual cultures and technologies, and consideration needs to be given to what information is presented and how. For example, providing relevant location information such as road and junction numbers rather than grid references which the TMC management systems are unable to interpret to determine the specific locality of the incident (Table 3.1).

4 Connected vehicles and devices in NRA response

This section explores the potential for connected vehicles and devices within two different aspects of NRA response: i) communication between emergency responders and the stopped vehicle, and (ii) integrated traffic management through in-vehicle services for other vehicles affected by the incident.

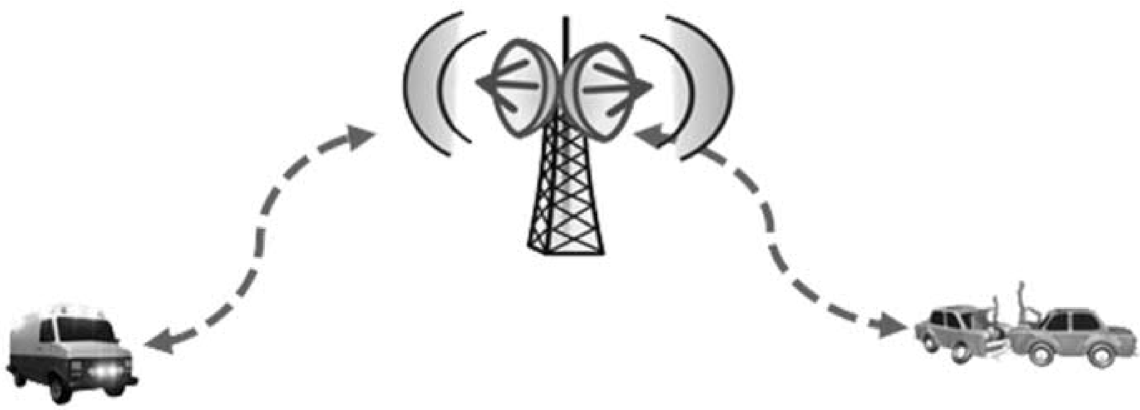
4.1 ISIS – post eCall incident support communication

A new CEN specification CEN TS 17875 [Ref. 7] has been created to support communication between vehicles involved in emergencies and the emergency responders en-route to the incident location.

As has been described in [Ref. 1], eCall establishes an audio call between the occupants of the calling vehicle and a public safety answering point (PSAP) and sends a defined minimum set of data. The PSAP may instigate response by emergency responders and at some point at the PSAP's choosing, will terminate the eCall. The scope of eCall is then at an end. eCall allows for the communication only between the PSAP and the vehicle occupants, not with the emergency responders. The PSAP may continue a call until the emergency responders arrive, but typically will terminate calls well before that [Ref. 7].

European research has identified that information from the affected vehicle can be of significant assistance to emergency responders [Ref. 7]. This includes information from vehicle equipment such as cameras (video or still image), special sensors e.g. gas or leakage, and passenger detection sensors. This further information is not in the scope of the eCall regulations, but is a post-eCall incident support activity. This is the kind of information exchange that the new CEN specification TS 17875 "Intelligent transport systems - eSafety - Incident Support Information System (ISIS) Architecture" is designed to support.

Figure 4-1 ISIS concept at the highest level [Ref. 7]



ISIS is an architectural specification identifying principles, patterns, and constraints, not complete protocols. It references the Cooperative ITS architecture base standard ISO 21217 and its principle of ITS stations, and the associated security standards. It is not a precise system specification. ISIS data/service provision is preceded by preparation phases to securely manage associated complexities. ISIS communications are initiated by the emergency responder – for example by a passenger in an emergency vehicle en route to the incident. One emergency responder may communicate with multiple affected vehicles simultaneously. Available sources are established, then communication of data values or streams from in-vehicle equipment can begin.

At time of writing in August 2022, ISIS is an architectural specification without any confirmed projects to define specific protocols or make implementations – either in vehicles that might be affected or for emergency response vehicles. The CEN TS is under vote so (assuming approval) publication might be expected in late 2022 (or early 2023). Its premise appears potentially useful, so interested NRAs might consider collaboration to progress further definition and piloting.

4.2 Integrated traffic management using in-vehicle services

Digitalisation has had a major effect on how we navigate through traffic to reach our destination. Road authorities have a long history of providing drivers with information on incidents and accidents via roadside systems. Over the years, these systems have become more and more advanced. In parallel, the use of mobile and in-car information and navigation services have been rapidly expanding. Already more than 90% of drivers have some form of mobile or in-car traffic information service at their disposal. These can provide drivers with the fastest or most convenient routes through the network based on their individual needs. In the end, road users combine all available information plus their experience when deciding how to respond and what route to take.

However, drivers also experience inconsistencies between the different information sources. Information and advice on roadside signs and signals sometimes conflict with information and advice from the connected devices in the vehicle. In some cases the advice from private sector organisations is considered unsuitable by the roads authority.

4.2.1 Public - private cooperation to improve traffic management

The “Traffic Management 2.0” initiative (TM2.0 [Ref. 8]), drawing members from across public and private sectors in Europe, is designed to advance public-private cooperation to improve traffic management. The largest-scale practical realisation of the ideas of the TM2.0 initiative to date has been the SOCRATES$^{2.0}$ project [Ref. 9].

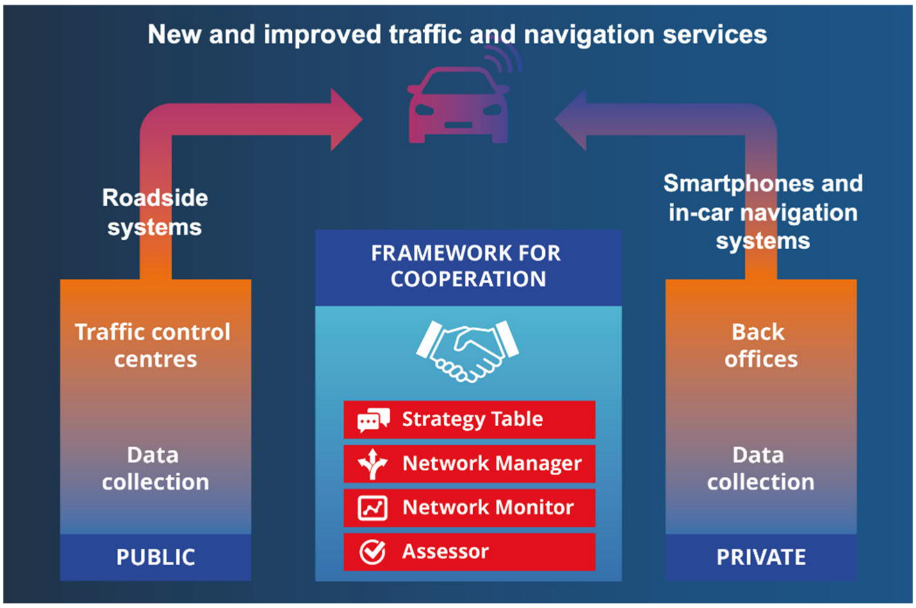
The traffic ecosystem is shaped by vehicles, road networks, road users, telecom networks, roadside systems, mobile and in-car systems, traffic management centres and private end user services. The SOCRATES$^{2.0}$ project assembled a representative sub-set of this ecosystem, with the aim of introducing traffic management in mobile and in-car connected services. A cooperation framework (summarised in Figure 4-2) was developed, common specifications were defined, and pilots were conducted in four countries, then evaluated. Over 10.000 road users participated in the pilots by using and evaluating the services.

SOCRATES$^{2.0}$ did not include a stopped vehicle use case, but its traffic management use cases are relevant for the wider network impact caused by a stopped vehicle. The relevance of its constructs for assisting with stopped vehicle response is further considered below.

4.2.2 The SOCRATES2.0 Cooperation Framework

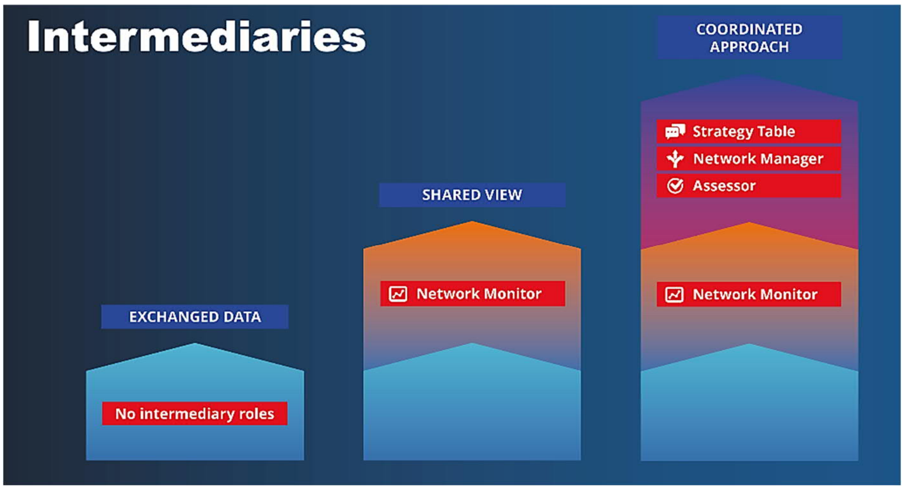
SOCRATES$^{2.0}$ defined three models of cooperation between public and private actors for traffic management. The two more complex models require “intermediary” roles (shown in Figure 4-3) which each could be performed by one of the main actors or by an independent organisation. Depending on the envisaged service or use case, the partners chose a cooperation model based on current or expected public and private interests and foreseen relationship between them in the delivery of the service. For example, to warn of the danger of a stopped vehicle, the “exchanged data” model may be sufficient, whereas to manage with the wider traffic network impact may require the “coordinated approach”.

Figure 4-2: The SOCRATES2.0 Cooperation Framework



The cooperation models and intermediary roles could be supported in the SOCRATES2.0 project with funding and committed project partners, but a further interesting research question is their wider applicability when the funded research project structures are removed. Mott MacDonald researched that question through interviews with road authorities who did not participate in the SOCRATES2.0 project and results [Ref. 10] are included in commentary on the models in the following sections.

Figure 4-3: Intermediary roles and cooperation models



4.2.3 The exchanged data cooperation model

This cooperation model is about exchanging data on a voluntary basis, using an agreed standard protocol. This foundation model is a supporting building block for the "shared view" and "coordinated approach" cooperation models described in the following sections. But it is also suitable for services aiming at spreading information without the need for further enrichment of the data or coordinating actions. This model could be applied for stopped vehicle hazard warning services.

The main focus is exchanging information with the aim of obtaining maximum information coverage for the end-users. Each party continues to improve its data and use its services to communicate with the end-user. The model has some similarity to the current-state-of-the-art in traffic information provision in some European countries, where national roads authorities publish traffic information that may be consumed by private sector service providers, and may also procure 3rd party data. However, the exchanged data cooperation model goes beyond current unilateral publications, by encouraging a conversation about the use case, which may increase the chance of the road authority's information reaching the vehicle and may increase awareness of how the information should be treated, such as the priority that should be attached to a stopped vehicle alert for nearby upstream vehicles. Yet in this model there is no commitment that the road authority's information will be used by the connected service providers.

There are multiple overlapping European traffic data standards, specifications and profiles, so it can be a challenge to agree on one standard and use it in the same aligned way.

4.2.4 The shared view cooperation model

This cooperation model builds on exchanged data and establishes a single shared view of the state of the network, from data supplied by the public and private sector organisations. This model is proposed to be suitable for use cases where value can be gained by sharing data from multiple sources to create a common situational picture. The shared view model requires the "Network Monitor" intermediary role, which is responsible for collecting data from road authorities and private data providers and providing a single consolidated view. This is considered especially useful if multiple data providers are available. The Network Monitor can perform data management tasks such as quality assessment, data completion and fusion of different public-private sources according to use case and business requirements. It distributes the common traffic state to all agreed parties and any other intermediary roles, so they can base their own services on a higher quality shared view.

Although this model does not entail contractual commitments to deliver the results of the shared view to in-vehicle services, the organisational commitments to a shared view and the agreement of the principles of how that view is formed might be considered to increase the chances of the road authority information (such as a stopped vehicle alert) reaching vehicles.

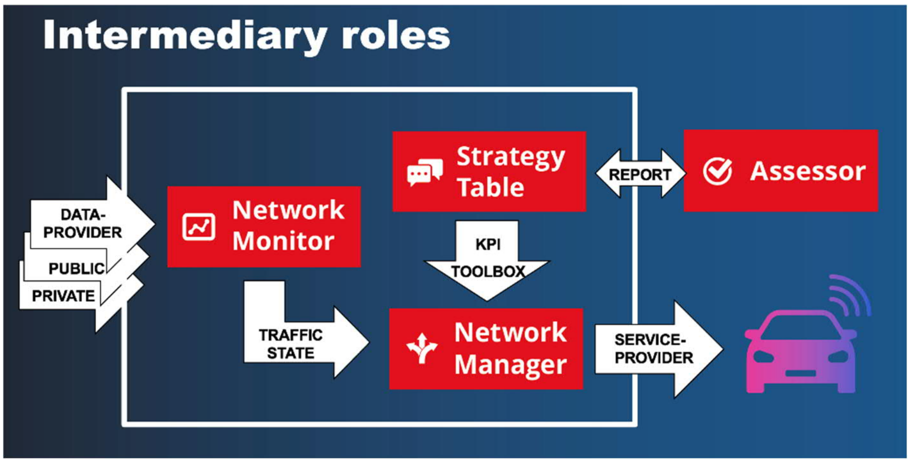
SOCRATES$^{2.0}$ showed that the Network Monitor could not be any existing private sector data provider because that could prevent participation of other private sector providers. The Network Monitor should be neutral and trusted, with no interests in commercial data provision – which implies to us that it must be public-funded. Interviews with road authorities beyond the SOCRATES$^{2.0}$ project showed national differences in acceptance of the idea of a Network Monitor intermediary. It seemed more accepted in the Netherlands and Germany, where there are already national services that can be considered in varying degrees to perform a somewhat similar role, than in the UK and Sweden where there was no similar national service. The majority of organisations interviewed believe that any Network Monitor should be national, to make it practical for service providers to participate. However, in UK there was a difference of views between central and local authorities, each considering it the other's responsibility, and doubts were expressed on funding and commercial viability.

4.2.5 The coordinated approach cooperation model

This cooperation model builds on the shared view model. In the coordinated approach, the partners identify common problems and develop solutions based on coordinated actions from all parties involved to achieve a set of agreed common goals. An impact-driven business model may apply, in which actors are rewarded for the positive impact they have on traffic. Road users may be offered incentives to encourage uptake.

This approach is suitable for use cases in which a set of commonly identified and agreed goals can only be achieved by coordinated actions of all parties. For example, the parties can aim for a better distribution of traffic over the available road network (which might be in response to the potential congestion that may be caused by a stopped vehicle). Although this clearly addresses a public goal (network optimum), it does not necessarily have to conflict with the aim of private service providers to optimise the individual goals (user optimum) of their users. The challenge here is to agree cases where the public and private goals can align, and jointly develop coordinated services to achieve these goals. In addition to the Network Monitor, the coordinated approach requires three further intermediary roles, shown in Figure 4-4.

Figure 4-4: Intermediary roles



Building on the shared view of a Network Monitor, the Strategy Table role forms a shared view of goals for traffic, and the traffic-affecting services available from both road operators and vehicle/mobile services providers which can potentially support these goals. The complementary Network Manager intermediary role determines which of these actions are needed for the current network state and makes requests to road operators and vehicle/mobile services providers to implement these actions. The Assessor evaluates the performance of the network management, and potentially determines financial reward for the participants (as well as providing feedback to the Strategy Table.) The Assessor is recommended to be independent from the roads authority and data providers.

Interviews with roads authorities beyond the SOCRATES$^{2.0}$ project showed interest but also considerable doubt on the viability of this model which appears to require ongoing additional public funding.

4.2.6 Conclusion

Public-private cooperation can be envisaged as part of the response[1] to a stopped vehicle. The road authority can publish a hazard warning with the aim of service providers getting this into nearby upstream vehicles as quickly as possible. Information provided in the vehicle, which may include speed reduction advice, should then be consistent with information presented on signs and signals. Such consistency can be expected to improve traffic safety.

In addition to the hazard warning, the public and private actors may for some locations be able to define the scenario in which significant congestion may be caused by the stopped vehicle and agreed potential alternative routes can be communicated in a consistent way

[1] Also the detection, which is discussed in SHADAR D5.1.

through both roadside signs and in-vehicle services.

Alignment of such measures requires investment from all involved stakeholders. Public and private parties must be aware of each other's goals and intentions so a common trust basis can be built. This is necessary to implement a cooperation model that will enable this kind of integrated traffic management and its resulting response and safety benefits.

5 Conclusions

5.1 Summary

SHADAR has explored the barriers and enablers to support response improvement via human reporting, increased information in the TMC and the effective presentation of information to the operator to inform effective decision making. There are a number of factors which support improved response, fundamentally starting with the detection of an incident and then a suitable level of verification of the incident event that will support a TMC operators' decision to commence response. Ensuring an efficient and effective response to ensure the correct resource requires the TMC to be provided with relevant information, such the vehicle type e.g., electric vs diesel/petrol and location details. Currently such key information is not always available or inaccurate which adversely effects effective response.

Without technologies such as CCTV, RADAR or other detection systems to alert operators to a stopped vehicle, TMCs are dependent on the driver, other road users or passers-by to respond effectively by providing a recognised road authority with the correct details in a trusted format, for example, using highways phone or a report into the police. Currently alerts via apps such as Waze or social media have yet to provide enough evidence to the TMCs that they can are a trusted source of information that will inform an immediate response.

5.2 Considerations and recommendations

The following provides considerations and recommendations for improved hazard response for the three key areas (behaviour, fusion, connectivity) explored in this report.

These include solutions that can be adopted, and considerations that should be made when adopting these solutions. The solutions range from fairly obvious best practice which may be new only to some countries in some aspects, to more experimental ideas. Because each country has a different context and starting point, there is a limit to how concrete the description of solutions can be – each idea has to be tailored for the context of each national road operation.

5.2.1 Road user behaviours

Ultimately it is expected that in-car automated solutions will remove the need for human reporting and provide additional information that can help response. However, until those systems are ubiquitous there is a need for accurate reporting by human road users.

Solution: driver education

Research conducted for WP2 (stopped vehicle detection and reporting), WP 3 (response) and WP 5 (detection improvement) identified that outside of the control room, addressing the competence and capabilities of drivers, through campaigns, education programs and legislation can support the effectiveness of the control room response in the long term, as drivers have a greater understanding of how to behave.

Driver education on these topics is potentially multi-faceted – topics include how to behave when your vehicle is coming to a stop, and when it stops, how to behave if you pass a stopped vehicle, how to behave when the vehicle in front of you stops, how to understand and obey instructions from the road operator, and how to report a stop. There has already been a campaign in England to educate on these topics (Highways England, 2021).

Solution: exploiting available technology to improve location reporting

One of the most important requirements for human reporting is the accuracy of location information, which affects the speed of response. The NRA interviews and WP5 noted that reporting by navigation/geolocation apps such as what3words, Google maps are valuable contributions due to their ability to deliver specific location references. Where an operator[2] has a scripted conversation with a road user then that might suggest to the user that they use any data geolocation apps that they have on their mobile to help improve location description. Further study would be required to confirm the practicality and detail of this idea (e.g. what is the current level of availability of easy-to-use location reporting on Android and Apple phones, would oral communication be sufficiently error-free, are any alternatives to coordinates practical, would the average saved time from better precision be worth the average time cost of the conversation).

Consideration: review and minimise steps from emergency services contact to TMC contact

The interviews with NRAs showed the possibility for considerable delay (e.g. 20 minutes) between a road user trying to initiate contact and the information reaching a TMC. While in some countries this process may already be optimised, the quote delay suggests that in at least some countries there may be benefit from a review of the processes involved, to identify any possibilities for a faster transfer of information between parties.

Best practices: Clear hazard warnings

SHADAR WP4 [Ref. 3] noted regarding hazard warning information that consulted road users desire short and precise information, repeated information, multichannel information, and multisensory information (seen and heard). Some even request multilingual information - although that may conflict with overall conciseness and user attentiveness.

The study was not at the level of scale or detail to scientifically distinguish specific parameters for these qualities, but warning given at 700m or less before the stopped vehicle tended to prompt comments that this was not enough notice.

5.2.2 Exploiting fusion of multiple data sources

Solution: implement a data fusion regime

Table 3.1 notes new information from combining multiple sources which the TMCs would find useful to support better response. Interviews noted that multiple data sources can provide verification of an incident, and increase confidence in alerts. All NRAs felt that increased trusted information into the TMC would be useful.

A flexible traffic management system should support the addition of new incident detection sources. Enhancement to today's traffic management systems would be required to present new kinds of information, and to support the concept of statistical data fusion producing confidence for alerts. The concepts are not complex, but the practicality of the change depends on the characteristics of each traffic management system.

Consideration: Establishing trust requires knowledge of the ground truth which may be expensive, time consuming and difficult to acquire. Without a ground truth study, statistical data fusion will be less accurate, but trust may be built up over time from an understanding the number of positive vs false detection and verifications that are received.

Best practice: Operator trust levels are key when introducing new sources of data into the TMC, so for the uptake of new data sources and system presentation to be successful,

[2] The direct contact from the road user may not be with NRA but with the police.

control room operators and stakeholders need to be engaged from the start with the integration of the technologies and how they support improvement in response time (section 3.4).

Consideration: Introducing new sources will change the overall detection rate and the false alarm rate experienced by operators. Agreement on operationally acceptable levels of false positives when fusing data need to be considered. The operational tolerance of false alarms also influences the choice of fusion regime and how confidence in an alert affects its presentation to the operator.

Consideration: Although interviews were positive on the value of extra information from fusing new sources, there is concern of operator overload in literature. For each new kind of information the trade-off between the potential to either add value or overload the operator should be considered.

Consideration: Fused data needs to be able to differentiate between separate incidents to ensure effective response. Operational concern over the performance of this aspect of data fusion suggests that test cases should be used to verify that performance of a fusion system will be satisfactory. Such test cases may consist of two physically close but distinct stopped vehicle incidents, each reported by a different source. When only one clears, the fusion system should not report that the situation is clear.

Consideration: Data from detection sources needs to be in a format which is easily translatable by the TMC. For example, the provision of grid references when identifying an incident will cause delay if the TMC systems only relate to location information such as road and junction numbers.

Solution: prioritise alerts in the operational user interface (using data fusion results)

When multiple data sources provide additional information to operators, the need for simplification and/or prioritisation was noted.

Fused data could support prioritisation of response and resources when there are reports of multiple incidents. A traffic management system enhanced to support statistical data fusion can calculate the confidence of an alert. Additional information from additional detection sources may allow further categorisation. A mechanism to prioritise alerts in the operational user interface, according to confidence and/or perceived urgency, could allow quick understanding of where to focus attention, and help avoid operator overload.

An analysis of scenarios by operational stakeholders would identify the different ways in which priority, trust and confidence should influence presentation. The use of colour, position, and numeric confidence were all considered useful tactics to support response decision-making.

Solution: use any existing confidence data available from the sources

Some detection sources provide metadata that can be used not only to influence data fusion but may even be used more directly in simpler rules about operational focus. For example Waze alerts include confidence and reliability scores, and a road authority could simply define what levels are required in order to take further action.

Solution: judiciously integrate weather and road condition information

Some interviewees saw benefit in targetted integration of weather and road surface condition information along with alerts, which could be useful to indicate the hazard level and aid preparation for response support. However, other interviewees considered this could distract from more important information. This suggests such data should be highlighted only in defined exceptional cases.

Solution: performance information dashboards

Having all detection data coming through a data fusion system gives possibilities for performance reporting, which can be especially useful where operational action logs can also be accessed. Performance information dashboards (Appendix C) were agreed by interviewed NRAs to be potentially useful in understanding monthly trends and support road management response. Understanding the effectiveness of different technologies in supporting detection and response was seen as strategically useful in knowing where to invest to maintain or improve NRA performance.

5.2.3 Connected vehicles and devices

Solution: cooperation with private sector information service providers

There is potential for improved response from drivers via road users receiving additional information from in-car or mobile devices. However, effort is needed to avoid inconsistencies between differing information sources so that information received by the driver will be trusted and responded to. Without effort on public-private cooperation, in-car information provided by private organisations may conflict with that supplied by the NRA. Some private sector service providers have shown interest in cooperation through participation in initiatives such as Data for Road Safety, Traffic Management 2.0, and the SOCRATES$^{2.0}$ project.

More specific patterns for such cooperation were proposed by the SOCRATES$^{2.0}$ project, but our research suggests that the patterns that go beyond data exchange are not likely to achieve sustained benefits without ongoing funding. The topic is further explored at the Traffic Management 2.0 initiative in which participation by road authorities is free of charge.

(Future) Solution: standardised data communication between emergency responders and vehicles involved in incidents

At an earlier stage is the potential of the CEN ISIS idea for data communication between emergency responders and vehicles involved in incidents. Benefit has been suggested by research, though given the early stage of the specifications further research seems required to confirm value and viability, and significant further definition would be required before piloting. Road authorities who see potential in the idea might consider engaging with the current standards development process at CEN TC 278.

6 References

Ref No.	SHADAR Deliverable	Document Title
1	D2.1	Stopped vehicle detection and reporting – current methods. Rev. C. July 2021
2	D3.1 Annex B	Trans-national study of control room operations and responses
3	D4.1	Results of the behavioural simulation study (expected September 2022)
4	D5.1	Stopped vehicle detection and reporting – research results. July 2022
5	D3.1	Response Current Practices Rev. A (Final)
6	D5.1 Appendix	Storyboards
7		CEN TS 17875 (draft) "Intelligent transport systems - eSafety - Incident Support Information System (ISIS) Architecture", reviewed as FprCEN/TS 17875 July 2022.
8		TM2.0 | Traffic Management 2.0 (tm20.org)
9		Socrates 2.0 SOCRATES2.0 | Nationaal Dataportaal Wegverkeer (ndw.nu)
10		"Wider applicability of SOCRATES2.0 results: TM2.0 Task Force report", January 2022, available to TM2.0 members, may be available on request from TM2.0.
11		"Go left! We launch our biggest ever motorway safety campaign", March 2021, https://nationalhighways.co.uk/about-us/go-left-we-launch-our-biggest-ever-motorway-safety-campaign/

7 Glossary

Acronym	Meaning
CEDR	Conference of European Directors of Roads
eCall	Emergency Call
GPS	Global Positioning System
NRA	National Road Authority
NH	National Highways
PSAP	Public Safety Answering Point
RWS	Rijkswaterstaat (Netherlands Ministry of Infrastructure and Water Management)
SHADAR	Stopped Vehicle Hazards – Avoidance, Detection and Response
SVD	Stopped Vehicle Detection
TII	Transport Infrastructure Ireland
TMC	Traffic Management Centre
TS	Transport Scotland
UI	User Interface
WP	Work Package

Appendix A – Other response improvement research topics

This Appendix records consideration during WP6 on possible tasks that were not all pursued, which are included here in case of usefulness to suggest future work.

In WP3, to develop our understanding of the factors which support or hinder the response, we worked with National Highways to produce a case study of the East Regional Operations Centre (ROC). The case study provided an understanding of the processes, technology, and systems in place to support an effective response to stopped vehicles, however the factors which limit the response were insubstantial. This was attributed to the technology in place, supported by a user centric approach to integrating stopped vehicle radar detection within the ROC; and the established processes and systems which enable an effective, well-established response, irrespective of scenario.

Those areas for improvement tended to be external to the control room, including future linkages with connected and autonomous vehicles, influencing driver behaviour to reduce the likelihood and impact of a vehicle stopping in a live lane, increasing public knowledge about how to report an incident and stakeholder processes. With this in mind, we did not see value in taking forward a suggested improvement to the East ROC's response to stopped vehicles, given that the WP3 research did not identify key areas for improvement.

Other options identified were:

- Undertake WP6 with a different ROC, where issues relating to radar stopped vehicle detection technology adoption, accuracy (radar detection false alarms) or usage is known to National Highways.
- Take forward the factors which support an effective response, such as the processes which supported the East ROC's successful integration of stopped vehicle radar detection, to a different National Road Authority.
- Explore other data sources which notify the control room of stopped vehicles; we recommend this would not be suitable at the East ROC's given that operators did not cite issues relating to the current radar detection.
- Where radar detection does not exist, explore options for ROC integration with in-car technologies such as C-ITS or e-Call, however we note the challenges relating to this given that this notification would be issued via the car manufacturers' control rooms.
- Undertake research with drivers to identify the enablers to encourage safer driving, which will support the ROC's response to a stopped vehicle.
- Undertake research to identify improvements stakeholder communications to the ROC when a member of the public calls an external stakeholder to report a live incident.

Appendix B – Interview top guide and scenarios

Work Pack	Q No.	Baseline Questions
		Review of scenes (scenarios) Advise that there are potentially multiple sources of information to inform Stopped Vehicle Detection (SVD). We are looking to understand the requirements for data fusion in receiving, interpreting and presenting these multiple sources to an operator to improve SVD.
5.6	1	**Scene 1. CCTV unavailable** **Rural road, no roadside tech, an accident occurs = multiple low-level reports leading to high confidence report** • Manual eCall activation • Waze activation (type hazard) • Waze activation (type accident minor) • Manual eCall activation • Reports are fused to indicate a high likelihood/medium impact event a) Which of these pieces of information are useful to you in supporting a response to SVD b) Would the police pass on an unverified report to you? If not, would you like them to? c) An automated link would give you an alert sooner, although it would always be unverified initially. How do you see this trade-off? Do you think that would tend to improve response overall? d) How much of a difference would it be for response to have the additional information you wouldn't get from a voice call: integrated location, recent position trace, vehicle type? e) Would the fusing of eCall reports Waze alerts help improve response? - If so, why and how
5.6	2	**Scene 2. Major road breakdown = RADAR and auto eCall = better event details** • RADAR activates, tells us the location and lane • Automatic eCall (containing vehicle details) in same location • Operator knows the location (from RADAR) and the vehicle details (from eCall), operators know which vehicle to look for, could initiate recovery more quickly • eCall tells us the vehicle is electric, allowing the operator to inform responders a. Does the combination of RADAR plus the eCall and additional vehicle data improve response?

		b. If so, why and how c. If not, why not
5.6	3	**Scene 3. CCTV not available. Major road multiple collisions, no RADAR in area** • Traffic detectors (e.g. MIDAS) activate traffic slowdown (low likelihood, low impact event) • Then manual eCall received (now medium likelihood, low impact event) • Then multiple Waze events - hazard on the road, accident major (now high likelihood, high impact event) a. Assume there is no CCTV in the area, how does that impact your actions b. If there is CCTV, what further information would be useful c. Do you need a combination of eCall information and other information e.g. notification of slow moving traffic before you investigate further? d. What other information would you need in order to send out resource e. Would the addition of Waze information add / change your response? f. The author of this scenario has suggested (shot 11-12) that when congestion changes to freely moving traffic, the potential hazard level from the stopped vehicle increases, and so the urgency of the alert in the HMI should be increased. What do you think about that?
5.6	4	**Scene 4. Critical incident, multiple collisions** • RADAR alert • 3 auto eCall activations (3 details of vehicles) • Multiple manual eCall activations • Multiple Waze activations • Additional alerts (which could be many) could be suppressed in the area to avoid distracting operators a. The combination of RADAR, CCTV, eCall, passive in-car system response, multiple Waze reports and the visualisation of these – would this improve your response to the incident, if so why and how b. The author of this scenario has suggested that environmental factors might affect the potential hazard level from the stopped vehicle, and so the urgency of the alert in the HMI should be increased. What do you think about that?
5.6	5	**Scene 5. CCTV unavailable. Breakdown at night, rural area, bad weather** • Waze report, accident (normally low likelihood, medium impact but raised to medium likelihood and high impact due to weather and night time) Would you respond to a Waze report alone? Would you require further evidence of a breakdown before sending out a responder? What additional evidence is needed?
5.6	6	**Scene 6. Waze alert in RADAR area, no RADAR activation = improve false alarm detection**

		• Traffic detectors (e.g. MIDAS) activate traffic slowdown (low likelihood, low impact event) • Waze alert – accident (medium likelihood) • RADAR does not activate (now back to low likelihood as RADAR didn't fire, more likely a false alarm a. Information into the TMC is Inductive loop indicating traffic flow and speed MTM/ MIDAS activated so what impact does the lack of RADAR warning have on response? b. Would incoming Waze alert(s) alone be enough to send out a responder? If not, why not.
5.6	7	Where **no CCTV** is available, what impact do you see the different technologies having on control room operations and their detection, verifying and response to a stopped vehicle.
5.6	8	Of the forms of information given in the different scenes, what combination would inform an immediate response (given CCTV is not available)
5.6	9	There are possibilities for new sources of information and more detection with different levels of quality and potentially different levels of operator confidence in the information. • How would it affect the way the control rooms make decisions about whether to respond and when to respond?
5.6	10	Do you think the new sources of information and detection received by the control room will have an impact on stakeholders (such as maintainers, police, incident support units, Highway's traffic officers outside the control room)? • If so, in what way?
		Non-scenario based questions
5.5	11	What can the driver/passengers/ passers-by do to help support improved response to a stopped vehicle in a live lane?
5.5	12	What difficulties do you think the driver/passenger /passer-by has in helping to support improved response to a stopped vehicle in a live lane?
5.3	13	Study suggests that the specific lane of a stopped vehicle could be determined by radar SVD sensors, perhaps not along its full range of projection but in a subset of that range, closer to each radar device. a. If that information was available, how would you like to see it used? b. Would you consider using it as an organisational policy to automatically set lane-specific signals and signs in advance of any human operator verification? (if so, what level of confidence would you need in order for that to happen?) c. Would you find it useful to help automate current operational tasks e.g. focus CCTV on the affected lane, or do you prefer seeing a zoomed-out view at first anyway? d. Do you see it as improving response time?
		User Interface (UI)
5.6	14	Although we understand that simplicity is ideal, the detection technologies are not perfect and provide information that carries

		uncertainty. When there are multiple sources for the same potential stopped vehicle event, these might be grouped *and* shown independently, with some indication of confidence, like colours (here redder is more confident) or numeric probabilities – both individually and overall. • What information would you find useful to see on a dashboard? Why?
5.6	15	The potential hazard is shown alongside potentially relevant information such as traffic levels and environmental conditions. • Would you find the combination useful? If so, why?
5.6	16	Integration of CCTV focussed on the potential hazard, seems important. What difference does not having CCTV images make to your response?
5.6	17	Shows the integration of vehicle details gained through lookup via the eCall identification. Does this help with improved response? • If so, why, if not, why not. Under the tipped car icon there is a vehicle trace which can be obtained from eCall. Would that kind of information be useful? • If so, why. If not, why not
5.6	18	Shows ambient environmental conditions superimposed on a dynamic map. Would you find that kind of visualisation useful? • If so, why. If not, why not.
5.6	19	Shows a negative detection (from radar in this case, it may be that the radar is faulty) as counter-evidence to the other sources which have detected something. • What impact would this have on how you decide to respond?
5.6	20	How useful is the way the user interface has been illustrated?
5.6	21	How could it be improved?
5.6	22	Is there anything missing?

Appendix C – Performance management

With several kinds of stopped vehicle detection sources and data fusion, a technology manager may want to see how each source is performing, using reports that could be reviewed periodically or on demand. This may be especially useful for connected vehicle sources whose impact may grow or shrink over time as technologies and/or brands grow or shrink in popularity.If the reports can access not only the detection logs but also the related operational action logs, they can present more metrics.

SHADAR Report D5.1 [Ref. 4] presents and explains mock-ups of performance managent dashboard reports. Those screens were presented to the NRAs as part of the semi-structured interviews conducted for WP6, and their feedback was as follows:

Purposes and usefulness

- A performance management dashboard was generally considered helpful for gaining insights to support road management and response.
- The comparison of the performance of different technologies in the same terms was generally considered useful.
- Two potential purposes are optimisation of existing technology and informing new or continued investment decisions.
- Some NRAs would use these annually or 6-monthly.
- Some NRAs would want to see trends over time (e.g. sets of monthly changes) to support NRAs in being able to understand current and future trends and help support road management strategy.
- Changes in the performance of data sources might signal a need for improvement, not only in detection but perhaps also in verification processes.
- Performance data informs confidence in the data sources.
- There is a significant distinction between sources from infrastructure of the NRA and third party external sources - the former can be optimised by the NRA.
- The statistics allow the purchaser to give concrete feedback or requests to improve to the technology providers.

Choice of metrics

- Seeing non-detections and possible false alarms by specific technologies is interesting and could be used for improvement.
- Limits to what can be presented without ground truth data are important to understand.
- Ground truth data (and the richer statistics that it supports) is valuable – especially when a technology is first introduced.
- The statistics available when ground-truth data is available are more useful than those available without.
- Of statistics computable without ground-truth data, the number of times that a source is first-to-detect and number of detections unique to a source seem particularly useful.
- Seeing incident response performance time statistics could be useful for performance improvement (this is already done by some NRAs).
- Seeing statistics for specific locations is considered likely to be useful for multiple purposes – resource planning, identifying new or growing hot spots, identifying gaps or problem locations requiring optimisation, calibration, or troubleshooting.

These findings inform requirements for any such reporting developments by NRAs.