Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

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

Work Package 3: Response Current Practices

Deliverable D3.1

19 November 2021

Revision A (Final)

CEDR Call 2019: Safe Smart Highways

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

D3.1 Response Current Practices

Due date of deliverable: 30/4/2021

Actual submission date: 19/11/2021

Start date of project: 1/10/2020 End date of project: 30/09/2022

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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’ as defined by the Description of Research Needs for Safe Smart Highways.

Stopped vehicles on the highway network present 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.

The focus of this document is the incident management which begins once a stopped vehicle incident is reported to a control room. Our approach incorporated both primary and secondary research to develop an understanding of the control room practices, and the factors which influence control room responses to stopped vehicles in live lanes.

The control room response is informed by many elements including the nature of the information received, timeliness of the information, and the internal processes which inform the decisions and activities that result in a response. We explored how these factors contribute to an effective response that minimises the risk of secondary incidents and facilitates stakeholder actions to achieve the best possible outcomes.

Generally, control rooms respond to stopped vehicles by reacting to the information they receive from external sources, such as the police, traffic officers, and/or the public. However, through the introduction of detection technology, which alerts the control room to a stopped vehicle, and intelligent transport systems, which dynamically support the implementation of traffic management measures, control rooms have a greater role in minimising the risk which stopped vehicles in live lanes present.

The literature review provided some understanding of the factors which influence control room operations and responses, particularly in relation to the use of technology and stakeholder collaboration. However, with the advancement of Stopped Vehicle Detection (SVD) technology, the human interface is likely to become the most inconsistent component in the system. Operators are influenced by cognitive and organisational factors, and external stimuli which may affect their ability to apply a homogenised approach.

The primary research identified organisational, cognitive, and physical factors which support the control room in effective response to stopped vehicles in live lanes, to a greater or lesser extent. Through the discussions, it was concluded that the organisational factors have the greatest influence within the control room, which safeguard its functions by shaping how it operates both internally and externally, ensuring a consistent approach is followed, regardless of incident type. Organisational procedures also limit the influence of cognitive factors, identified within the literature review, which could potentially deviate from protocol.

Organisational procedures also drive forward the advancement of efficiencies and improvements through a continual process of development. These result in procedural changes and / or new technologies, which ultimately deliver benefits to motorists through a reduction in delay times as the control room is able to respond faster to

stopped vehicles.

Both the primary research and the literature review identified the introduction of SVD technology as providing operators with a greater understanding of what is occurring on the network, with enhanced levels of situational awareness and subsequent procedural response decisions compared to sections of the network where operators must look for incidents following external reports.

Without SVD, the links and sequences of detection and reporting are complex, with different contact methods, procedures, and technologies to alert the operator to a possible stopped vehicle. Greater complexity of communication and system links results in time delay when detecting, reporting, and responding to the event by control room operators.

When SVD is introduced to the control room, organisational factors play an integral role in the successful integration of the technology into operations. For example, excessive SVD false alarms can affect the cognitive factors which facilitate the efficiency of the control room, as operators disengage with and distrust the technology. Sufficient user testing with operators is crucial to addressing this, as it secures buy-in and empowers operators to identify improvements which enable the successful integration of the technology into the control room. Furthermore, training, refresher training, and on the job experience ensure operators have the expertise to maximise the benefits of the SVD investment.

Control rooms with SVD also have a greater understanding of the incidents that may quickly become non-events, data which was unavailable prior to introduction of radar detection technologies. This could assist roads authorities to develop an understanding of why drivers stop in live lanes and inform future approaches which influence this behaviour whilst minimising the risk to other drivers.

Outside of the control room, addressing the competence and capabilities of drivers, through campaigns 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 if their vehicle stops. Furthermore, real time messaging to other drivers on the network, with supporting information as to why speed limits have reduced or lanes have closed, secures greater compliance to the traffic management measures initiated by the control room.

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1.1 Background

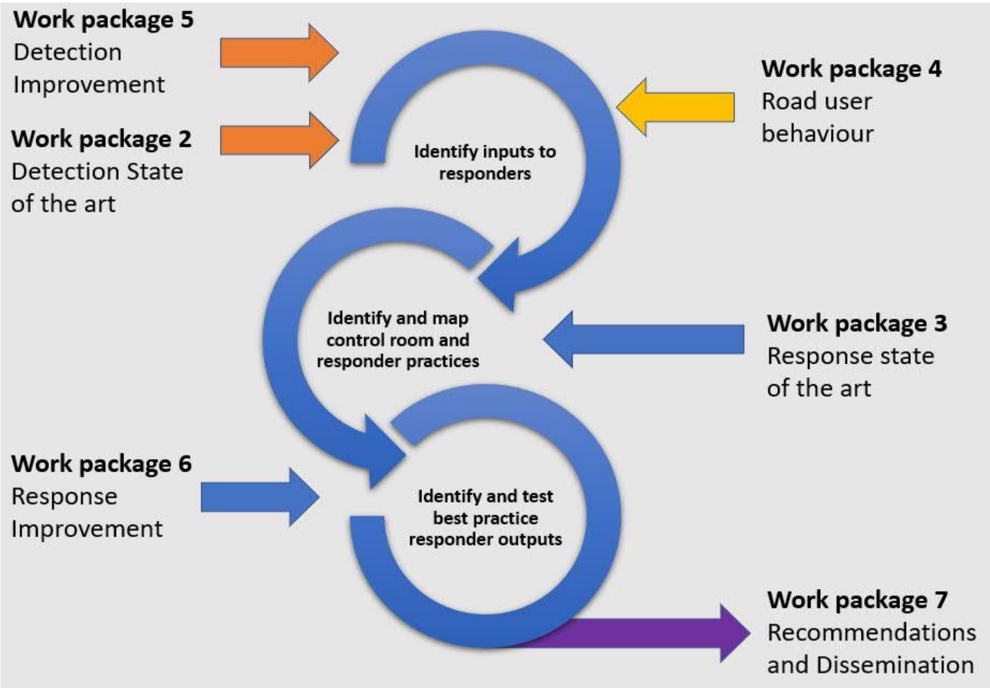
The project 'SHADAR' (Stopped vehicle Hazards – Avoidance, Detection and Response) addresses the objective of 'Preventing collisions with stopped vehicles in a live traffic lane' as defined by the Description of Research Needs for Safe Smart Highways.

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.

1.2 Work Package 3

The SHADAR project consists of six distinct work packages as illustrated in the figure below, fitting within a project management framework (work package 1).

Figure 1.1: SHADAR Work Packages



The focus of this document is work package 3, which considers the current state of incident management phases which begin once a stopped vehicle incident is reported to a control room.

Generally, control rooms respond to stopped vehicles by reacting to the information they receive from external sources, such as the police, traffic officers, and/or the public. However, through the introduction of detection technology, which alerts the control room to a stopped vehicle, and intelligent transport systems, which dynamically support the implementation of traffic management measures, control rooms have a greater role in minimising the risk which stopped vehicles in live lanes present.

The control room response is informed by many elements including the nature of the information received, timeliness of the information, and the internal processes which inform the decisions and activities that result in a response. For work package 3, we specifically explore how these factors contribute to an effective response, which minimises the risk of secondary incidents and facilitates stakeholder actions, to achieve the best possible outcomes.

1.2.1 Our Objectives

The aim of work package 3 is to:

- Develop an understanding of the control room practices.
- Understand the factors which influence control room operations and responses to stopped vehicles in live lanes.

To deliver these objectives, we undertook an international review of existing highway control room operations and literature to inform a thematic analysis of factors which influence control room operations and responses. In addition, a series of semi-structured interviews were undertaken with national road authorities, including representatives from both operational and strategic backgrounds, to understand the factors which support an effective control room response to a stopped vehicle in a live traffic lane.

1.3 Structure

Following this introduction, the document is structured as follows:

- Our methodology is summarised in Section 2.
- To assist the reader, a glossary of relevant intelligent transport systems (ITS) terms and acronyms is provided in Appendix A.
- We provide an overview of the key findings from the literature review in Section 3; Appendix B details the documents used in the final analysis. Each publication is assigned an index number which is then used in references from the main text in square brackets, such as [1].
- We present our control room baseline in Section 4 informed from interviews with Transport Scotland, Highways England[1], ASFINAG in Austria, and Rijkswaterstaat in the Netherlands.
- We provide a detailed baseline case study from Highways England in Section 5.
- We set out our conclusions in Section 6.

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[1] Since conducting the bulk of work in this report, Highways England's name has changed to National Highways. Since references to the organisation in this report are typically to work conducted with or by Highways England when it was so named, for simplicity this report uses the name Highways England throughout.

2 Methodology

2.1 Introduction

Our approach incorporated both primary and secondary research to develop our understanding of the control room practices, and the factors which influence control room responses to stopped vehicles in live lanes.

The review did not separately consider stopped vehicles in tunnels.

We present our approach to work package 3 within the following sub sections: firstly we describe our methodology for undertaking the review of existing literature, and secondly we provide an overview of the primary research approach.

2.2 Literature Review Method

A systematic approach to identifying suitable research materials, articles and papers was applied to ensure the review could be replicated and meet the research objectives. The generic search terms used are summarised in table 2.1 below, these terms were used in combination to focus the search results.

Table 2.1: Generic search terms

Search terms
Smart motorways
Control rooms
Traffic control centre
Operator
Responder
Highways
Motorways
Traffic management centre
Incident management
Incident detection
All lane running
Human factors
Stopped vehicle detection
Stationary vehicle detection

The search for literature from the UK and internationally made use of search engines such as Google Search, Google Scholar and Microsoft Bing, supplemented by literature provided by the wider SHADAR project team. In addition to this, specific trade journals, electronic library and publishing databases were used.

We made use of the SHADAR project team to obtain research, reports and papers from Austria and the Netherlands. We also utilised Mott MacDonald’s international networks to reach out to ITS and network management specialists in North America, Southeast Asia, and Oceania, and made a direct approach to a leading external researcher.

Research materials such as articles, think pieces, reports, and papers, produced before 2010 were excluded due to the rapid evolution of ITS technologies. However, a small number of materials produced prior to 2010 were included as they focussed on the organisational and cognitive factors associated with control room operations as opposed to the technologies.

Using the search terms, research materials, articles, and papers were identified, and their abstracts or summaries read to assess against relevancy and applicability to the research objectives. Following this initial assessment, several documents were removed, and Appendix B summarises the documents used in the final review.

To identify high level themes, human factors principles were applied as utilised in control rooms in high hazard and performance-focused industries such as rail and nuclear. These principles focus on the individual, the task, the organisation, and the factors that influence control room operations and stakeholder response. These factors can be understood as:

- The physical: such as technologies that impact operations either within the control room or external to the control room such as CCTV, radar detection and telecommunications.
- The cognitive: things that impact the operator and stakeholders such as situational awareness, decision making and communications.
- The organisation: the impact this has on collective or individual response including culture, process, key performance indicators (KPI's) and training.

From these factors, key themes were identified to provide a high-level understanding of the research materials and enable the quick identification of documents that may be relevant to the research objectives.

2.2.1 Limitations of the Research

The resulting database includes works from England, Scotland, Austria, South Africa, Germany, the Netherlands, and Sweden.

The review looked to compile international evidence, with a specific focus on Europe, from a range of countries, however the search for insight into the factors which affect the control room response was inconclusive as published literature on the subject matter was limited. It should be noted that many documents identified were from the UK and this could be attributed to the combination of Highways England's progress in this area, its research strategy and transparency policy:

"To support this, we'll publish all reports and documents that we're required to under our licence agreement with the Department for Transport and our statutory obligations, or to fulfil legal requirements." Highways England

The wider SHADAR team provided support to obtain non-UK case studies, however, identifying suitable international examples within the context of the work package 3 research objectives was difficult. The partners provided published materials from a wider geographic range including USA, Finland, and Germany, but these were not added to the database due to insufficient direct relevance to the specific research topic.

Mott MacDonald searched its international networks including specialists in North America, South East Asia, and Oceania for evidence however this proved to be inconclusive, with Transport for New South Wales' Network Optimisation and Integration Manager noting that *'the southern hemisphere is generally behind Europe'*.

Many international case studies concentrated on the technologies used to manage motorways and detect stopped vehicles, with little evidence of the control room factors. This could be attributed to the fast pace of innovation underpinned by extensive research to drive forward technological advancement. This is considered further within SHADAR Work Package 2.

The review also found research associated with the control room and human factor elements when detecting and responding to stopped vehicles highly limited, this contrasts with the availability of literature that focuses on the technology used to detect stationary vehicles. However, for the purposes of the review, the research team included materials which concentrated on technology but did discuss the human interaction with the system.

When it became clear that this was not an extensively researched subject area, we expanded our generic search terms (presented in Table 2.1) to include papers that did not contain these phrases to widen the scope. This did not result in the identification of further research to support our research objectives.

The unavailability of research within the public domain could be for reasons of commercial or organisational sensitivities or the research could even be considered detrimental to public safety or interest. Furthermore, security measures could inhibit the ability to conduct academic research which relies upon observational research methods to study traffic management control rooms.

This lack of data highlighted the importance of collecting primary research tailored specifically to our objectives and our approach to this is summarised within the following section.

2.3 Primary Research Method

To provide greater depth to our understanding of the human factors which influence the control room response to stopped vehicles in live lanes, primary research was undertaken with key representatives from national road authorities.

A series of semi-structured interviews was held between March – June 2021 with stakeholders with a strategic interest and operational involvement in managing stopped vehicles in live lanes. Stakeholders represented:

- Transport Scotland.
- ASFINAG in Austria.
- Rijkswaterstaat in the Netherlands.
- In England:
  - Highways England.
  - ConnectPlus.
  - West Midlands Police.

Interviews were conducted using video conferencing platforms such as Microsoft Teams and Zoom. Participants were recruited from the project team and the CEDR partners.

Interviews were facilitated using a topic guide which covered a range of topics and incorporated the literature review key findings to provide further insight and/or validation. Key topics included:

- The control room processes in place to manage stopped vehicles in live lanes.
- Technologies and resources.
- Training and resilience.
- Situational awareness.
- Driver behaviour.

We provide a copy of the topic guide within Appendix C.

Highways England was selected as a detailed case study to provide insight relating to the systems which enable the control room to effectively respond to stopped vehicles in live lanes. Unfortunately, due to COVID-19 restrictions, the research team was unable to undertake observational research within the control room. As an alternative, the baseline case study was developed virtually, in collaboration with representatives from Highways England's South Mimms Regional Operational Centre (ROC).

To develop the case study, interviews with operators and their stakeholders were structured around four key areas:

- Background, including the technologies and resources available within the control room.
- The control room's protocol to stopped vehicles in live lanes, including the actions taken in relation to specific stopped vehicle scenarios and the communication processes.
- How the control room develops situational awareness.
- The impact of the control room's actions on driver behaviour.

Appendix D provides a copy of the case study proforma.

2.3.1 Challenges and limitations of the Primary Research

Understanding the challenges and limitations the study team encountered are useful when considering the context for primary research findings, including the factors outside of the research team's control. We provide an overview of these below:

- One of the key limitations of utilising a case study approach is that our conclusions are drawn from a small sample size. However, the benefits of this methodology is the ability to explore the factors which influence the control room response in depth, particularly within the context of how control rooms are integrating stopped vehicle radar detection technology.
- The timing of work package 3 coincided with both the UK's COVID-19 restrictions and Highways England's response to the Department for Transport's (DfT), Transport Secretary's Smart Motorways Stocktake actions:
  - The UK's COVID-19 restrictions resulted in alteration of the research methodology from observational research to semi-structured interviews to avoid unnecessary contact and travel. Whilst insight was drawn from a wider sample,

including four traffic control rooms, we were unable to observe how operators respond to stopped vehicles in situ. To address this, a series of interviews and discussions were held with representatives from Highway's England's East ROC's, to explore in depth each element of the stopped vehicle process.
  - The stocktake actions affected participation in the early stages of the primary research resulting in a delay to complete the Highways England case study.
- Securing participation in the project was challenging, particularly when identifying suitable representatives from stakeholders external to the control room. This resulted in a delay to the overall programme as a stakeholder from the police forces operating within the East ROC's jurisdiction (Thames Valley or Metropolitan police forces), could not be identified.[2] To address this, an interview was undertaken with a representative from the Central Motorway Police Group (from another region in England) who provided a general perspective of how the police liaise with Highways England's control rooms rather than providing specific insight to the East ROC.

2.4 Recommendations and Conclusions Method

Recommendations and conclusions were identified by combining the findings from the literature review and the primary research.

The outputs of this exercise will link into work packages (4) Road User Behaviour and (5) Detection Improvement and inform the (6) Response Improvement work package.

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[2] Police forces within England are responsible for developing their own approach to managing the recovery of stopped vehicles, in partnership with Highways England and other stakeholders. This may vary across the forces, such as differences in technology, resourcing, and strategic aims.

3 Literature Review Key Findings

3.1 Introduction

We summarise the key findings from the review below, organised by human factors category, and provide a transnational database of the research reviewed within Appendix B. Each research item is referenced within the database and where applicable, key findings are summarised in this section.

3.2 Physical Factors

When considering the physical factors that impact operations either within the control room or external to the control room, several themes were identified. For control rooms with access to stationary vehicle detection, there is a greater opportunity to proactively manage the network, greatly reducing the overall incident response time due to an almost instantaneous detection time. Furthermore, the safety benefits were also noted. In particular, the use of radar detection on all lane running sections of smart motorways[3] in England against a background of increasing traffic flows demonstrated that safety objectives had been met, leading to the UK Department for Transport committing to extend the technology to all smart motorways operating all lane running [1].

Whilst detection technology enhances the control room's ability to proactively manage and respond to incidents, a number of challenges were noted. Firstly, detection technology can generate false alarms, resulting in unnecessary work for the control room operators and distracting them from their day-to-day tasks. This could potentially divert resources from other critical tasks, resulting in a loss of confidence in the system's ability to deliver the desired safety benefits. As part of Highways England's trial of stopped vehicle detection (SVD) technology, a series of recommendations were made to reduce the number and impact of false positive alarms, these included [1]:

- Removing coverage of Emergency Refuge Areas (ERA) and other non-live lane hot spots areas, as these alarms are not operationally essential. This would increase confidence that the SVD alarm is detecting a significant event and allow the configuration of an integrated traffic management system.
- Auto-positioning the pan tilt zoom (PTZ) camera to a pre-set position relating to the location of the SVD alarm. Having this footage automatically displayed in the digital display screen to bring the incident to the operator's attention would enable a more efficient verification of incidents.
- Through technology improvements to reduce the likelihood of false positive SVD alarms and increasing accuracy, automatic signalling could be enabled to facilitate

[3] In England, smart motorways are sections of motorway that use traffic management methods to increase capacity and reduce congestion in particularly busy areas. These methods include using the former hard shoulder as a running lane, and using variable speed limits to control the flow of traffic, supported by technology such as CCTV, detection technology, variable signs, and sensors.

an instantaneous response to the incident, such as automatically requesting speed limits.

Secondly, the Highways England SVD trial recommended prioritising the SVD audible alarm over the base system's regular alarm which control room operators expressed annoyance with as it distracted operators from other activities [1].

The literature review also identified lessons learnt from public transport control rooms specifically relating to the physical factors which influence the control room's response. In particular, Lischke et al [26] carried out observational research within a public transport control room in Germany, highlighting how staff members make system-relevant and safety-critical decisions, supported by information displayed on large high-resolution displays (LHRD). The use of LHRDs enabled the research team to observe common work practices and identify challenges for interacting with LHRDs, including the need for adequate input techniques and to present relevant information on the best spatial position for it to be recognised by the user.

3.3 Cognitive Factors

Relevant research relating to the cognitive factors that impact upon the operator within the control room were limited, with findings from this element of the review coming predominantly from one author, Dr Rachel Gordon [20, 21, 22]. Dr Gordon undertook observational research within highway control rooms; specific findings within the context of the research objectives are briefly summarised below:

- To understand how the control room responds to incidents, an ethnomethodological approach should be applied: specifically, through observing how operators prevent happenings from becoming incidents over time. Dr Gordon highlighted the importance of observing the non-events to fully appreciate the benefits of the control room.
- Through a process of validation, supported through technology and stakeholders, the control room seeks to incrementally build up their understanding of what is happening on the network. Highways England's National Traffic Control Centre was cited as an exemplar of how events must meet a set of criteria, utilising diagnostic technology, which restricts the operator's interpretation.
- The sociotechnical nature of understanding events and responding to incidents can create hindrances to collaborative work including technical difficulties, distrust (false alarms), communication difficulties (different stakeholders understanding / classifications of congestion) and differences in organisational environments. In the context of Highways England, the author suggested there were different frames of reference used in the way regional and national control centres identified incidents or events due to differences in the availability of diagnostic tools.

The review also identified cognitive factors that influence the control room response within the CEDR Transnational Road Research Programme's PRIMA project [19]. The project identified that the success of implementing detection systems was dependent on early engagement with users such as control room operators, highlighting potential conflict between the top down (e.g. senior managers, stakeholders external to control room operations) and bottom-up viewpoints (control room operatives). The project recommended that new tools / technologies should be taken to operators who are likely to use them to gain a user-centred design input, and an engagement event in control centres in the Netherlands was cited as an example of user input.

Other cognitive factors were found within a review of the Providentia project in Germany [17, 18], which included the implementation of a sensor system built into the highway to track traffic. The challenges of large screen applications resulting in the loss of orientation were identified as placing physical demand upon the control room operator. Measures put forward to address this included eye tracking and removing spatial constraints within the control room to provide the operator with fast interaction possibilities.

Finally, the review found a small amount of literature which suggested that the human element of traffic management was the least consistent component of the system [17, 18]. This was in comparison to the infrastructure, which remains fixed and constant; and electronic equipment which is tested, manufactured and maintained to various levels of reliability and consistency.

3.4 Organisational Factors

The literature review also identified organisational factors, and these tended to relate to training, control room resources and operational processes with stakeholders and partners.

The review highlighted the need, when introducing new technologies, to develop standardised procedures and provide training with both control room operators and stakeholders to enable the successful integration of new systems. This should note changes in terminology, such as lane numbering where emergency responders may still refer to the hard shoulder rather than an altered numbering scheme [12]. In addition, 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 found the impact of technology unavailability or failure, combined with other scenarios such as peak traffic or severe weather conditions, was a key technology risk, however 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.

As outlined in section 3.2, the Highways England SVD trial recommended measures to manage the number of SVD alarms, particularly when scaling up the system to other parts of the motorway network and consequentially increasing the number of alarms generated. To support the control room response to this challenge, organisational measures included providing a dedicated resource to react to SVD alarms, formalised procedures, and KPIs to monitor response times. The SVD trial also identified differences in RCC operators' perceived detection rate and the recorded system detection rate, highlighting a potential training need [1].

In the Netherlands, the Ministry of Infrastructure and the Environment acknowledged that Managed Motorways should not be treated as normal motorways. Hard shoulder running and plus lane operations resulted in increased workloads for traffic operators, however this should be moderated by use of a flexible ITS system, providing clear and concise information to drivers, and educational interventions to promote the desired driver behaviour [9].

Organisational factors were also identified within the CEDR Transnational Road Research Programme Traffic Management, 2017 end of programme report. The outcomes of various CEDR research projects were considered at a workshop with key stakeholders including representatives from the National Road Authorities of Ireland, England, Belgium-Flanders, and the Netherlands. When discussing the “Pro-active Incident Management” (PRIMA) project, the workshop identified there could be potential for conflict when multiple agencies, dealing with incidents, have different objectives (police, road operators etc.). The workshop key findings highlighted Highways England's approach to address this, through shared control centres for road operators and emergency services, providing aligned procedures resulting in multiple agency buy-in [24].

In addition to the PRIMA project, the CEDR workshop identified the success of implementing short term traffic prediction systems from the STEP project in the Netherlands which relied on early engagement with control room operators to explore the users’ experience of new tools and technologies. This finding reiterated the importance of introducing human factors from the start of the application of traffic management measures, as highlighted in the Management of European Traffic using Human-Orientated Designs (METHOD) project [28].

Whilst METHOD focused on the road users’ needs within the context of traffic management, it also made a number of observations which supported our literature review objectives:

- Interviews with key traffic personnel from the Netherlands highlighted there is a process for incident reviews, whereby traffic managers/operators review *‘what worked well’* and *‘what could be done better in the future?*’.
- When training new traffic management operators in the Netherlands, the emphasis is on teaching the staff member to be independent and proactive traffic managers. Training is predominantly done on the job and operators must follow guidelines which ensures their decisions are always safe if adhered to.
- With the advancement of ITS applications, there is an expectation that operators in the Netherlands will find tasks become easier. The focus of operators’ work will shift from road traffic managers overseeing safety and traffic flow to information managers.
- In Finland, there is an expectation that the role of operators within the Traffic Management Centre may change from exploiting singular pieces of data to large amounts because of the way information is received sooner and processed faster.

The METHOD project also identified concerns relating to the situational awareness of traffic management operators in the Netherlands [27], highlighting that future trends in the complexity of traffic combined with the growing amount of data is likely to place additional pressure on operators. This may impact upon operators’ ability to form a clear mental picture of the traffic situation, resulting in a lack of situational awareness.

Considering other European collaborative approaches, the review noted two case studies within the context of the research objectives. In Austria, collaboration between the motorway operator, ASFINAG, and national broadcaster ORF the central coordination point for traffic information, resulted in harmonisation between the two organisations' systems, providing greater opportunities to disseminate messages relating to disruption [9]. In Sweden, the National Transport Management system, delivered collaboratively via 4 regional control centres, providing partners and stakeholders with a reliable and consistent incident response across all modes and locations [24].

The review also identified that preventative measures to actively reduce the number of stopped vehicles in live lanes could support the control room function. Enforcement type interventions were highlighted within Highways England's Intervention Framework for Safer Driver Behaviour. In particular, the review noted organisational factors delivered via the control room, such as Driver and Vehicles Standards Agency stopping powers delegated to Highways England's Control Room operators as part of a pilot, did minimise disruption associated with unroadworthy vehicles [3].

Finally, cyber security and organisational measures to address network resilience were referred to in a small number of articles, particularly in relation to systems integration with stakeholders and partners [14].

3.5 Summary

The literature review provided some understanding of the factors which influence control room operations and responses, particularly in relation to the use of technology and stakeholder collaboration. However, with the advancement of detection technology, the human interface is likely to become the most inconsistent component in the system. Operators are influenced by cognitive and organisational factors, and external stimuli which affect their ability to apply a homogenised approach. Literature on this was limited and the research team explored this further within the primary research with stakeholders from the national road authorities.

4 Control Room Baseline: Primary Research Findings

4.1.1 Introduction

At the time of the research, the UK based research team was unable to visit control rooms to undertake observational research due to COVID-19 lock down restrictions. We therefore relied upon the insight provided via interviews with representatives from four European national road authorities (NRAs).

The interviews provided the research team with qualitative data from a range of control rooms responsible for networks with unique characteristics and access to different technologies. This provided greater depth to the literature review findings, drawing insight from four very different control rooms to develop a baseline of current operations.

We provide an overview of our key findings within the following sub-sections, providing a baseline which explores the current response to stopped vehicles in live lanes to understand the human factors elements which may support or hinder a response.

4.2 National Road Authorities Background

The four NRAs have a unique set of characteristics which provided the research team with a diverse perspective of control room operations.

4.2.1 ASFINAG

ASFINAG, (Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft which is German for motorway and highway financing stock operator), is a federal agency, operating and maintaining over 2,000km of motorways and expressways in Austria. ASFINAG is publicly owned but does not receive any state funding, relying upon the revenue generated through road user tolls, which is reinvested back into the infrastructure.

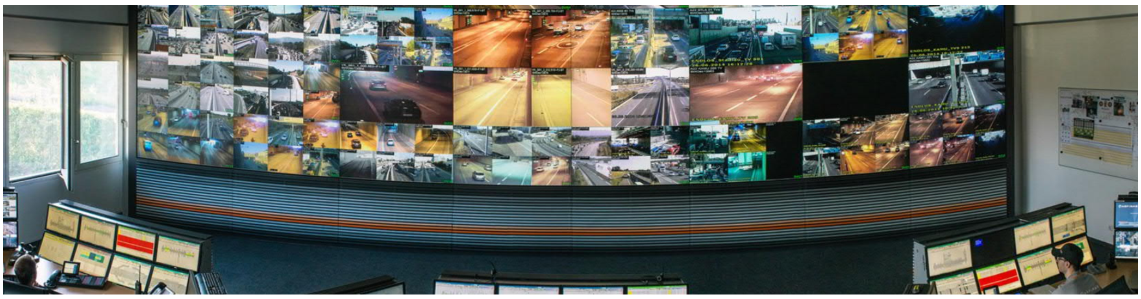
Figure 4.1 ASFINAG's highway network

Source: BMK: https://infothek.bmk.gv.at/20-jahre-vignette-was-passiert-mit-den-maut-einnahmen/

ASFINAG has nine traffic management centres (VMZ) which respond to incidents, coordinate with the local emergency teams, and act as a central point for communication. Each VMZ is responsible for clearly defined route sections and usually has at least two operators within the control room at any time, supported by field operators patrolling the route.

A significant part of ASFINAG’s network includes the management and operation of tunnels, given the Alpine topography. Tunnels have high safety regulations and standards with automated processes in place to detect stopped vehicles. On non-tunnel sections, the VMZ responds to incident reports from the public or stakeholders, rather than utilising detection technology.

Photo 4.1: ASFINAG Traffic Management Centre

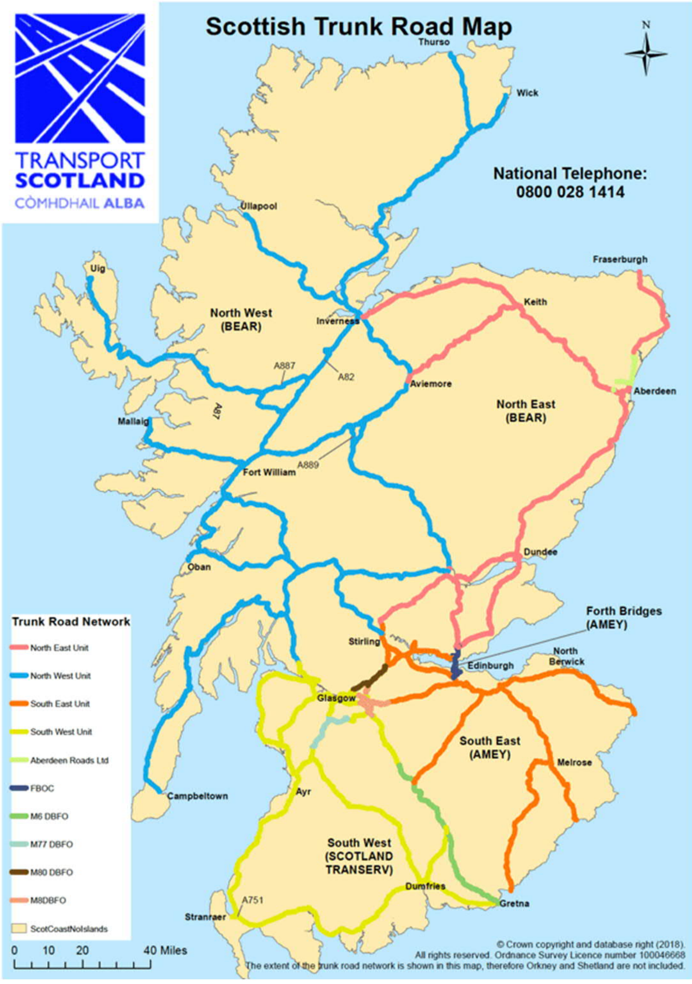


Source: ASFINAG

4.2.2 Transport Scotland

Transport Scotland is responsible for the maintenance and management of the trunk road network in Scotland, on behalf of the Scottish Ministers. The network is over 3,000km long and ranges from the M8's ten lane carriageway in the centre of Glasgow to single carriageway sections in the west Highlands.

Figure 4.2 Transport Scotland's trunk road network



Source: Scottish Trunk Road Network Asset Management Strategy, Transport Scotland, 2018

Transport Scotland has one traffic control centre, the Traffic Scotland National Control Centre (TSNCC), currently operated by the Traffic Scotland operator Amey. The TSNCC implements traffic control and network management measures, coordinates traffic information with key stakeholders and the public, and operates the emergency roadside telephones located on the trunk road network.

During the day, the TSNCC usually has five operators, one social media representative, and one or two police officers in post. At night, there may be three operators in the control room but this is reviewed and is scaled up if required, based on potential adverse weather conditions or events. In the winter months, a Meteorological Officer may also be present. Other key roles include the Lead Engineer, who acts as a focal point between the TSNCC and Transport Scotland's Operating Companies, which are private sector companies responsible for delivering a programme of maintenance.

The TSNCC does have stopped vehicle detection loops available to manage parts of the M9/M90 where buses use the hard shoulder during periods of congestion. In addition to this, Traffic Scotland has undertaken trials to use existing CCTV cameras to develop detection, in conjunction with ITS technologies, to support future connected and autonomous vehicles (CAV) buses. However, the TSNCC does not currently utilise detection technology to identify stopped vehicles in live traffic lanes, relying upon reports coming into the control room from stakeholders or the public, or through a third party data service from INRIX which detects slow moving traffic.

4.2.3 Highways England

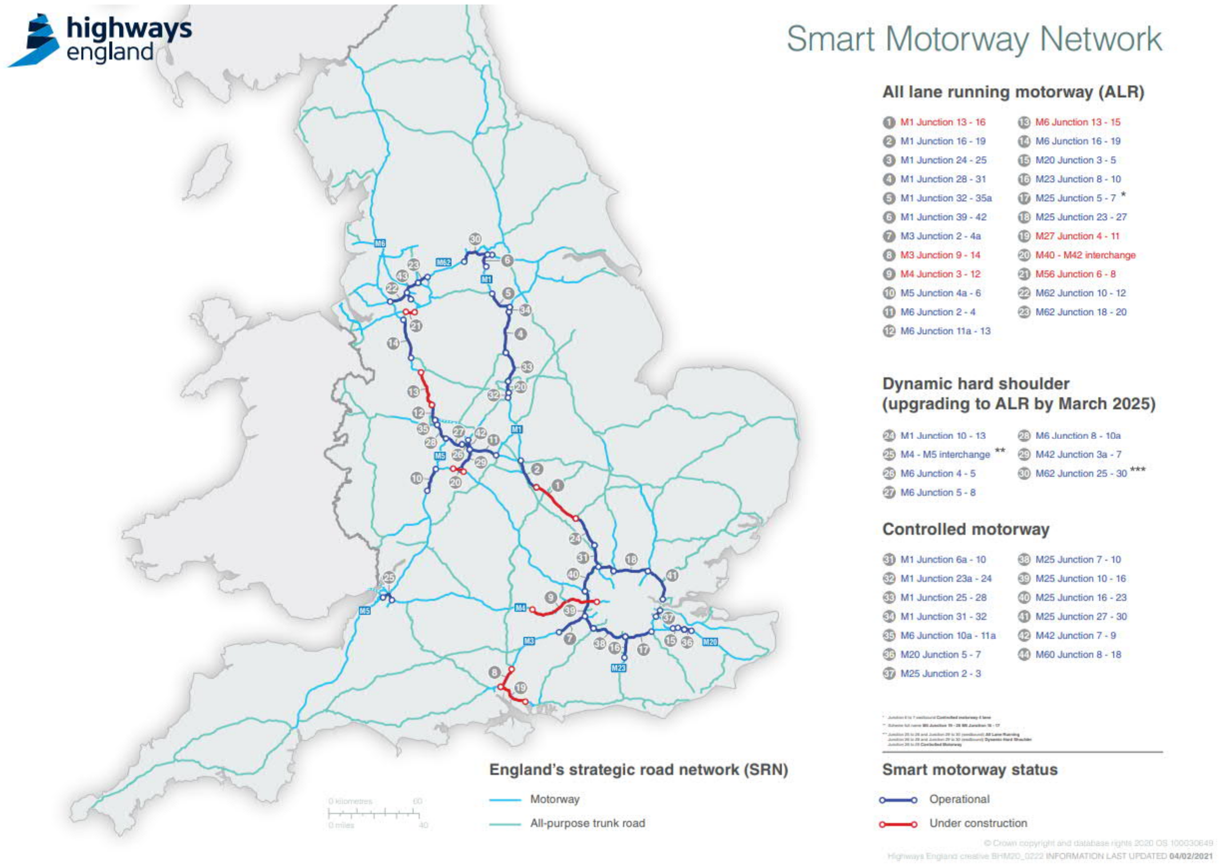
Highways England[4] is the government company responsible for operating, maintaining, and improving the strategic route network in England. Highways England's network totals over 6,000km and carries around a third of all traffic.

In the busiest sections of the strategic route network, Highways England have introduced Smart Motorways, which removes the hard shoulder role to increase capacity and reduce congestion. Key to this is the use of technology to detect stopped vehicles, variable signs, and signals to alert drivers to hazards, and emergency areas which are set back from the carriageway.

Highways England operates seven regional operations centres (ROCs) and the National Traffic Information Service, which includes the customer contact centre which coordinates emergency calls from the public with the ROCs. The ROCs are responsible for incident management, including the implementation of traffic management measures; stakeholder liaison; and keeping customers (their network users) informed. ROCs that manage smart motorways have access to detection radar technology which provides a faster response to stopped vehicles in live lanes. At the time of writing, large sections of the network do not have access to dedicated stopped vehicle detection technology, resulting in the control room responding to reports of stopped vehicles from outside sources or through MIDAS (Motorway Incident Detection and Automatic Signalling), which detects slow moving traffic using induction loops.

[4] Highways England was renamed National Highways while this report was being finalised. Since our research was performed with Highways England, we have retained that name in this report.

Figure 4.3 Highways England's Smart Motorways network



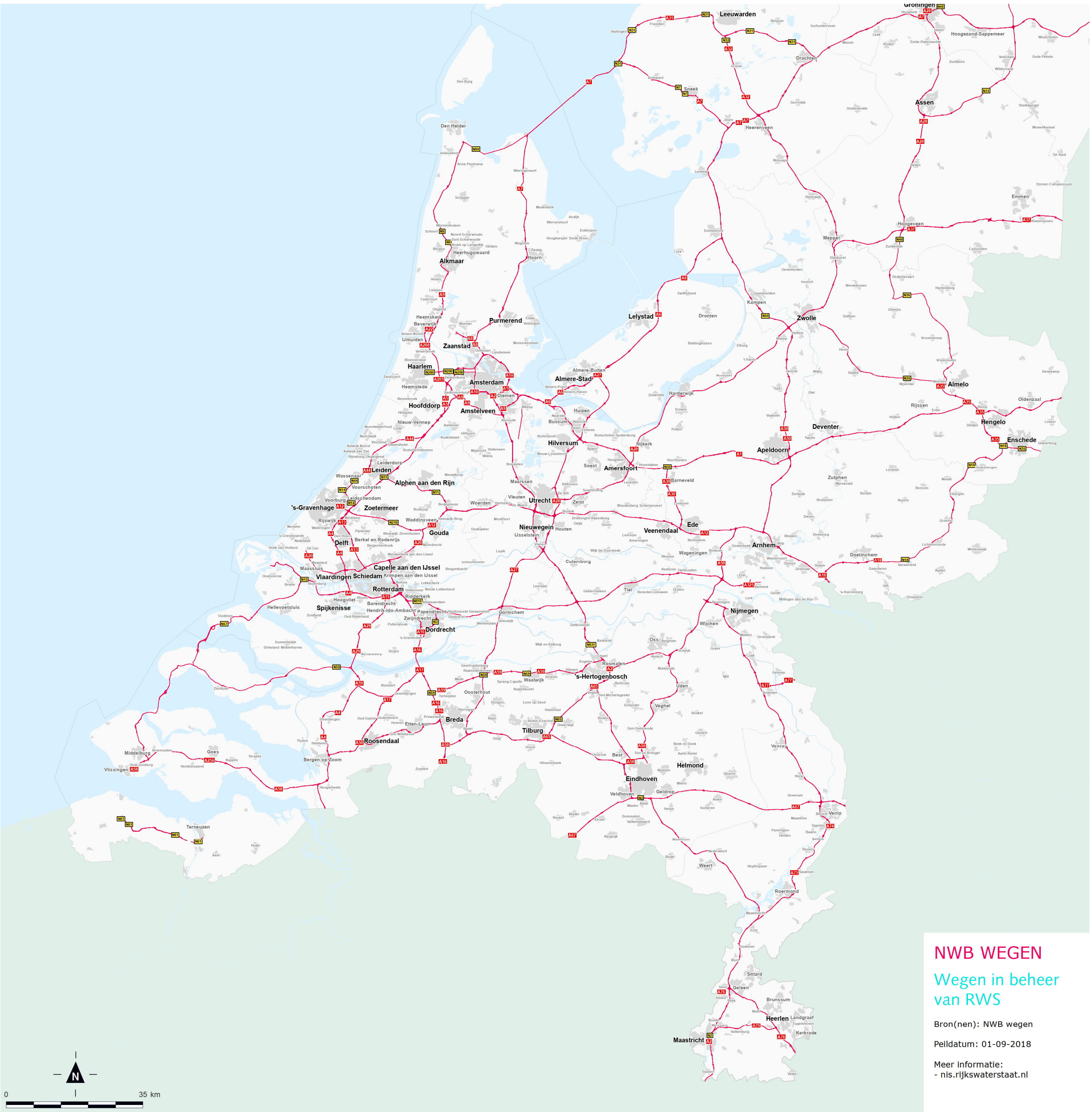
Source: Highways England

4.2.4 Rijkswaterstaat

Rijkswaterstaat is an executive department of the Ministry of Infrastructure and the Environment in the Netherlands and is responsible for the management and operations of its traffic network.

The Netherlands has a relatively dense, intensively used motorway network and relies upon smart traffic management to maintain network optimisation., Rijkswaterstaat has five traffic centres across the country managing over 3,500km of motorways and expressways. The traffic centres respond to incidents, supported by detection and communication resources including cameras and variable message signs (VMS), and manage congestion drawing upon dynamic, intelligent transport solutions.

Figure 4.4 Rijkswaterstaat trunk road network

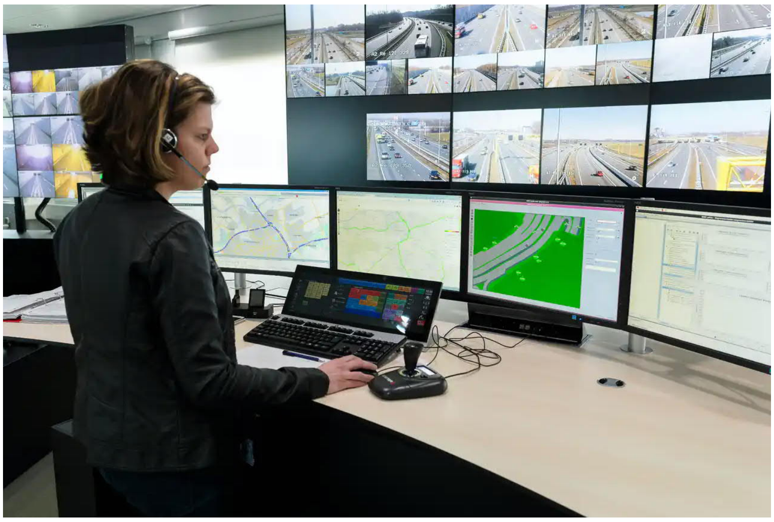


Source: Rijkswaterstaat

Within each control centre there is a dedicated resource available to respond to stopped vehicles. For those parts of the network where automatic incident detection is unavailable the control centre relies upon reports from queue detection technology, the police, traffic operators on the ground, or the public.

For major incidents, these are passed to the Traffic Centre of the Netherlands (VCNL) who coordinate the response and liaise with key stakeholders such as service providers, the Nationaal Dataportaal Wegverkeer (NDW) responsible for network data, and ANWB who provide roadside assistance.

Photo 4.2: Use of Rijkswaterstaat's Advanced Traffic Management System within the Control Centre



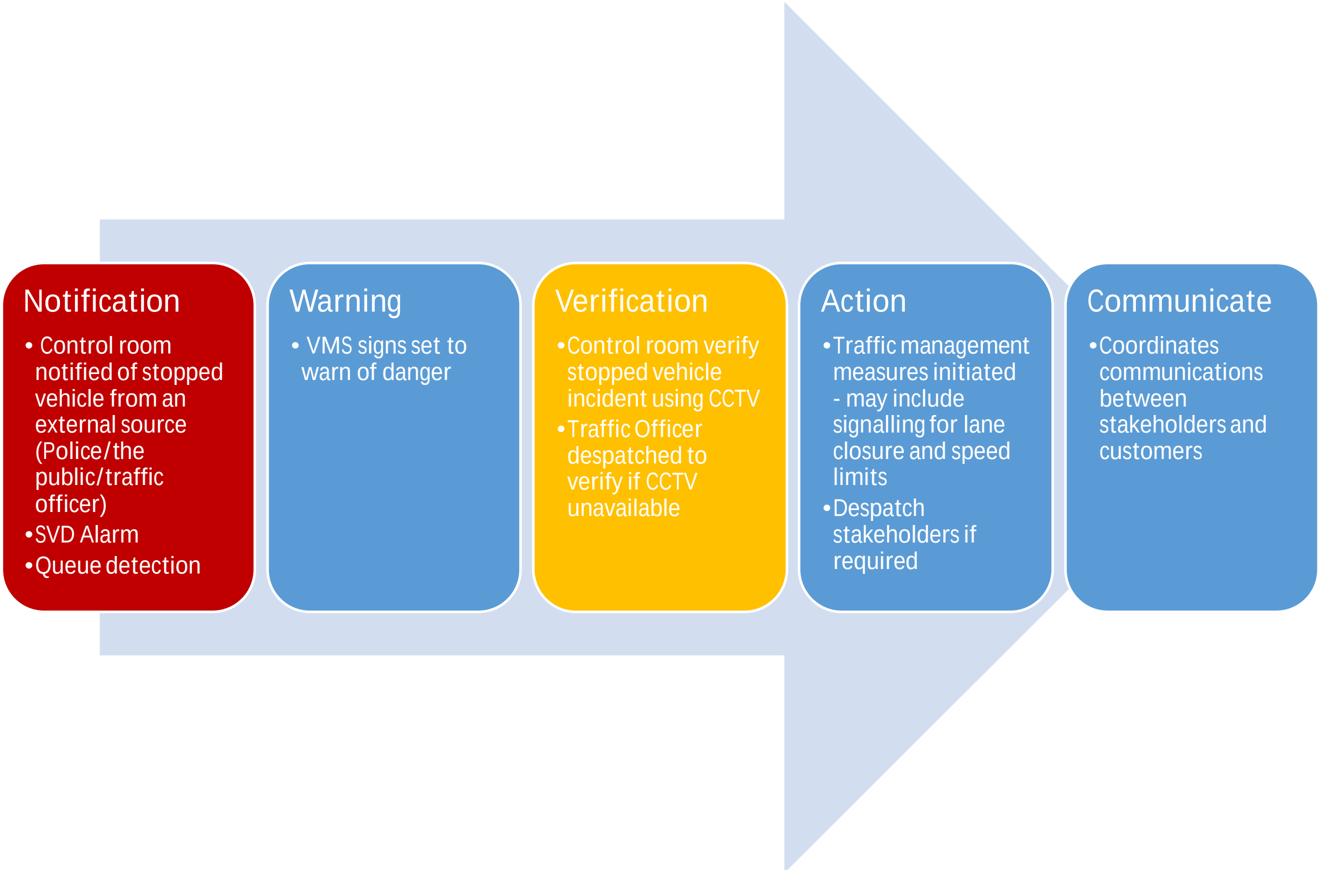
Source: Rijkswaterstaat

4.3 Control Room Process

Each NRA has clear and tested processes in place to manage the control room response to stopped vehicles in live traffic lanes. Operators do not deviate from protocol or make individual decisions; however, the traffic management measures may vary depending upon the nature of the incident or network conditions, following very similar processes as shown in the subsequent figure.

Control room inputs are highlighted in the red box, which sets out the various sources which enable the control room to become aware of a stopped vehicle in live lanes.

Figure 4.5 Stopped vehicle control room process



For control rooms with access to stopped vehicle detection technology, the process followed is similar to Figure 4.5 , however the time taken to verify the incident (shown in orange) is significantly reduced as the integrated system identifies the closest CCTV camera. This reinforces the literature review findings, whereby those control rooms with access to stopped vehicle detection are likely to achieve enhanced levels of safety due to their faster response time.

When detection technology is unavailable, the role of the control room reverts to the traditional responder, whereby operators seek to validate incident reports notified from external sources or, in some cases, investigate queues detected via traffic management systems. Notable differences between the NRAs are highlighted as follows:

- For confirmed sources, such as the emergency services or traffic officers, Highways England sets speed restriction signals in conjunction with warning signs, taking more decisive action earlier on in the process.
- For both Rijkswaterstaat and Highway England control rooms, where staffing levels are greater than Transport Scotland's and ASFINAG's requirements, the task of verification and action are delegated to different operators.
- The Rijkswaterstaat control room follows a set process, but operators do make decisions individually relating to traffic management measures such as lane closures.

The interviews identified the challenges the control room experiences when dealing with a stopped vehicle, particularly when attempting to locate the incident and liaising with stakeholders. For sections of the network without detection technology, the speed of the control room response is reliant upon the quality of the information provided relating to the incident location. Most notably Highways England identified responding to the information provided from untrusted sources, such as the public, as problematic because customers could be unfamiliar with their geographical location or unaware of how to use the distance marker posts.

When liaising with stakeholders, it was noted that terminology can occasionally differ, particularly when dealing with emergency services who may refer to different lane numbers within all lane running sections of the network. For control rooms without automated communication systems, updating stakeholders with the same level of information was also highlighted as a challenge, particularly in the Netherlands' regional traffic centres. Finally, Highways England noted differences in how emergency services directly communicate with the control room. In particular, regional police forces have different mechanisms, including via their own control room, adding an additional layer of communication to the process.

4.3.1 Physical Factors

As part of the interviews, the physical factors which support or obstruct the control room's response to stopped vehicles in live lanes were explored. The discussions highlighted how technology enables a rapid incident response, contrasted to scenarios when operators are required to locate incidents on the network not covered by detection technology in response to reports from trusted and untrusted sources.

The interviews revealed varying levels of ITS technologies available to assist control rooms detect and respond to stopped vehicles, with all control rooms making use of incident management systems to log incident details.

The most sophisticated detection systems tended to be located within ASFINAG's tunnels, whereby enhanced safety requirements dictated the use of highly automated detection systems such as radar and acoustic technologies.

For Transport Scotland, stopped vehicle detection in conjunction with their existing CCTV network is being trialled to support the introduction of CAV bus services on sections of the motorway network. Other notifications include automatic queue detection, which covers Scotland's central belt, detecting abnormal congestion occurring at unusual times. Following an alert, the control room investigates further using CCTV or by sending traffic support personnel or the police to the area.

Highways England and Rijkswaterstaat use radar detection to be notified of stopped vehicles in live lanes on all lane running sections of their networks, outside of this the control rooms are supported by automatic queue detection notifying operators of abnormal queuing.

Other technologies included eCall, via the police or car manufacturers' call centres, with ASFINAG equipping some control centres with C-ITS technology to enable fast and secure communications between infrastructure and vehicles.

Table 4.1: NRA Control Room Technologies

National Road Authority	Control Room Technologies/Tools
Transport Scotland	INRIX private sector data service Google maps CCTV Incident Management System (IMS) CAV CCTV detection trial Social media
Highways England	COBS system: • MIDAS queue detection • CCTV • Stopped vehicle radar detection • Signs and signals Controlworks IMS Hootsuite (social media management tool)
Rijkswaterstaat	Automatic incident detection (AID) Traffic management loop system Waze CCTV Uniform logging system (UDS) IMS
ASFINAG	Detection loops Acoustic warning systems - tunnels CCTV IMS Indirect technologies also include E-call (via the Police or car manufacturers call centre)

The interviews did not reveal any issues or challenges with the use of technology within the control room, however the following observations were noted:

- Technology supports the control room to rapidly respond to incidents of stopped vehicles in live lanes.
- When introducing new technologies to the control room, key success factors include engagement with operational staff at the developmental stage to provide insight from staff that are likely to use the tool and allowing sufficient time for training/coaching.
- CCTV cameras can occasionally fail, due to damage or, very rarely, network outage. In most cases, situational awareness can be still be achieved using an alternative camera or a traffic officer is sent to the scene to investigate.
- The larger VMS signs allow the control room to issue enhanced communications to drivers to support speed restrictions and lane closures, resulting in greater driver compliance when compared to the information issued via smaller VMS signs.
- Prior to stopped vehicle detection technology, control rooms had no knowledge of the number of vehicles which stop in live lanes for short periods of time and then continue as the issue is resolved. With detection, control rooms are notified within seconds of the vehicle stopping, however these incidents may become non-events if the vehicle restarts before picked up by the operator on CCTV.

Other physical factors included how control rooms adapted to the COVID-19 pandemic, with the introduction of new layouts to support social distancing.

4.3.2 Cognitive Factors

When exploring the cognitive factors which affect the control room response, the primary research revealed similar themes to the literature review. Firstly, operators follow organisational processes when dealing with a stopped vehicle in a live lane, which encompass detailed protocols for different types of incidents for example, incidents involving hazardous spillage. These procedures limit the operator's ability to deviate from protocol to make individual decisions, including:

- Wording for the VMS signage is pre-scripted; operators select the most appropriate message based upon the incident and the associated traffic management measures.
- Operators are responsible for implementing traffic management measures, drawing largely upon the set protocols, although there was some evidence that operator experience is also a factor.

Similar to the cognitive factors identified within the CEDR Transnational Road Research Programme PRIMA project [19], the primary research identified that the success of implementing new technologies within the control room is dependent on early engagement with users such as control room operators. Interviewees noted that engagement which enabled the refinement of new tools, and training were critical stages within the implementation plan and recommended that sufficient time should be allowed to support these tasks.

4.3.3 Organisational Factors

The organisational factors which support the control room's response to stopped vehicles included the development of skills, the identification of procedures including the linkages with stakeholders external to the control room, and resilience measures, discussed in turn as follows.

All NRAs provide new operators with training prior to starting within the control room, however key to the development of their skills is on-the-job training which provides exposure to incidents, cementing the classroom-based learning. New operators are supported through mentoring, and following completion of the initial training staff receive refresher training at regular intervals. Other training exercises include the introduction of new technologies or procedures.

As previously discussed, the interviews revealed the standardised operating procedures which support an effective response to stopped vehicles in live lanes. Highways England reported key performance indicators (KPI) in relation to response times while ASFINAG noted the requirements from the StVo (Road Traffic Safety Act, German for Strassenverkehrsordnung), where they are obliged to act as quickly as possible. Key to achieving these requirements are shared and tested protocols which effectively set out the processes to deploy resources and minimise inefficiencies. Technology plays a crucial role in this, providing the control room with the tools to alert operators to incidents and highlight unusual traffic conditions.

Interestingly, the literature review noted concerns that the complexities of traffic combined with the growth and availability of data may affect operators' ability to develop a clear mental image, affecting their situational awareness. However, this was unsubstantiated within the primary research, with interviewees advocating that technology optimises the decision-making process, alerting operators to network deviations.

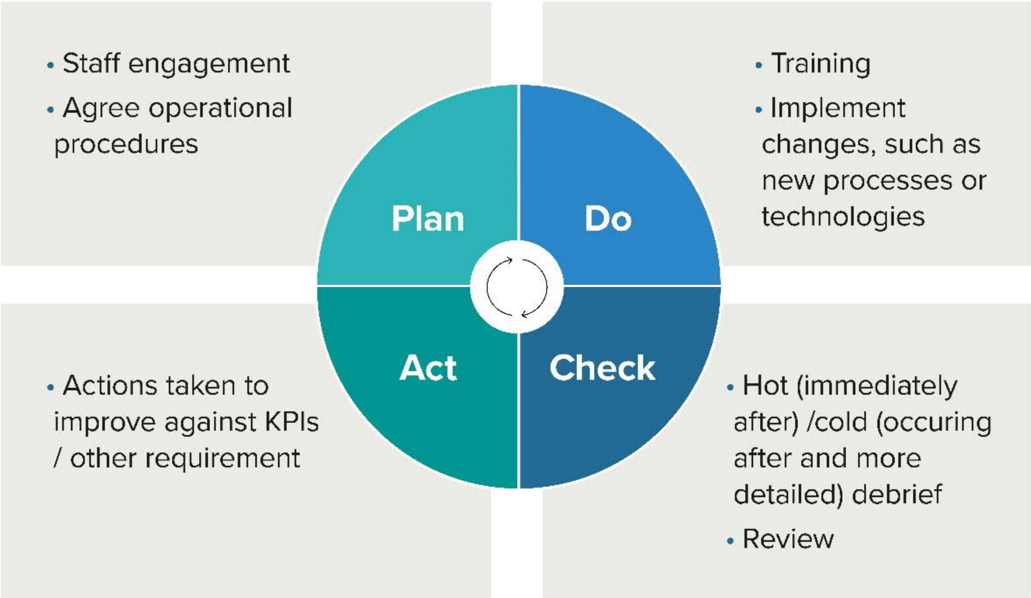
The interviews clearly demonstrated how the control room provides a crucial link between an incident and stakeholders by receiving information, prompting action, and sharing information across all parties. This relationship is symbiotically supported by shared and aligned operational procedures, facilitated through technology and physical space:

- The interviews revealed that control rooms often included representatives from the police and/or operators sharing the same physical environment.
- Many of these stakeholders had direct lines of communication with the control room, either via the incident management systems' telecommunication facility or by telephoning directly.
- Interviews with Highways England revealed the challenges when engaging with regional emergency services, highlighting their South Mimms control room engages with nine police forces with varying lines of communication. For those police forces with direct lines of communication, such as through the ControlWorks system, a streamlined and collaborative response could be achieved.

All NRAs interviewed revealed an iterative process of plan/do/check/act as shown in Figure 4.6. In addition to this, the continual development model supports the staff development process, highlighting potential training needs or providing useful case studies for new staff to learn from.

Figure 4.6 highlights the continual development of the control room's capabilities. Key to this approach is a system of review, whereby the NRA, in conjunction with their stakeholders, undertakes an assessment to identify areas for improvement following an incident. This may result in changes to operational procedures or modifications to technology to deliver improvements which support the control room meet its KPIs or other objectives. In addition to this, the continual development model supports the staff development process, highlighting potential training needs or providing useful case studies for new staff to learn from.

Figure 4.6 Control room Plan/Do/Check/Act process



Source: Mott MacDonald

The literature review identified concerns relating to cyber security, particularly with reference to systems integration with stakeholders and partners. The interviews revealed that NRAs have strategies in place to manage this risk, and there were no reports that cyber security had impacted upon the control room's ability to respond to stopped vehicles. Other organisational resilience measures included how the control room adapted to COVID-19, ensuring backup was available if operators were required to isolate at short notice.

4.3.3.1 Driver Behaviour

Finally, the interviews identified the external factors in place to support the NRAs achieve their strategic objectives, including driver education which seeks to ensure that drivers understand what they must do if their vehicle stops in a live traffic lane. For the Netherlands and Austrian NRAs, drivers have legal obligations which must be adhered to, including displaying a warning triangle and wearing a high visibility vest / jacket. In addition to this, drivers and their passengers must move to a safe place, such as behind crash barriers.

Highways England reported that driver behaviour varied. For vehicles which stop in lane one, previously the hard shoulder, drivers tended to get behind the crash barriers, however when stopping in the middle lane or lane 3, driver behaviour was less predictable. There was recognition that the control room was starting to see changes to driver behaviour following Highways England's Go Left campaign (see Figure 4.7), with greater compliance and understanding of where drivers need to get their vehicle to if they breakdown or need to stop in an emergency.

Figure 4.7 Highways England GO LEFT campaign material

Source: Highways England

Both Highways England and Rijkswaterstaat noted occasional issues relating to compliance when lanes were closed, and drivers were notified via the gantry signs. Herd behaviour is often observed, whereby drivers are influenced and copy other motorists who ignore lane closure signs shown on the gantries. Highways England reported most violations occur when a stopped vehicle was in lane 2, resulting in the closure of both lanes 2 and 3.

Photo 4.3: Highways England Smart Motorways Gantry, Lane Closure Signs and Signals

Source: Devitt Insurance

4.4 Summary

The primary research identified the organisational, cognitive, and physical factors which support the control room effectively respond to stopped vehicles in live lanes, to a greater or lesser extent as shown in Figure 4.8.

Through the discussions, it can be concluded that the organisational factors have the greatest influence within the control room, safeguarding its functions by shaping how it operates both internally and externally, whilst identifying and delivering procedural changes and/or new technologies to improve efficiencies.

Organisational procedures limit the influence of cognitive factors which could potentially deviate from protocol. Furthermore, through the introduction of detection technology operators have a greater understanding of what is occurring on the network providing enhanced levels of situational awareness compared to sections of the network where operators must look for incidents following external reports.

Influencing driver behaviour through NRA-led campaigns 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 if their vehicle stops. Furthermore, real time messaging to other drivers on the network, with supporting information as to why speed limits have reduced or lanes have closed, can secure greater compliance to the traffic management measures initiated by the control room.

Interestingly, control rooms now have a greater understanding of the incidents that may quickly become non-events, data which was unavailable prior to introduction of dedicated stopped vehicle detection technologies. This could assist NRAs to develop an understanding of why drivers stop in live lanes and inform future approaches which influence this behaviour whilst minimising the risk to other drivers.

Figure 4.8 Control room success factors

Source: Mott MacDonald

5 Control Room Case Study: Highways England

5.1 Introduction

This section presents a case study from Highways England's East Regional Operations Centre (ROC) to provide further insight on control room operations with access to stopped vehicle radar detection. We explore the processes in place within the control room to support an effective response to a stopped vehicle in a live lane, including:

- How operators develop situational awareness.
- Undertaking link analysis to document the relationships between the control room inputs and outputs.
- Exploring the communications both within the control room and externally with stakeholders.

This case study was informed through interviews with ROC operators, non-operational managers involved in Highways England's stopped vehicle radar detection capital infrastructure programme, and external stakeholders such as ConnectPlus Services and the police.

5.2 Background

The East ROC is located in Bedford and delivers the real time traffic management of one of the busiest and diverse sections of Highways England's network, including the northern half of the M25, London's orbital motorway. The ROC monitors and manages traffic conditions of major strategic road routes into London and on the more rural sections of the strategic road network in locations such as Norfolk and Suffolk.

The ROC has access to a range of ITS technologies, including stopped vehicle radar detection installed on the busiest sections of the strategic road network, as part of Highways England's investment in Smart Motorways. Radar technology is located on the M25 and on parts of the M1, providing the control room with the opportunity to rapidly implement traffic management measures which protect stopped vehicles in live lanes and minimise the risk of secondary incidents. For other sections of the motorway network not covered by radar detection, the ROC relies upon reports from sources outside of the control room and queue detection technology such as MIDAS.

Within the ROC there is one team manager overseeing between 9 and 12 operators during the day, and 5 operators at night. Operator numbers are increased if required as a response to planned events (e.g. the Duke of Edinburgh's funeral), forecast bad weather, or during planned outage of technology when the control room may rely upon old systems whilst new technologies are updated. Roles include radio dispatch, call handling, and signs and signals. In addition, one operator is dedicated to the customer desk, responsible for liaising with the National Traffic Operations Centre (NTOC) in Birmingham and pushing out messages via social media regarding delays which may impact their customers.

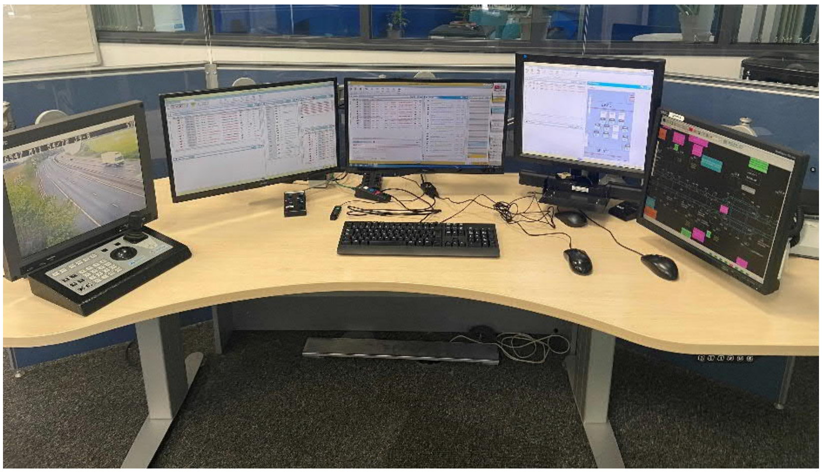
Operators also perform support role functions which are undertaken between responding to emergency calls. These include:

- Dynamic hard shoulder – undertaken by the signs and signals operator/s.

- Asset delivery jobs such as infrastructure defects - undertaken by the call handler/s.

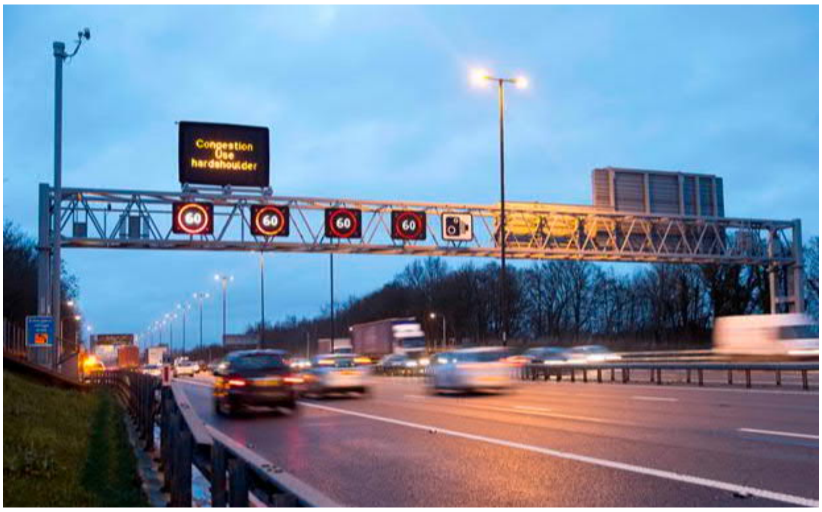
Other desks within the control room are associated with non-ROC operational functions, including the technology contractor (1 desk) and maintenance contractor (2 desks).

Photo 5.1: ROC Operator Desk



Source: Highways England

Photo 5.2: Example of Smart Motorways VMS warning signage



Source: Highways England

5.3 Technologies

The ROC has access to a range of technologies which support operators to gather information efficiently, assess abnormal situations, and apply effective traffic management measures. Controlworks provides the centralised incident management system, whilst the Control Office Based System (COBS) has been key to enabling operators develop situational awareness of the network, and both systems are discussed further as follows.

5.3.1 ControlWorks

Fundamental to the ROC's operations is the ControlWorks system, providing an incident management platform incorporating communication channels and other data sources. Within the ControlWorks system, the ROC is able to communicate with Traffic Officers and a number of the Police Forces with access to the system, maintaining a repository of information with all activities undertaken logged.

5.3.2 The Control Office Based System (COBS)

Although Highways England is in the process of deploying a new traffic management system (CHARM) which will replace COBS, the deployment is not yet complete and the operational dedicated stopped vehicle detection facilities so far have been integrated only with COBS, so it is COBS that is considered in this report.

Highways England's COBS application pulls data from numerous subsystems, providing the ROC with a centralised approach to traffic and incident management. COBS draws data from different software and hardware sources, including:

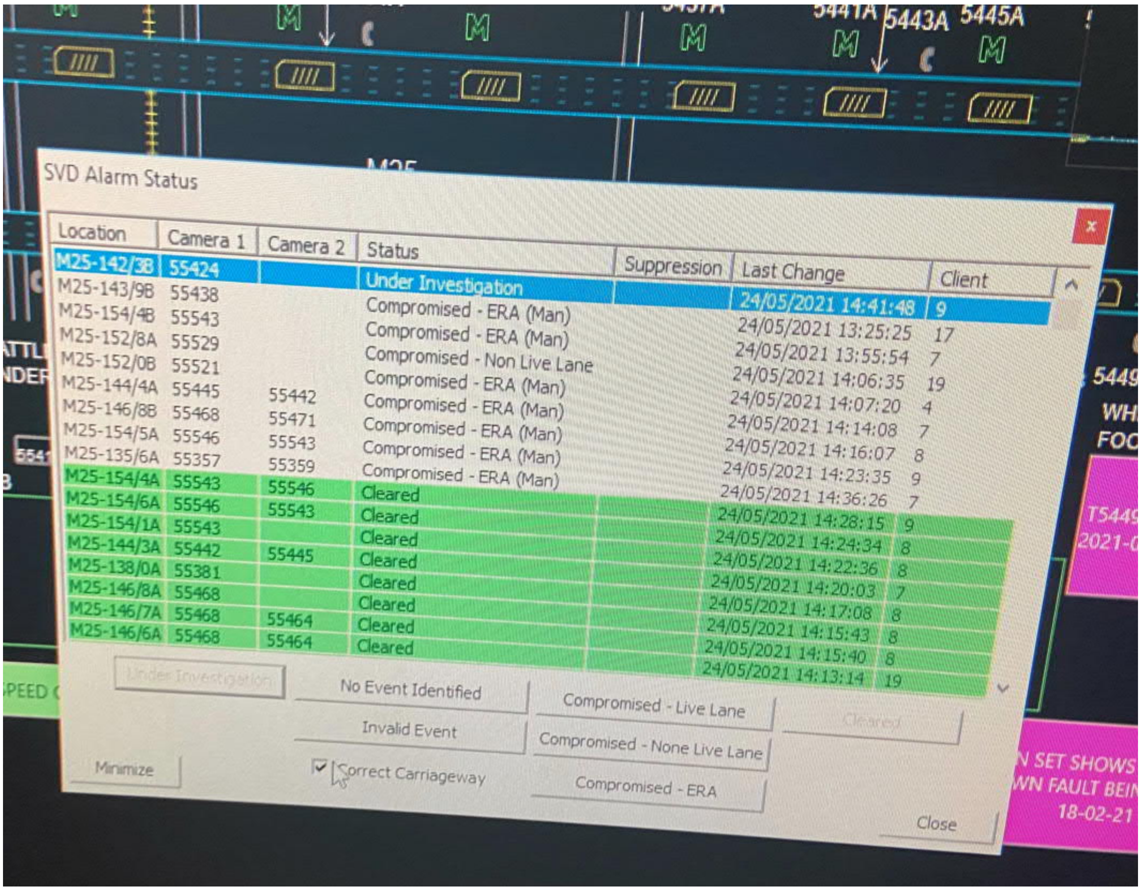
- The VMS system which enables the ROC to dynamically manage the smart motorway via verge mounted signs and signals displayed on overhead gantries.
- MIDAS, which provides the ROC with automatic notifications of queuing as a result of congestion or an incident. In addition, MIDAS provides automated warnings to road users through its automatic signalling system.
- Pan-tilt-zoom CCTV cameras which are positioned to provide full coverage of the carriageway.
- The emergency telephone system, which provides a direct link to the ROC from an emergency telephone located at specific intervals alongside the motorway and/or in the emergency refuge areas.
- Roadside weather stations.
- SVD radar detection scanning the carriageway every 500m. An algorithm identifies potential stopped vehicles, issuing an alert via the COBS system with a location reference to allow the operator to locate and verify using CCTV. See 5.3.2.1 for further detail.
- The dynamic hard shoulder system providing additional capacity when required.

Through our discussions with the police, it was noted that police forces with access to ControlWorks can also access Highways England's CCTV network. This provides stakeholders with the opportunity to gain an immediate understanding of the event prior to arrival at the incident.

5.3.2.1 Stopped Vehicle Detection

The busiest sections of the ROC's network operate as Smart Motorways, with all lane running to increase capacity and reduce congestion. The COBS user interface alerts users with an audible alarm and a pop-up window displaying current and recently cleared alerts, as shown in Photo 5.3.

Photo 5.3: Eastern ROC's SVD Alarm Status Screen



Source: Highway England

Features include:

- Identification of the appropriate nearest cameras to the stopped vehicle to improve response times.
- Distinction of live lane and emergency refuge area (ERA) alerts, to help operators prioritise responses.
- Automatic association of alerts with predefined locations, to give operators a familiar location description for each alert.
- To minimise false positives, operators can suppress specific sections of carriageway to avoid being alerted unnecessarily.
- Within the Eastern ROC, the SVD system is integrated into COBS, which triggers a warning to drivers via VMS.

The operator uses the alert location and camera recommendations to check the carriageway visually using CCTV. If the stopped vehicle is confirmed, the response action includes setting signals and initiating recovery. The status of the stopped vehicle alert is updated in the alerting system.

As an interim solution during the deployment of CHARM, a web-based alerting tool was developed which in addition to a tabular view also featured a geographic map view of the alerts - a feature appreciated by operational representatives. However, the map-based alerting tool was not yet in operational use at the time of the research.

5.3.3 Signing and signalling details

A VMS is activated to display a message related to an incident (or accident) downstream, at distance not greater than 5km or 2 junctions from the incident area or any queues which have formed as a result of the incident.

The message needs to include both a place name and a junction number related to the incident, or just the junction number if that is not achievable. All accident or incident related pictograms must be shown within a red warning triangle.

If an accident or incident is reported by anyone other than an approved source (such as a traffic officer), the local operator may set a maximum speed limit of 60mph with a supporting text legend that begins ‘REPORT OF …’ where VMS are available. If the ‘REPORT OF …’ legend is not appropriate, then the ‘INCIDENT’ legend will be used.

If an operator receives details from an approved source then appropriate non-lane-specific signs and signals can be set immediately. Once the exact details of an accident or incident have been confirmed by one of the approved sources then appropriate lane-specific signs and signals are set as required.

The classification "Accident“ is used in the majority of the cases including those when roads have been closed due to collisions. The classification "Incident“ is usually used when the road has been closed to deal with other types of situations such as security threats or suicide attempts

5.3.3.1 Stationary traffic

For stationary traffic which is being held or trapped behind an incident and is unable to move for more than 15 minutes, then the regional control centre will consider setting VMS to inform customers of: the type of incident, the progress at scene, and the likely time for clearance. Below is a list of all the legends that could be used in those occasions:

- `SERIOUS ACCIDENT (ROAD CLOSED)`
- `SERIOUS INCIDENT (ROAD CLOSED)`
- `M* J*-J* NOW OPEN QUEUE CLEARING`
- `ROAD NOW OPEN QUEUE CLEARING`
- `SWITCH OFF ENGINE`
- `AWAIT INSTRUCTION`
- `DO NOT MOVE VEHICLE`
- `STAY IN VEHICLE`

- STAY WITH VEHICLE
- RETURN TO VEHICLE
- HARDSHOULDER KEEP CLEAR
- KEEP HARD SHOULDER CLEAR
- DEBRIS BEING REMOVED
- TRAFFIC BEING RELEASED
- AIR AMBULANCE ON SCENE
- TRAVEL INFO ON LOCAL FM
- A/M* J*-J*ACCIDENT CLEARED

5.4 Communications

The ROC utilises a range of communication channels and methods to communicate with other operators, stakeholders and the public as summarised in the table below. In addition, we highlight the enablers which support an effective response and the challenges identified via the interviews with stakeholders outside of the ROC.

Table 5.1: ROC Communication Channels

Communication channel	Audience/Stakeholder	Enablers to an effective response	Challenges
ControlWorks	• Other operators within the ROC. • NTOC. • Highways England Traffic Officers. • Police with access to the ControlWorks police channel. • The public via emergency telephone.	Incident management system used to record every stage of the ROC's response. All verbal communications relating to an incident are recorded within the ControlWorks system. Interoperability between various systems.	Not all stakeholders have access. Quickly locating incidents notified by the public via the NTOC when the caller does not have accurate location details.
ROC Telephone	• Other emergency services without access to ControlWorks. • Asset management and maintenance contractors.	The simultaneous deployment of Incident Support Units (ISUs) with Traffic Officers can achieve a faster incident recovery time. Traffic Officers can provide a direct link between the ROC and stakeholder responders at the scene. ISUs can request hard shoulder access or to pass under a red 'X' lane closure from the ROC via their control room to reach the incident faster.	Requires operators to update ControlWorks separately. Does not provide a direct line of communication between stakeholders to support on the ground. Terminology can be misused when dealing with stakeholders who are unfamiliar with smart motorways operations.
VMS and matrix signals. See photo 5.4.	• Road users.	Incident communications are provided via VMS direct to verge mounted signs. The more detail relating to the type/nature of the facilitates greater driver compliance.	Driver compliance, particularly when insufficient information is provided. The size of VMS signs can vary resulting in ROC operators selecting the

Communication channel	Audience/Stakeholder	Enablers to an effective response	Challenges
		All VMS messages are agreed and predetermined by the NTOC. The ROC operator selects the most appropriate message relating to the incident.	wrong message for the sign size. The operator must select a different message which meets the maximum number of characters for the sign.
Social Media	• The wider public.	Incidents resulting in lane closures and/or delays of over 15 minutes are pushed out via social media channels, through Hootsuite. Tweets can be picked up by local travel news and other stakeholders to be retweeted and/or pushed out via their channels reaching a wider audience. See figure 5.1 for an example.	Social media responses can be reliant upon the availability of operators who may be undertaking other incident response tasks.

Photo 5.4: Examples of VMS and matrix warning signals and signs

Source: Highways England

Figure 5.1 Example stakeholder twitter messaging

Source: Twitter

5.5 Process Mapping

Communication and response follows a set process, utilising technology to optimise performance and record all actions taken, logged on the ControlWorks system.

Key findings and observations from the interviews are highlighted below:

- The interviews found no evidence that the ROC's process is deviated from, however tasks such as social media monitoring and messaging may not be prioritised if resources are constrained due to a major incident.
  - Interestingly, the police stakeholder noted that the police often delivered a more dynamic approach to addressing an incident, which may not fit within Highways England's standard operating procedures; this is reflected on in the multi-agency debrief sessions.
- Within the ROC there are clearly defined roles for signs and signals, call handler, and dispatch, however a number of tasks are undertaken dependent upon operator availability rather than role, and this would be overseen by the team leader.
- With SVD radar detection, drivers receive early warning of incidents initiated through the automated COBS signs and signal system. Similarly, when a trusted source notifies the ROC, drivers receive early warnings initiated via the signs and signals operator.

- For incidents notified by the public via 999, the police will be notified of the event prior to the ROC. Police handlers create a log, which is sent to the ROC, for validation.
- The police benefit from using the same incident management system, ControlWorks, as the ROC, which provides a single source of information relating to the incident and the response.
- The police are dispatched to incidents if there is a risk of harm or suspected criminality. For these incidents, the police act as the lead agency from the scene.
- The CCTV coverage is key for monitoring the scene, providing the ROC, ConnectPlus and the police (forces with access to ControlWorks) with an understanding of what is happening on the ground and incident progress.
- ConnectPlus is not currently co-located within the ROC and operate their own control room. Key points to note relating to ConnectPlus:
  - ConnectPlus usually dispatches their ISU after the traffic officer reaches the scene, however it was noted in the interview that Highways England is moving towards a simultaneous dispatch approach to reduce the incident response time and the potential delay to road users.
  - ConnectPlus strategically position ISUs at points on the network where incidents are more likely to occur or at points where it enables the unit to reach incidents within the 20-minute KPI time.
  - The ROC notifies ConnectPlus of a ISU requirement via the landline telephone.
- The traffic officer acts as the 'controlling mind' from the scene, controlling the incident response from the scene and updating the ROC.
- Traffic management measures are initiated in stages as the ROC develops a greater understanding of the incident.
- Warning VMS are deployed earlier in the process when the report is received from trusted sources.
  - Blanket speed limits and blocked lane signs are initiated.
  - Lane closure instigated once the ROC has reviewed and verified the incident using CCTV.

We provide two process maps to summarise the ROC's approach taken to respond to a stopped vehicle: the first (Figure 5.2) sets out the process whereby the ROC is informed of an incident via SVD radar detection, the second (Figure 5.3) presents the approach when the ROC is notified via external sources.

Key points to note include:

- Signs and signals operators are shown as green within the process maps.
- Call handler is shown as blue.
- Dispatch is shown as orange.
- Differences between the two process maps include:

- In figure 5.3, the ROC is notified of an event via an external source which results in an additional step within the process map whereby the call handler is required to locate the incident.
- For unconfirmed sources, as shown in figure 5.3, the ROC cannot set blanket speed limits and lane closures, until the incident is verified on CCTV.

Figure 5.2 ROC SVD radar process map

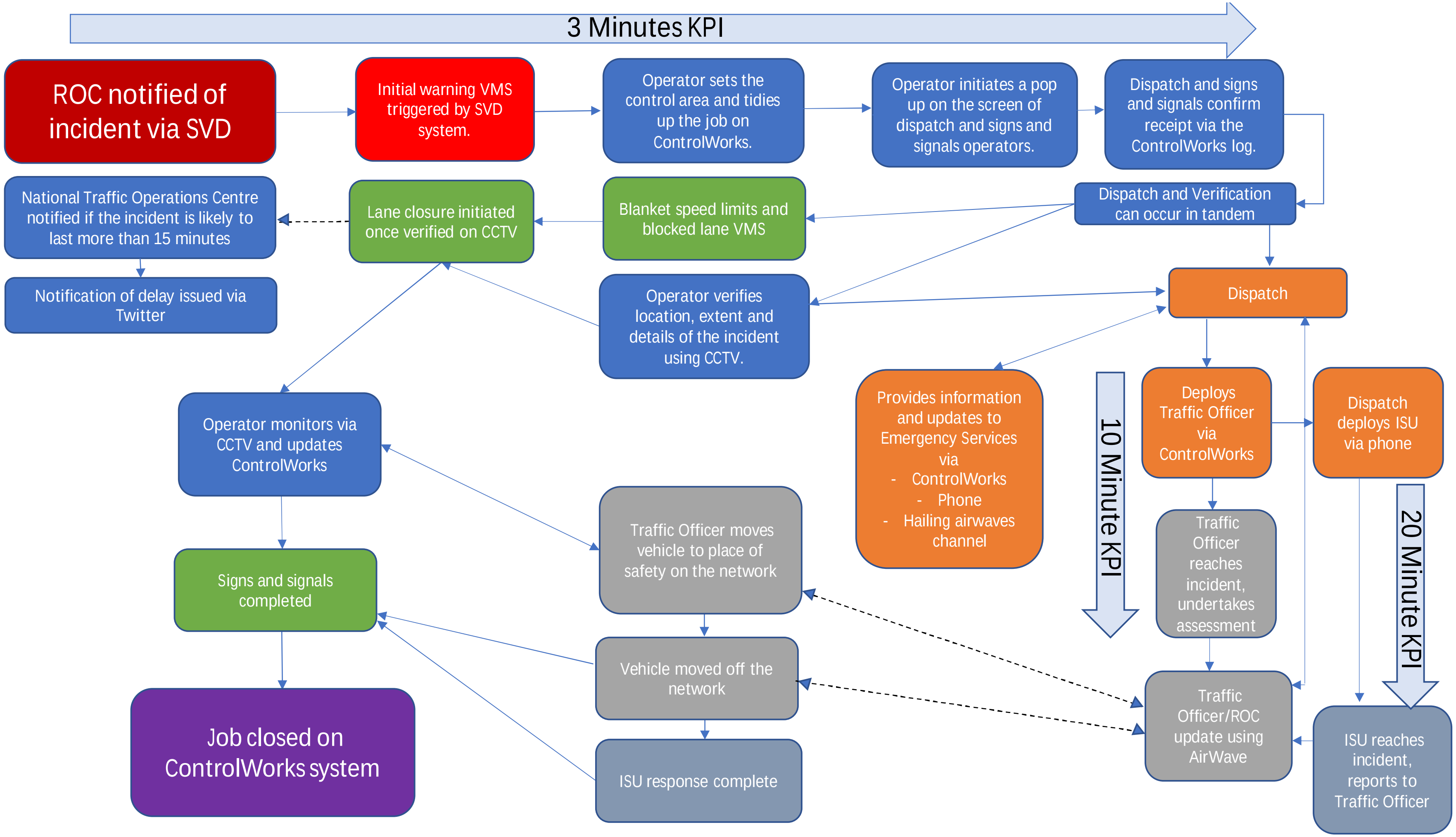
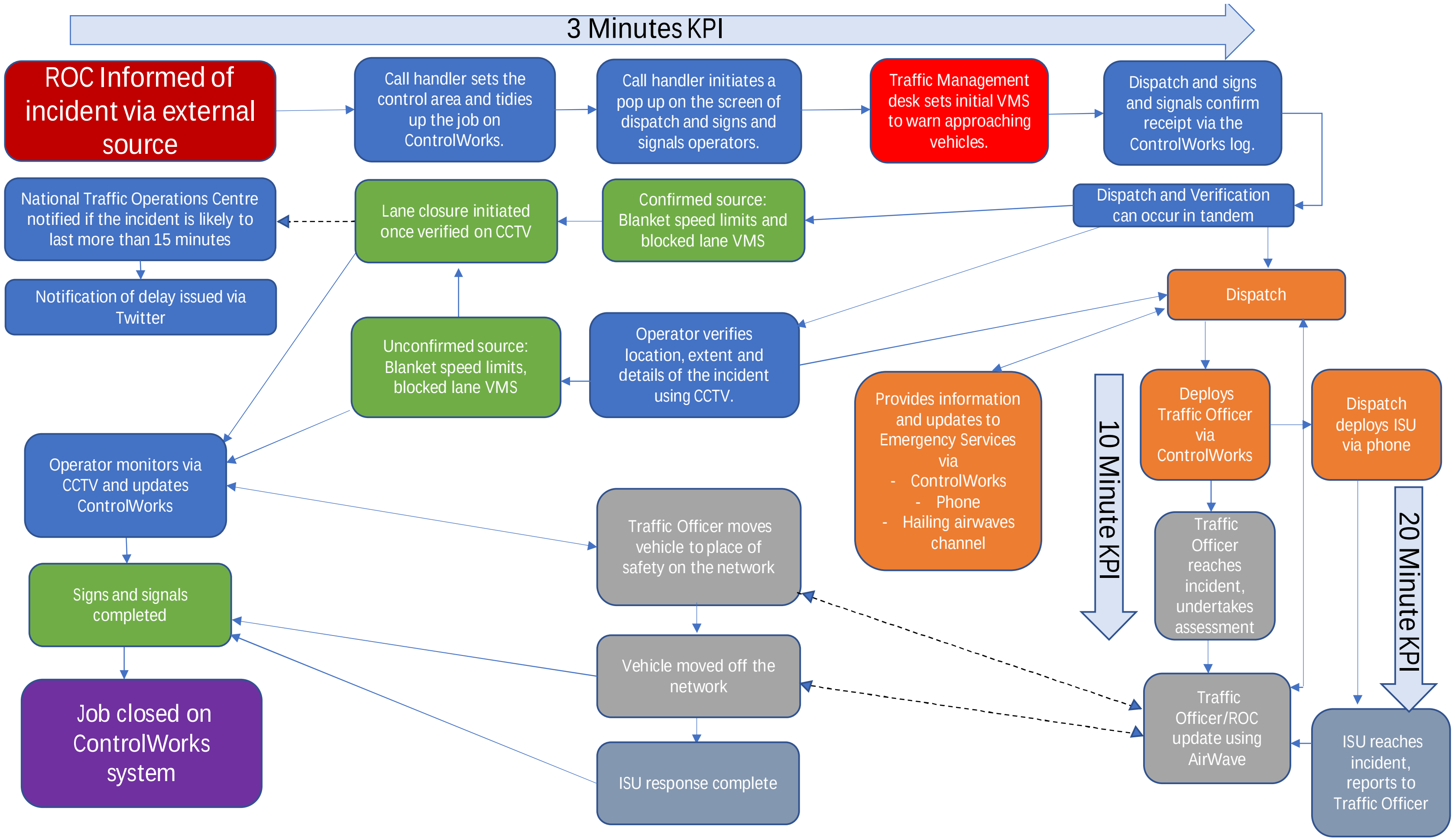


Figure 5.3 ROC stopped vehicle incident process map



5.6 Link Analysis

A link analysis is an evaluation method used to identify and represent relationship 'links' in a system and to determine the frequency, importance and nature of these links.

For this project, a link analysis assessment was undertaken to document the relationships between the ROC's inputs and outputs, to identify the factors involved in the control room's response, and the impact these may have on each other.

The link analysis illustrates that the key difference between SVD and non-SVD use occurs at the front end of the detection, reporting and confirmation process, and that normal procedures are then followed whether SVD is employed or not.

Figure 5.4 illustrates the linkages between inputs and outputs, including the relationships between the system, processes and people required to deliver an effective response when SVD is available. To avoid repetition, the link analysis without SVD concentrates on the inputs, given that the subsequent steps are identical.

When triggered, the SVD reports to a single system (COBS) which immediately informs the ROC operational staff of a potential situation and its location. Without SVD, the links and sequences of detection and reporting become more complex, with both confirmed and unconfirmed sources using different contact methods, procedures, and technologies to alert the operator to a possible stopped vehicle. This greater complexity of communication and system links adds time delay when detecting, reporting, and responding to the event by the ROC operator.

Figure 5.4 ROC link analysis with SVD radar detection

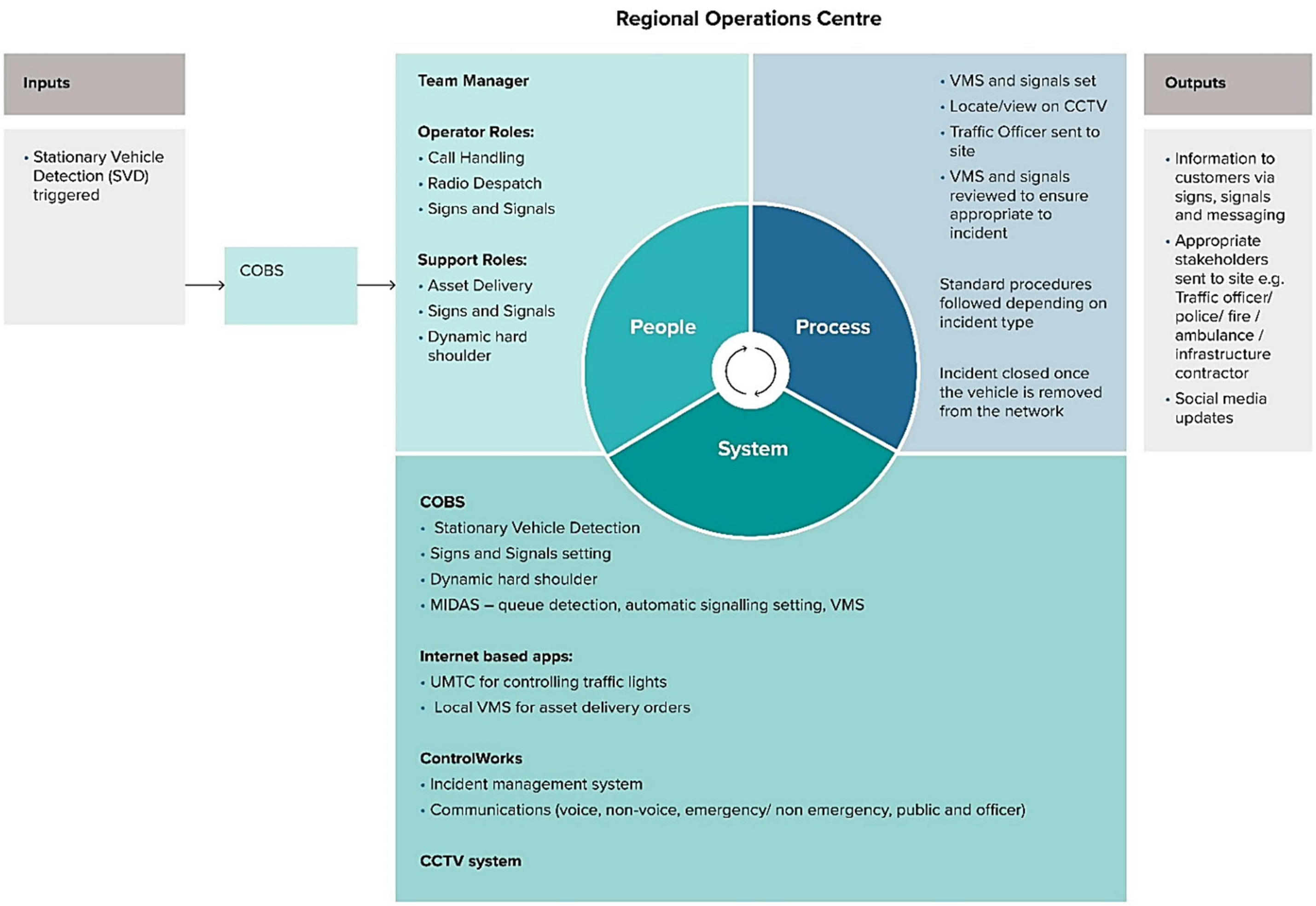
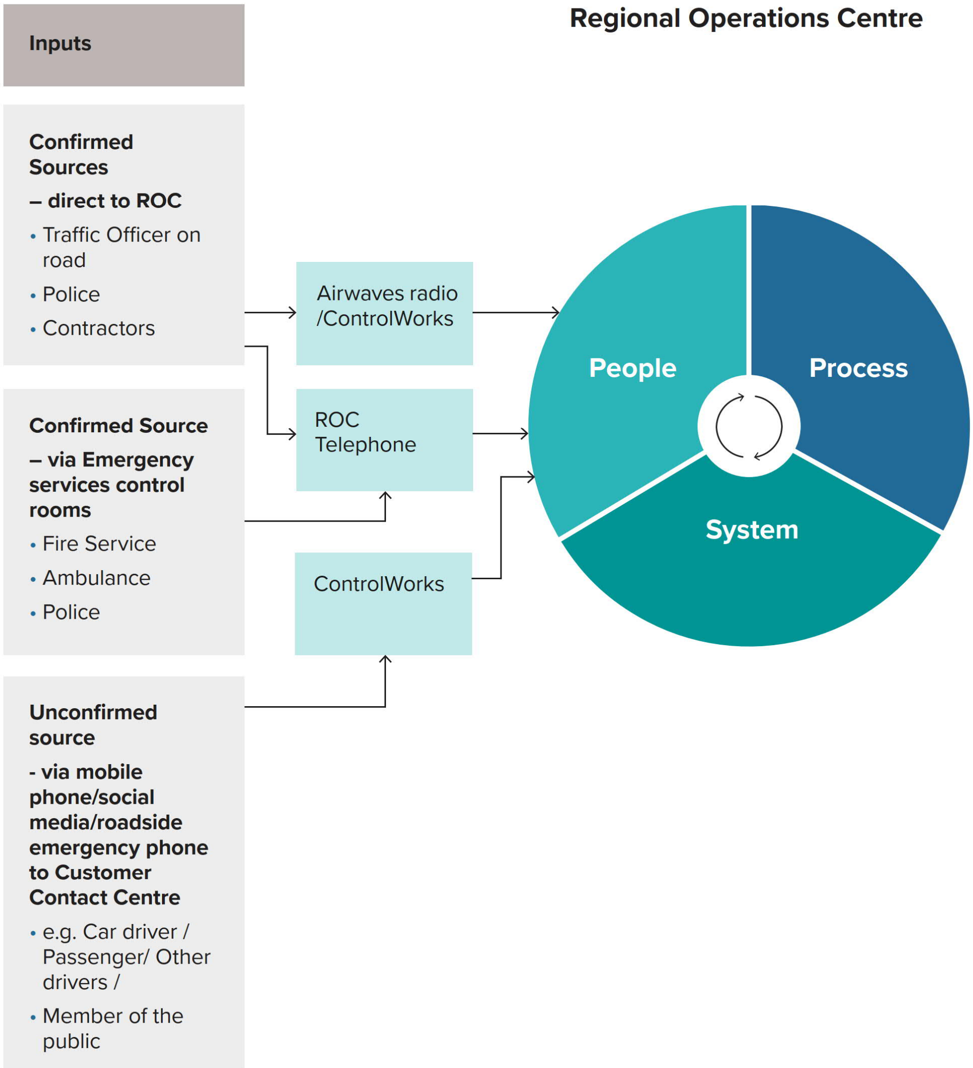


Figure 5.5 ROC inputs link analysis with no SVD radar detection



5.7 Situational Awareness

To be able to plan or solve problems effectively in the dynamic situations often experienced in a highways control room, the personnel involved need to firstly be alerted to an incident. Once knowledge that an event has happened has been received, the operator must then gain a relatively accurate understanding of the immediate situation to anticipate the implications of the event to the users of the road and to the stakeholders.

Being alerted to a situation, gaining immediate understanding of the event, and projecting the future status as the event unfolds, is a concept known as situational awareness. The level of situational awareness gained by the operator impacts their decisions and actions. These decisions and actions are additionally influenced by factors such as the operators' own experience, knowledge and training, and task and environmental factors such as workload, the design of the systems they use and established organisational processes.

Applying Dr Mica Endsley's[5] model of Situational Awareness to the ROC context, three key factors were identified in relation to the ROC operator gaining situational awareness to inform their decision making and related actions. In relation to stopped vehicles and other potential incidents, this is summarised below and illustrated in Figure 5.6.

- Perception: Operator perceives the relevant elements relating to the incident as currently exists, prior knowledge of the physical environment, reading information displayed from a pop-up screen, hearing the SVD alarm or receiving information via the ROC telephone.
- Comprehension: Operator develops an understanding of what has happened through the technologies, such as CCTV and other personnel to gain an understanding of the significance of the incident on current road traffic. For example, a car stopped in a live lane because it has run out of fuel provides a different insight to prospective needs compared to a stopped diesel truck with a potentially ruptured fuel tank.
- Projection: Once the operator comprehends the meaning and significance of the immediate situation, they will project into the future the potential impact of the situation.

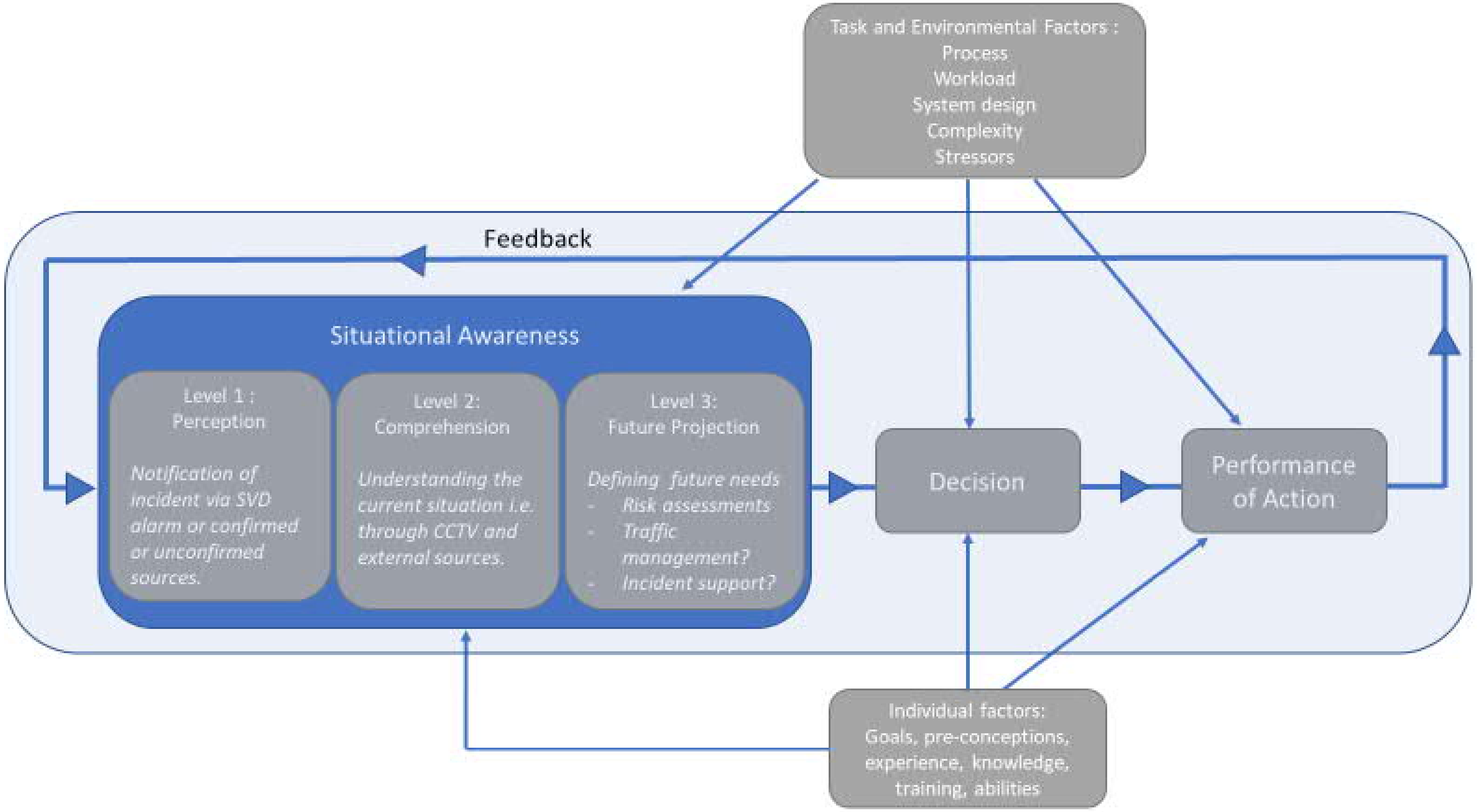
The combination of these three elements and the influence of the individual operators' own mental model, based on factors such as experience, training and pre-conceptions, provides the operator in the ROC with a level of situation awareness that informs their decision making and subsequent actions. This will include immediate activities such as setting VMS signs and signals and recognising future issues that may need attending to such as secondary collisions, impact of spillages, and/or the formation of queues. All of which will require the operator to make dynamic decisions whilst considering the potential need for further actions including updated traffic information and greater stakeholder engagement such as police, road maintainers and ambulance.

Situational awareness is particularly noted for its relevance in understanding the causes of disasters and accidents when awareness has been lost and is used within

[5] Endsley, M.R.: Toward a Theory of Situation Awareness in Dynamic Systems, 1995

Highways England to contribute to its continual improvement process, supporting learning from past incidents to identify changes to processes, systems, and/or resources to improve future operations.

Figure 5.6 ROC situational awareness



5.8 Scenario Testing

ROC operators were presented with a series of stopped vehicle scenarios, to test the processes and confirm the research team's understanding of the factors in place which support an effective response. The scenarios were based upon the emerging simulations developed as part of Workpackage 4, Road User Behaviour, to provide an understanding of the likely control room response to supplement and provide further depth to the road user research.

The scenario testing identified that the ROC response does not deviate from protocol, with incidents notified through confirmed sources resulting in a faster response.

Scenario	Conditions	Traffic Levels	Incident	ROC Response	Enablers
1.	During day light hours. Good visibility. Carriageway: 2 lanes.	Light.	Stopped vehicle in lane 2. Vehicle has no hazard lights on.	1. What is our source of information? 2. Do we have contact with the driver? 3. Advise driver to get to a place of safety. 4. Can we find it on CCTV? 5. What signs and signals are available? 6. Once located on camera, process initiated – (1) signs and signals, (2) dispatch traffic officer, and (3) monitor. 7. Lane 1 remains open.	Confirmed source of information enables a faster response time as the ROC is not required to verify location before issuing warning VMS. CCTV coverage to provide situational awareness. Availability of signs and signals to dynamically implement incident traffic management.
2.	During day light hours. Light rain. Carriageway: 3 lanes.	Light.	Stopped vehicle in lane 3. Vehicle has hazard lights on. Driver is standing next to the vehicle.	1. What is our source of information? 2. Do we have contact with the driver? 3. Advise driver to get to a place of safety. 4. Can we find it on CCTV? 5. What signs and signals are available? 6. Once located on camera, process initiated – (1) signs and signals, (2) dispatch traffic officer, and (3) monitor. 7. Lanes 1 and 2 remain open.	Confirmed source of information enables a faster response time as the ROC is not required to verify location before issuing warning VMS. CCTV coverage to provide situational awareness. Availability of signs and signals to dynamically implement incident traffic management. Contact with the driver to advise on locating to a place of safety.

Scenario	Conditions	Traffic Levels	Incident	ROC Response	Enablers
3.	During day light hours. Good visibility. Carriageway: 3 lanes.	Heavy.	Stopped vehicle in lane 1, no hard shoulder. Vehicle has hazard lights on. Driver is standing next to the vehicle.	1. What is our source of information? 2. Do we have contact with the driver? 3. Advise driver to get to a place of safety. 4. Can we find it on CCTV? 5. What signs and signals are available? 6. Once located on camera, process initiated – (1) signs and signals, (2) dispatch traffic officer, and (3) monitor. 7. Lanes 2 and 3 remain open.	Confirmed source of information enables a faster response time as the ROC is not required to verify location before issuing warning VMS. CCTV coverage to provide situational awareness. Availability of signs and signals to dynamically implement incident traffic management. Contact with the driver to advise on locating to a place of safety.
4.	During day light hours. Heavy rain, poor visibility. Carriageway: 3 lanes.	Medium.	Stopped vehicle in exit slip lane. Vehicle has no hazard lights on.	1. What is our source of information? 2. Do we have contact with the driver? 3. Advise driver to get to a place of safety. 4. Can we find it on CCTV? 5. What signs and signals are available? 6. Once located on camera, process initiated – (1) signs and signals, (2) dispatch traffic officer, and (3) monitor. 7. Exit slip closed if required.	Confirmed source of information enables a faster response time as the ROC is not required to verify location before issuing warning VMS. CCTV coverage to provide situational awareness. Availability of signs and signals to dynamically implement incident traffic management.

5.9 Summary

The case study revealed the organisational procedures in place to standardise Highways England's response to stopped vehicles in a variety of different contexts. Through these procedures, both the control room and their stakeholders understand their roles and responsibilities to effectively respond to incidents and minimise the impact of a stopped vehicle on the strategic road network.

The introduction of SVD technology has provided operators with a greater understanding of what is occurring on the network and within a shorter timeframe, providing enhanced levels of situational awareness compared to sections of the network where operators must look for incidents following external reports.

Operators develop an understanding of the incident, which is supported through the training received, embedded via practical experience and substanitated by the extensive CCTV network. This enables operators to refine their ability to project the potential impact of the situation and respond accordingly.

Without SVD, the links and sequences of detection and reporting are more complex, with both confirmed and unconfirmed sources using different contact methods, procedures, and technologies to alert the operator to a possible stopped vehicle. This greater complexity of communication and system links introduces a significant time delay when detecting, reporting, and responding to the event by the ROC operator.

6 Conclusions and Recommendations

6.1 Conclusions

The literature review provided some understanding of the factors which influence control room operations and responses, particularly in relation to the use of technology and stakeholder collaboration. However, with the advancement of SVD technology, the human interface is likely to become the most inconsistent component in the system. Operators are influenced by cognitive and organisational factors, and external stimuli which may affect their ability to apply a homogenised approach.

The primary research identified organisational, cognitive, and physical factors which support the control room to effectively respond to stopped vehicles in live lanes, to a greater or lesser extent. Through the discussions, it can be concluded that the organisational factors have the greatest influence within the control room, which safeguard its functions by shaping how it operates both internally and externally, ensuring a consistent approach is followed, regardless of incident type. Organisational procedures also limit the influence of cognitive factors, identified within the literature review, which could potentially deviate from protocol.

Finally, organisational procedures drive forward the advancement of efficiencies and improvements through a continual process of development. These result in procedural changes and / or new technologies, which ultimately deliver benefits to motorists through a reduction in delay times as the control room is able to respond faster to stopped vehicles.

Both the primary research and the literature review identified the introduction of SVD technology provides operators with a greater understanding of what is occurring on the network, providing enhanced levels of situational awareness and subsequent procedural response decisions compared to sections of the network where operators must look for incidents following external reports. Furthermore, the integration between control room systems, such as SVD and Highways England’s COBS, trigger warning signs via VMS almost instaneously, resulting in a faster control room response to prepare drivers for potential hazards in live lanes.

Without SVD, the links and sequences of detection and reporting are complex, with different contact methods, procedures, and technologies to alert the operator to a possible stopped vehicle. Greater complexity of communication and system links results in time delay when detecting, reporting, and responding to the event by control room operators.

When introducing SVD to the control room, organisational factors play an integral role in the successful integration of the technology into the current operating systems. For example, excessive SVD false alarms can affect the cognitive factors which facilitate the efficiency of the control room, as operators disengage with and distrust the technology. Sufficient user testing with operators is crucial to addressing this, as it secures buy-in and empowers operators to identify improvements which enable the successful integration of the technology into the control room. Furthermore, training, refresher training, and on the job experience, ensures operators have the expertise to maximise the benefits of the SVD investment.

Interestingly, control rooms with SVD also have a greater understanding of the incidents that may quickly become non-events, data which was unavailable prior to introduction of radar detection technologies. This could assist NRAs to develop an understanding of why drivers stop in live lanes and inform future approaches which influence this behaviour whilst minimising the risk to other drivers.

Outside of the control room, addressing the competence and capabilities of drivers, through NRA-led campaigns 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 if their vehicle stops. Furthermore, real time messaging to other drivers on the network, and in the furture through C-ITS technologies, with supporting information as to why speed limits have reduced or lanes have closed, can secure greater compliance to the traffic management measures initiated by the control room.

6.2 Recommendations

While response improvement is the topic of the forthcoming work package 6 of the SHADAR project, which should consider improvement opportunities suggested by the investigation of current methods, we can briefly note here a set of recommendations which have already become apparent through our research. These address the factors which influence control room operations and responses to stopped vehicles in live lanes.

- SVD technology addresses the time delay when detecting, reporting, and responding to events, furthermore the integration of SVD with other technologies, such as signs and signals, facilitates an almost instantaneous response. When implementing SVD technology into the control room, consideration must be given to the end user, through user centred testing with operators to allow for refinements and secure buy-in to the technology.
- Consideration should be given to the organisational factors which support the effectiveness of the control room's operations, allowing for the continual improvement of systems, the development of skills, and consistency in processes, particularly with external stakeholders.
- Cooperation between the control room and stakeholders is enabled through shared incident management and communication systems. Consideration should be given to the technologies and organisational factors which facilitate the control room and key stakeholders, such as the police and stakeholders responsible for operating and maintaining the network, to deliver a streamlined and uniformed response.
- Control rooms with SVD have a greater understanding of the incidents that may quickly become non-events. This data should be used to assist NRAs develop a greater understanding of why drivers stop in live lanes, to facilitate a whole system approach to address compliance and reduce driver error.
- External to the control room, addressing driver behaviour through education and enforcement will support the effectiveness of the control room's response. Education is not a short-term solution and requires a long term sustained approach to encourage a greater understanding of the factors which contribute to safe driving on the motorway network. Enforcement of lane closures and variable speed limits will also address the non-compliance of road users. Both education and enforcement should be aligned to consideration of the level and type of message provided to drivers through signs and signals to encourage and support compliance in the short and long term.
- Digital technologies, such as C-ITS, can communicate warnings directly to drivers providing sufficient time for drivers to take the necessary steps to avoid harm. However, consideration should be given to the potential cognitive overload occurring within the vehicle and on the carriageway, via signs and signals. This could be exacerbated by differences in the language or terminology used in the C-ITS warning and the information displayed on the carriageway.

A. Glossary

Glossary for use with this document and research cited in Appendix B.

Acronym	Terminology
AA	Automobile Association
ALR	All lane running
AMI	Advanced Motorway Indicators
ANPR	Automatic Number Plate Recognition (ALPR in USA)
ASFINAG	Autobahnen- und Schnellstraßen-Finanzierungs-Aktiengesellschaft
ATM	Active Traffic Management
ATMS	Advanced traffic management system
CEDR	Conference of European Directors of Roads
CCTV	Closed Circuit Television
CHARM	Common Highways Agency and Rijkswaterstaat Model (for traffic management)
COBS	Control Office Base System
DfT	Department for Transport
DoRN	Description of Research Needs
EDB	Events Data Base
ERA	Emergency Refuge Areas
HA	Highways Agency – now Highways England
HE	Highways England – replaces HA
HF	Human Factors
ICE	Institute of Civil Engineers
IET	Institution of Engineering and Technology
IHE	Institute of Highways Engineers
ITS	Intelligent Transport Systems
KSI	Killed or seriously injured
LBS	Lane Below Signal
LHRD	Large High-Resolution Display
MIDAS	Motorway Incident Detection and Automatic Signaling
MOT	Test for fitness of a road vehicle (UK)
NTCC	National Traffic Control Centre
PTZ	Pan Tilt Zoom
R&D	Research & Development
RCC	Regional Control Centre
RWS	Rijkswaterstaat
SHADAR	Stopped Vehicle Hazards – Avoidance, Detection and Response
SRN	Strategic Road Network
SVD	Stopped Vehicle Detection
Tii	Transport infrastructure Ireland
TMC	Traffic Management Centre
VMS	Variable Message Sign

B. Trans-National Research Review Database

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
1	Stationary Vehicle Detection System (SVD) Monitoring, IBI Group on behalf of Highways England (March 2016)	https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/Knowledge+Compendium/2016-17/Stationary+Vehicle+Detection+System+(SVD)+Monitoring.pdf	Highways England (HE) commissioned a trial of roadside Stopped Vehicle Detection (SVD) technology to determine if sufficient additional safety benefits could be achieved to warrant inclusion either as part of the smart motorways all lane running (ALR) design, or on other parts of the network which exhibit similar physical characteristics. The document presents the evaluation findings including interviews with RCC Operators and makes recommendations for a rolled out system to other parts of the ALR network.	√√√	√√	√√	Stopping in live lane of SMART motorway (with no SVD) triples danger vs traditional with hard shoulder. Key Performance Indicator - 3 minutes to set signal changes (red X) once an incident is verified. Analysis of CCTV footage for non SVD all lane running motorways, found the average time to discover incidents is 17 minutes. For a detection system to be viable it must have a high detection rate combined with a low false alarm rate. False positive detections provide unnecessary work for RCC operators, could potentially prevent them from dealing with other more critical tasks and lose faith in the systems' ability to deliver the desired safety benefits. Interviews with RCC Operators found differences in the perceived detection rate and the recorded system detection rate, highlighting a potential training need. The trial recommended the following to reduce operator interactions: - removing coverage of Emergency Refuge Areas (ERA) to reduce the number of SVD alarms, as these alarms are not operationally essential. - dedicated RCC resource to respond to SVD alarms. - present the CCTV to the marker post of the SVD alarm. - SVD alert interface to auto position the COBS window's view to focus on the marker post where the SVD alert was raised to enable operators to quickly select and set appropriate signs and signals. - If ERA and other non-live lane hot spot areas can be omitted from the detection zone, the system could be configured to automatically request speed limits while the SVD alarm is present. This would be reliant on a high level of confidence there is a genuine SVD event. - RCC Operators should review all events to ensure alarms are not stated as cleared before the vehicle is left. Other recommendations included: - developing standardised operator procedures, and delivering training in their use would lead to a reduction in time a vehicle is left undiscovered without any action taking place. - audible COBS alarms need to be disabled, while the SVD audible alarms should be retained.	Time to detection Accuracy of the SVD alarm RCC Operator training	UK
2	Smart Motorways Safety Evidence Stocktake and Action Plan, Department for Transport (DfT) (2020)	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/873000/smart-motorway-safety-evidence-stocktake-and-action-plan.pdf	DfT undertook an evidence stocktake to gather the facts on the safety of smart motorways. A wide range of data was considered, and evidence based conclusions were drawn. The action the Government will take in response to this research is set out in an Action Plan.	√√√			Evidence / findings / rules for road users (including breakdown in live lane). Risk of collision between moving and stopped vehicle higher on SMART than non-SMART motorway. Advantages of SVD is that it is designed to specifically detect a stationary vehicle, typically within 20 seconds, set a message automatically on electronic signs and alert a control room operator who can see the incident on CCTV, close lanes and dispatch an on road HE traffic officer to attend to the stopped vehicle. Vehicles can break down in a live lane both on conventional and smart motorways. For smart motorways, technology can protect a vehicle stopped in a live lane as gantries can be used to display a red X to close the lane to traffic. Within the action plan a commitment is made to extend SVD to all ALR smart motorways, end the use of dynamic hard shoulders, introduce additional traffic officer patrols, greater communications of smart motorways to increase awareness of smart motorways and how to use them, changes to the law to enable detection of red X violations and enforcement using cameras and closer working with the recovery industry.	SMART vs non-SMART motorway collision risk Driver education Technology	England, UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
3	An intervention framework for safer driver behaviour on the SRN (May 2017), L. Dorn/ Highways England (HE)	https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/Knowledge+Compendium/2016-17/An+Intervention+Framework+for+Safer+Driver+Behaviour+on+the+SRN.pdf	The report identifies users of the strategic SRN who are more likely to be non-compliant, and to identify which non-compliant behaviours should be addressed. Utilising the research findings, Highways England plan to develop effective interventions for behaviour change to support a reduction in KSI casualties on the SRN.	√			This research paper considered eleven non-compliant driver behaviours and looked to identify appropriate behavioural change interventions utilising best practice from other sectors and stakeholder engagement. Three implementation plans containing evidence-based countermeasures for three priority behaviours (inappropriate speed, close following and mobile phone use) were developed mapped across educational, engineering and enforcement intervention types. The paper discusses the impact of lane Red X sign and non-compliance, highlighting that a third of drivers do not know what to do when they see a red X sign displayed. Interventions considered to encourage compliance included engineering (sign formats, size, flashing lights), educational and enforcement measures. Specifically, to the control room, the paper notes that Driver Vehicle Standards Agency stopping powers were delegated to HE's Control Room Operators to identify vehicles with poor roadworthiness, that do not hold a current MOT.	Driver behaviours Behaviour change theories	England, UK
4	Highways England Best Practice Human Factors Guidance (2010)	https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/2009-11-knowledge-programme/HF_Guidance_PIN_510540.pdf	This document contains guidance to summarise the best practice human factors approach to system/product design and development, within the general project lifecycle, in order to provide support to HE in creating more cost effective and usable designs.	√	√√	√	Guidance document for general human factors for HE which have the potential to reduce human error. The document contains a flowchart to assist HE project teams understand if HF is relevant to the design and development of the project, highlighting how the application of HF can save costs via a more efficient design process and through the creation of an enhanced end product. Document provides an approach to incorporating HF into product design and development through 11 steps.	Human Factors best practice	England, UK
5	Motorway Event Management - Austria	https://rno-its.piarc.org/en/system/files/media/file/pdf_5102_asfinag_event_management_austria.pdf	This case study considers the combination of two systems newly developed by the Austrian motorway operator ASFINAG and national broadcaster ORF – in the form of radio station Ö3 which focus on Event Management. These two Austrian institutions have worked together on improving traffic and event management by developing an intelligent and innovative solution for harmonised creation and distribution of analogue (i.e. spoken) and digital traffic information. Through collaboration, the collection, updating and distribution of harmonised traffic information through as many channels as possible is enabled.	√			Changing mobility behaviour unveils new challenges and possibilities in the fields of devices and distribution channels (peer-to-peer, social media, radio etc.). This brought about initial questions and criteria around which the Austrian motorway operator's, ASFINAG, entire system could be shaped, with opportunities for systems integration with partners such as the Austrian broadcaster ORF, the central coordination point for traffic information in Austria who provides access to various channels to disseminate traffic related messages. Key considerations and requirements for greater harmonisation between ASFINAG and ORF's systems included consideration of the qualitative and quantitative aspects, automation of collecting, processing and distributing messages as well as design of the messages for optimal quality and level of service. Considering these requirements, ORF developed FLOW, a modular editing system for collecting, processing and distributing traffic messages through various channels. ASFINAG embedded their Event Data Base (EDB) into their system landscape for content management and analysing traffic situations, simplifying the location and verification of an event. Details on an event are populated into the system by the officer-in-charge through the responsible regional traffic control centre and verified by the managing editor. Additionally, the system proposes a traffic message which is verified, enhanced by further information and recommendations and distributed to a central data hub as well as to internal and external partners. In this way EDB depicts and incorporates the whole information chain. Information available from ASFINAG concerning road works, events and the traffic situation is made available to the FLOW system through the data hub. FLOW delivers traffic messages and updates back to ASFINAG using the data hub as well. Through the intelligent linkage of these two systems a consistent exchange of data and information between a road operator and a public broadcaster is implemented, resulting in actually harmonised traffic information dissemination via different channels (radio, TMCplus, internet, apps, etc.).	Stakeholder co-ordination	Austria
6	Human Factors Designing Smart	https://publications.ergonomics.org.uk/uploads/Designin	The Amey-Arup collaborative design team were commissioned by Highways England	√	√√		The introduction of human factors as an approach to motorway design enabled other technical disciplines to consider people at the centre of their	Human Factors design	England, UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
	Motorways (Arup 2019)	g-Smart-Motorways.pdf	to design two new Smart Motorways schemes on the M1 motorway, with Human Factors (HF) professionals included within a Smart motorways design team for the first time. The inclusion of HF proved that the value that could be added to the final product early in the project tender and scoping phases, including the added benefit of helping Highways England achieve their strategic aims of improved customer experience, road user safety and service delivery. As the application of a HF approach was novel to smart motorways design, there was little direction or standards to follow. The HF team had to explore methods to apply a user-centred approach to the design of all infrastructure and assets requiring human interaction to ensure the needs of all users - including customers, operators and maintainers - were considered at the beginning of the design process and were consulted during design development.				designs. Using human factors expertise ensured that all technical design solutions considered the people who would either use the road or be involved in its operation and maintenance. Buy-in from the motorway operators and maintainers has been promoted to ensure their needs and requirements were considered during the design. The HF team implemented a human-centred design process defined in the standard ISO 9241 - Ergonomics of human-system interaction and developed a HF integration plan. The plan identified the key stakeholder groups for the HF team to engage with including the operational users of the motorways, such as motorway maintainers, emergency services, Highways England's' Traffic Officers and Control Room Operatives, to understand their needs and requirements relating to different motorway assets. During these sessions, any user wants, and needs were captured and translated into user requirements that were continuously updated throughout the project and shared with the wider design team to enable them to produce design solutions while considering the needs of the end-users (a total of 114 user requirements were identified).		
7	Regulation 28 Report to Prevent Future Deaths, 2019	https://www.judiciary.uk/wp-content/uploads/2019/11/2019-0341-Response-by-Highways-England.pdf	Report from Highways England's Safety, Engineering and Standards Executive Director and Chief Highways Engineer, sent to the Area Coroner for Birmingham and Solihull, in response to a Regulation 28 Report to Prevent Future Deaths. This followed an inquest into the death of Dev Dilesh Naran, who died after the vehicle he was travelling in stopped in a live lane.	√		√	The document detailed the matters of concern relating to the incident and the actions taken by Highways England to mitigate risk to life on Smart Motorways. The incident occurred on the section of the M6 smart motorway which operated a Dynamic Hard Shoulder running scheme, with the hard shoulder running as live at the time of the accident. In addition to this, a series of engineering factors increased the risk of danger including the gap between emergency refuge areas, the lack of safe refuge for occupants of the vehicle to retreat to and the solid white line on the carriage way. The document highlighted that those managing the motorway had no system of automatic alert to a stopped lane vehicle and relied on MIDAS picking up slow moving traffic, 999 calls and calls from the general public. Actions to address this included the DfT's evidence stocktake of Smart motorways, educational campaigns relating to the use of Smart Motorways highlighting that motorists should only stop in an emergency and how they can reduce the likelihood of such an event occurring, new signage and associated orange surfaces. The report also notes that HE has started to trial new detection technology which uses radar to detect stopped vehicles and are exploring new technologies such as CCTV analytics, vehicles telemetry and crowd sourced data.	Driver education Detection Engineering measures	England, UK
8	Development of Freeway Management System, 2015	https://rno-its.piarc.org/en/system/files/media/file/pdf_8302_gauteng_its_freeway_management_development_project_case_study_final.pdf	Paper provides an overview of the Gauteng ITS Freeway Management pilot project, which is an extensive ITS initiative in South Africa. The pilot project involved the deployment of several ITS technologies, including fibre optic communications, CCTV surveillance, VMS, inductive loops, ramp meters and coordinated and controlled on a 24/7 basis at a centralised Network Management Centre.	√	√		Key lessons learnt from the ITS pilot included (1) the focus on device management rather than event and incident management, with the incident management process reliant on operator free form input instead of an automated or a system guided response with pre-defined or system recommended response plans. (2) The efficiencies of a single nationally adopted ATMS and ATIS platform, to streamline data sharing, recognising that the software required alignment with the Concept of Operations, to achieve the desired operational goals. (3) Issues of system unavailability due to theft and construction activity needs to be addressed.	Challenges of ITS integration	South Africa
9	HA Foresighting Project - Global Approaches to Managed Motorways and Research Activities, 2010	https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/2009-11-knowledge-programme/HA_Foresightin	This report collates and documents the current practice of Managed Motorway implementation by other transport operators combined with known research activities that have been undertaken in both the UK and internationally. The author looked to identify key trends and	√			Research on managed motorways implementation, including hard shoulder running and all lane running, utilising international best practice. Report highlights through a managed approach a reduction in accidents can be achieved but does not focus on incident management. Key findings relating to our research brief include: (1) The German system of managed motorways is similar to the UK, with the use of ITS to display lane and speed information virtually identical. The	Managed motorways interventions Technology	UK but with international best practice case studies from Europe and

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
		g_Project_-_Global_approach_to_managed_motorways_and_research_activities.pdf	drivers that may impact upon or affect the strategy for future Managed Motorway rollout on the Highways Agency (HA) network and understand where valuable lessons may be learnt from international best practice. The focus of the report is on the motorway network only and the effects on neighbouring networks (non-motorway) has not been specifically considered. It is however acknowledged that future requirements, such as travel demand management must consider the wider transport network.				report summarises temporary hard shoulder use in the Hessen area, which is triggered manually by the traffic control centre when flows reach 6,000 vehicles per hour, usually within the peak periods. The operation of hard shoulder running is monitored manually using pan-tilt-zoom cameras spaced every 750m which are programmed to move every few seconds in a predetermined pattern. Whilst the camera system is capable of detecting incidents on the hard shoulder, there is currently no automatic detection system in place. (2) In the Netherlands, a toolkit of techniques are implemented as individual components where required. The Ministry published a number of lessons learnt and observations from hard shoulder running and plus lane operations (comprises of an additional lane within the existing carriageway cross section achieved through narrower lanes and the hard shoulder combined with increased detection, monitoring and control through the deployment of technology). These include, a) recognising a Managed Motorway is not a normal motorway and cannot be treated as such, clear and concise information is required at all times. b) Authorities should be aware of increased workloads for traffic operators. c) Flexibility in ITS is required. d) The desired driver behaviour needs to be communicated strongly.		the USA.
10	Highways England Smart Motorways All Lane Running overarching safety report 2019	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/872153/SMALR_Overarching_Safety_Report_2019_v1.0.pdf	The report presents the combined findings for nine Smart Motorways All Lane Running schemes. Each scheme was evaluated separately by Atkins using a series of safety metrics and then combined to present a wider picture of the safety performance of All Lane Running.	√			The evaluation did not highlight any findings specific to control rooms however it should be noted that the research did identify that the overall performance of ALR schemes has improved. Against a background of increasing flows, the safety objective was met of no increase in the number or rate of fatal and weighted injury (FWI) casualties. Average compliance of Red X was above 94%.	Safety Compliance	England, UK
11	House of Commons Transport Committee All Lane Running Second Report of Session 2016-17	https://publications.parliament.uk/pa/cm201617/cmselect/cmtrans/63/63.pdf	The House of Common's Transport Committee inquired into All Lane Running as an approach to increasing capacity on the motorway network. The Committee received evidence from the emergency services, motoring organisations, Prospect (which represents HE's Traffic Officers), vehicle recovery operators and other stakeholders.	√			As part of the evidence provided, London Fire Brigade highlighted there is not a system in place to satisfactorily pass information about incidents between fire appliances at the incident and control rooms.	Stakeholder and control room co-ordination	England, UK
12	Smart Motorways (all lane running and hard shoulder running) Initial Incident Response National Operating Agreement December 2017	https://www.ukfrs.com/sites/default/files/2018-02/Smart%20Motorways%20NOA%20Issue%201%20V2%20%281%29.pdf	Operating agreement to guide the operational partnership between HE, the emergency services and strategic partners, applying to All Lane Running and Hard Shoulder Running schemes.	√			Recognises emergency responders may still refer to the hard shoulder or lane 1 when they are referring to Lane below signal 1 (LBS 1) or LBS2. RCC operators need to be aware of differing terminology to confirm lanes affected when dealing with hard shoulder running carriageways lanes.	Communications in Control rooms and with stakeholders	England, UK
13	Smart Motorways: What are they good for? Engineering and Technology Magazine Helena Pozinak	https://eandt.theiet.org/content/articles/2020/03/smart-motorways-what-are-they-good-for/	Magazine article on the safety risks of All Lane Running, which sets out an argument that detection technology should be in place first before the hard shoulder is used as a live lane to increase capacity.	√	√	√	Article setting out the limitations of smart motorways including a comment by Jack Consens, Head of Road Policy from the AA, that radar technology can result in a number of false alarms in high flow traffic whereby staff in control centres could waste time investigating rather than spotting a real emergency.	Limitations of technology	UK
14	Future Intelligent Transport Systems Strategy, Transport Scotland 2017	https://www.transport.gov.scot/media/40406/its-strategy-2017-final.pdf)	The Future ITS Strategy frames Transport Scotland's agenda for trunk roads and motorway ITS over the next 10 years and beyond. The core aim of the Future ITS Strategy is to provide clarity on Transport Scotland's priorities for the provision of ITS to contribute to the safe and efficient operation of Scotland's trunk roads and	√	√	√	ITS Strategy specifically notes the skills and expertise of operators managing the interface between different systems within the control room cannot be understated. Also considers the steps that could increase the levels of systems resilience and cyber security of the Traffic Scotland services and the potential integration of these services, information and data with the services of other users and stakeholders.	Skills and expertise of the operators to secure the benefits of ITS	Scotland, UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
			motorways and meet the needs of customers. It gives structure and direction for the development of action plans and funded delivery plans over successive five-year planning horizons.						
15	Highways England Provision of Traffic Data and Information, IBI Group, March 2019	https://www.orr.gov.uk/sites/default/files/om/highways-englands-provision-of-traffic-data-and-information-march-2019.pdf	IBI group were commissioned by the Office of Rail and Road and Highways England to review HE's provision of data and information to road users. The report summarises the findings from the review and sets out 12 recommendations for improvement to HE's provision of traffic information and data.	√			Stakeholders commented that national boundaries are important and the exchange of information between the relevant Control Centres matters.	Stakeholder, cross boundary communications	
16	Benefits and Challenges of Smart Highways for the User, Gesa Wiegand, LMU Munich, 2019	http://ceur-ws.org/Vol-2327/IUI19WS-IUIoT-4.pdf	This paper discusses the potential benefits and challenges of the use of a connected highway sensor system. The paper uses information gathered from a focus group of experts with reference to the project Providentia which included a sensor system built onto the highway to track traffic objects.	√	√√	√	The paper specifically covers the design of control rooms, drawing on lessons from nuclear power industries with a strong focus on safety and operator performance. The challenges of large screen applications can be the loss of orientation on large screens. Looking for the mouse cursor on large displays creates high physical demand. One possibility of improving control operators input techniques is eye tracking as suggested by Lischke et al. Control rooms need to be designed in a way that operators have no spatial constraint and have fast interaction possibilities.	Human factors	Germany
17	Connecting Safety, Smart Highways Volume 4, Ian Patey and Lucy Wickham, 2016	http://mailers.aladltd.co.uk/digital_issues/SmartHighwaysVol4No4.pdf	Article considers smart motorways, managed freeways and managed lanes which have become essential tools that enable road network operators (RNOs) manage congestion, underpinning economic wellbeing and growth. The authors look at how they remain safe, and how will they adapt to a connected future.		√	√	The article is predominantly on the use of technology but does note the roles people play in ensuring the effective operations of smart motorways. In the control room, people are responsible for verifying locations and severity, opening/closing lanes etc. but the article highlights that people can be the weakest link in the system. Infrastructure remains fixed and constant, electronic equipment is tested and manufactured to various levels of reliability and consistency, people are the least consistent and reliable elements of the system. The "professional" people are trained and tested but retain the potential to act differently in various circumstances – due to competing pressures, illness, etc. The article suggests the less reliance on people to enable the system to function the better, however this is not backed up by evidence.	Control room operations and technology Human factors	UK
18	The View from the Engineer, Smart Highways Volume 4, Mark Pleydell, 2016	http://mailers.aladltd.co.uk/digital_issues/SmartHighwaysVol4No4.pdf	Smart Highways' signals expert considers legacy systems within control rooms drawing upon his experience from reviewing the operations of a diverse range of control rooms.		√	√√	Article highlights the effectiveness of the control room is dependent upon the interaction of the staff with the tools provided to them and specifically discusses the issue of systems legacy and its potential impact upon the effectiveness of the operations. When new systems are introduced, they often displace features of their predecessors and the remaining functions that are still needed often become more obscure. Furthermore, the older the technology the more likely it is that the supporting documentation, spares, manuals, ongoing training, informed maintenance and many of the other supporting services that enable the function are missing or out of date, with the author noting that eventually a point is reached where no-one is sure what some of the systems do but do not understand the risk associated with decommissioning. The author highlights the need to review the systems known to have been deployed and the reasons for them, and then determine likely interactions between systems in the way that a lane control system needs congestion and incident data. Only then can these legacy systems be reviewed for their current relevance. The article concludes with the author appealing to those who have a role to play in a control room which is more than five years old, suggesting that serious thought is given to running an inventory of: the services provided, the tools used, the expertise of the staff, the availability of training, support, and user documents.	Control room technology Control room operations	UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
19	CEDR Transnational Road Research Programme - Traffic Management, 2017	https://www.cedr.eu/download/Publications/2017/CEDR-Contractor-Report-2017-04_Call-2013-Traffic-Management-End-of-Programme-Report.pdf	End of programme report summarising the work undertaken within the CEDR Transnational Road Research Programme entitled "Traffic Management: Supporting the implementation of innovation in traffic management solutions" running from April 2014 to December 2016. The programme consisted of three research projects including PRIMA, which considered proactive incident management. The document sets out the outcomes of the implementation of the three research projects, informed through a workshop. The workshop was held with CEDR, the National Road Authorities of Ireland, Belgium-Flanders, and the Netherlands, research organisations, consultancies and maintenance contractors.		√	√	The workshop identified the following key points relating to the implementation of the PRIMA project: - PRIMA's incident response modelling tools were regarded as useful for incident managers. - The speed of incident detection is crucial as cited by Highways England in relation to their (almost instantaneous) radar detection trial, where control centre operators have responded within 12 seconds. The event is detected by radar and control centre operators rapidly identify the closest CCTV. - The PRIMA project also identified the risks of systems causing too many false alarms, leading to lack of credibility, and also the risk of operators having too much reliance on the systems. It was felt however that many operators have extensive camera networks which are expensive to run and sometimes not used a great deal - therefore anything that uses data and sensors to work more efficiently was highlighted as desirable. - PRIMA also identified there could be potential for conflict when multiple agencies dealing with incidents have different objectives (police, road operators). Highways England's approach addresses this through shared control centres for road operators and emergency services providing aligned procedures resulting in multiple agency buy-in. The workshop also identified the success of implementing short term traffic prediction systems from the STEP project. This relied on early engagement of users such as control room operators as there could be conflict between the top down view and bottom up view. New tools/technologies need to be taken to operators for input. Example of engagement events in the Netherlands in control centres.	Stakeholder and control room co-ordination. Technology risks.	UK, Netherlands, Belgium and Finland
20	Ordering Networks, Motorways and the Work of Managing Disruption, Rachel Gordon, 2012	http://etheses.dur.ac.uk/6347/1/Ordering_Networks_Motorways_and_the_Work_of_Managing_Disruption_-_Rachel_Gordon.pdf?DDD14+	Thesis looks to develop a new understanding of the motorway network and its traffic movements as a problem of practical accomplishment. Thesis is based on a detailed ethnomethodological study of incident management in a motorway control room, which observed the methods operators used to detect, diagnose and clear incidents to accomplish safe and reliable traffic.		√	√	The thesis highlighted that traffic does not move by magic, it has to be planned for, produced and persistently worked at through active traffic management. The study highlights the intensely collaborative nature of work between operators and technology that permits the management of disruption at-a-distance and in real time. The actions of monitoring, detecting, diagnosing and classifying incidents and managing traffic are revealed to be complex and prone to uncertainty, requiring constant ordering work to accomplish. Diagnosing incidents or events is a multi-faceted process, which is incrementally put together by multiple associates and sources to interpret what is happening on the motorway. The author notes that these interpretations can be open to challenge dependent on different understandings of what the network should be like. The National TCC (NTCC) is used as an exemplar of how events must meet a number of criteria which restricts operator ruling on diagnosis. The diagnostic context draws on calculation and collaboration as the operators rely on their ability to build and maintain relationships with associates (on road patrol officers, CCTV feeds, control room colleagues and MIDAS alerts/abnormal congestion alerts) to help give access to conditions as they appear on the ground. The sociotechnical nature of diagnostic relations can create hindrances to collaborative work including technical difficulties (which can foster distrust of automated alerts), communication difficulties (such as different and competing vocabularies for describing congestion) and incompatibilities in the way different organisational contexts define similar phenomena (different frames of reference regarding what matters as incidents or events between the RCC and NTCC). The author notes differences between RCC and NTCC contexts, highlighting the diagnosis they offer for the same congestion event can be different which is attributed to the different frames of reference embedded in specific	Control room operations	England, UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
							diagnostic tools; and an absence of control room research, except for ergonomic and human factors research which consider the challenges of working in spatially distributed settings, which considers methods for collaboration with technology and stakeholders.		
21	Government and (non)event: the promise of control, Ben Anderson and Rachel Gordon, 2015	https://www.tandfonline.com/doi/full/10.1080/14649365.2016.1163727 -aHR0cHM6Ly93d3cudGFuZGZvbmxpbmUuY29tL2RvaS9wZGYvMTAuMTA4MC8xNDY0OTM2NS4yMDE2LjExNjM3Mjc/bmVlZEFjY2Vzcz10cnVlQEBAMA==	Control rooms routinely deal with happenings that might become events, attempting to hide events and their possibility from the users of infrastructure by undertaking various forms of action. Based on ethnographic research in a motorway control room, the paper considers how events are grasped and handled, focusing on detection-diagnosis-response work, to make happenings that may or may not become events, into their opposites (non-events).		√	√	The paper considers the role of control rooms as a necessary and constant background which ensures continuity to today's infrastructural, interdependent life. When considering how control rooms control events, the authors draw upon ethnographic research, compiled from observations of HE's managed motorways control room. The motorway control room is described as being at a spatial-temporal distance from quasi/non-events, highlighting belatedness as a key problem. Furthermore, the systems sense events through technology, whilst there is still scope for action that alleviates harm or damage, which may include ordinary disturbances that become nothing. Within the paper, the authors present a series of scenarios and attempt to map the decision process of the operator including the use of MIDAS to make sense of slow moving or stationary traffic. The paper notes the need for the operator to validate what technology or on the ground reports may be highlighting, to make sense of an incident which may or may not become an event.	Control room operations	England, UK
22	The Quality of Being Interested (or Interesting) in Research, Rachel Gordon, 2013	https://d1wqtxts1xzle7.cloudfront.net/31544315/Kaleidoscope_article.pdf?1373422637=&response-content-disposition=inline%3B+filename%3DBritish_Literary_Diaspora_in_the_Mediter.pdf&Expires=1607703817&Signature=cy5CNHgORFzEQH7Bl3ijimafdr9o27jS6tZ4EkDYyoNiZUpt6d5nDgxldmTE33xD8yBph8hOIEaQjBrNRunm6uBE2QqTmCru8N~QLl9b2ehgeBmLYyJYd5cs93IrXE5KHD8c7o~RCXp7wL~ux-46szU7LeoN6pKB6-MzG65RPY8pFPhQZS9CO4wDyfZ9NB60W8hla23gU7wd1Y6HqU3TEM65B3spq0UClymRnn1zrEty7AUX9wRr2TW9A8lsJWAIX9Usg3MPOCPc~jnkxsHPip5G95qo-AG-e5ZplOqWRR2~hwOJusfTmvtF-SNjkq15wJGPw6I81K79KxvGL3dOcw__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA - page=117	Paper considers the role of interest in the research subject where the author recalls her experience of observing operators in a motorway control room.		√	√	Paper considers the importance of an ethnomethodology approach to understanding the features of everyday settings that may be dismissed by research subjects/actors as being uninteresting or inarticulable given their mundanity. Author spends 6 months observing control room operators in the HA's regional control centre in the West Midlands.	Control room operations	England, UK
23	Operational challenges of managed motorways, S. Simpson and D. Kamnitzer, 2010	https://digital-library.theiet.org/content/conferences/10.1049/cp.2010.0366	While the concept of 'Design for Maintenance' is widely used and understood, the concept of 'Design for Operation' is a more novel concept that is explored further in this paper. The paper considers Managed Motorways, which dynamically controls the capacity both automatically and by direct intervention from control room based operational staff in response to fluctuating traffic demand.	√	√	√	Considers technology unavailability and the impact upon operations, including the loss of MIDAS data; and failures of Advanced Motorway Indicators (AMI) and VMS on gantries, hard shoulder monitoring and ERA and general network PTZ CCTV cameras. Sets out the approach to technology maintenance, using a prioritisation framework, to ensure those technology components defined as operationally significant are rectified promptly. The paper notes that even with an analytical process to address faults, it is not feasible to consider the full range of fault combinations, traffic conditions, weather etc which a new fault may occur. Therefore, there will always be a need for a dynamic risk assessment to be carried out by the operator to determine whether the current managed motorways operational phase can continue as it is or whether a change is required.	Technology risks	UK

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
24	National Transport Management in Sweden, Road Transport Information and Control Conference, Trevor Platt, 2014	https://digital-library.theiet.org/docserver/fulltext/conference/cp633/20140812.pdf?expires=1607088821&id=id&accname=id553876&checksum=D7D5C357C2360382931A7C09B6C6D1C4	This paper describes how the National Traffic management System in Sweden was delivered from a Contractor's and Client Authority and Operator perspective, particularly highlighting how a collaborative style of working and relationship with all stakeholders has contributed to the success of the system in meeting its objectives. The paper describes the current situation of the system and details some real examples of how incidents are managed at multiple levels on urban and inter-urban highways from its 4 main control centres.	√			Paper describes Sweden's National Transport Management system which operates from 4 Regional Control Centres to deliver a multi-layered service at local, regional and national levels. The centres are fully coordinated enabling any operator in any TMC to manage the network in any other TMC. The NTS architecture unifies over 100 technologies and over 40 systems with one keyboard, mouse and one virtual screen to manage all parts of the network. This approach minimises operator numbers as each operator performs multiple roles within each shift, resulting in optimised performance, delivered 24/7. By using the same system, partners are provided with a reliable and consistent incident response across modes and location.	Stakeholder and control room operations	Sweden
25	Operational benefits of advanced detector technology, IET Road Transport Information and Control Conference and the ITS UK Members Conference, I.J. Pengelly and P.T. Barton, 2008	IET Digital Library: Operational benefits of advanced detector technology (theiet.org)	Control room operators are faced with the challenge of sifting through ever increasing amounts of data provided to them by the systems they use on a day to day basis to manage the motorway and trunk road network in the UK. As the deployment of technology continues this situation will only get worse, which will hinder the ability of operators to differentiate between incidents and congestion. This paper reviews some of the ways in which new and existing detector technology can be used to assist the operators by presenting data in a format that allows informed decisions to be made quickly and efficiently.	√	√		The authors reflect upon the array of tools available to a control room operator at that time (2008), including MIDAS and CCTV, and potential developments. The paper identifies that the incident detection system was labour intensive, providing low level information, which requires the operator to perform analysis before they are able to take action to manage the situation and prevent escalation. The authors conclude that there are many tools which could be adapted to allow operators to make quicker and more informed decisions, making them one step closer to proactively managing.	Control room operations Technology	UK
26	Understanding Large Display Environments: Contextual Inquiry in a Control Room. Lars Lischke, Sven Mayer, Andreas Preikschat, Markus Schweizer, Ba Vu, Paweł W. Wozniak, Niels Henze, 2018	https://www.medien.ifi.lmu.de/pubdb/publications/pub/lischke2018understandinglarge/lischke2018understandinglarge.pdf	Control rooms are one of the few locations where large high-resolution displays (LHRD) are used within the workplace. To understand the challenges in developing LHRD workplaces, the researchers conducted a contextual inquiry at a public transport control room in a major city in the south of Germany. The research considers the physical arrangement of the control room and describes the interaction with visually displayed content.	√	√√	√√	Within the public transport control room, complex processes are monitored and managed. Staff members are required to make system-relevant and often safety-critical decisions supported by a large amount of information displayed on LHRDs. The usage of large display spaces enabled the researchers to observe common work practices and identify challenges for interacting with LHRDs. A key challenge highlighted within the research related to performing input onto larger display screens, particularly when moving the mouse cursor across the display space. Visually searching for the cursor, even on a small area, causes a high distracting demand. The research considered direct touch as a solution to replace the cursor, however this would only be applicable if the whole display is in arm's range. For LHRD, eye tracking could support tasks, particularly as the distance between the user and the screen is not restricted. When working with LHRDs, the visual position of an event becomes essential and the need for relevant information to be recognised by the user is dependent upon how it is presented on the graphical user interface. The research found that when a manually opened application window or dialogue box appeared outside the focus area, the user must search the graphical user interface visually. This could cause safety consequences if the user dismisses an important notification triggered by the system. To manage this, carefully designed notification and event systems are required based on an understanding of how users interact with the visual space provided by the LHRD. This includes a detailed understanding of human visual perception on large visual areas and making use of the user's head and gaze position to detect the user's visual focus area. The authors suggested the input focus could be used as a position for notifications and displaying new dialogues and application windows.	Control room operations Technology	Germany

Ref. No.	Title	Database Link	Focus of Literature	Background	Human Factors	Explore further in Task 3.2	Findings specific to control room operations and stakeholder responses	Key Themes	Country
27	Situation Awareness in Traffic Management Control Rooms, Ellemieke van Doorn 2017	https://www.ectri.org/YRS13/Documents/Papers/Session1b/YRS13_Session1b_van_Doorn_DVS_Paper.pdf	Academic paper which considers the challenge of how operators within traffic management centres deal with many different information systems, requiring to integrate the information from these systems into one reasoning model.		√√	√	The author highlights how trends within Dutch traffic management (an increase in the quantity of traffic, the complexity of traffic, corridor management and a growth in data amongst others) could endanger the effectiveness of traffic control due to the complexity of information presented. Information presented on sperate information system interfaces could make it difficult for operators to generate a clear picture of the traffic situation, resulting in a lack of situation awareness. The author noted there was insufficient knowledge of how to overcome the deficiencies of information intensive traffic management interfaces.	Human factors Control room operations	The Netherlands
28	CEDR Call 2013: Transnational Road Research Programme METHOD Managing European Traffic using Human-Oriented Designs. Human factors in traffic management operations – Best practices and recommendations. Elina Aittoniemi, 2016	https://www.cedr.eu/download/other_public_files/research_programme/call_2013/traffic_management/method/CEDR-METHOD-D2.2-Technical-Report-2.pdf	Document reports the outcome of work on creating a human factors framework for traffic management operations in the METHOD project (Managing European Traffic using Human Oriented Design, CEDR call 2013). The report was informed through a literature review and interviews with traffic management personnel in the Netherlands, Finland and the UK. The report predominantly focusses on human factors from the road users' point of view.	√	√√	√	Interviews with key traffic personnel from the Netherlands highlighted there is a process for incident reviews, whereby traffic managers/operators review 'what worked well' and 'what could be done better in the future?'. When training new traffic management operators in the Netherlands, the emphasis is on teaching the staff member to be independent and proactive traffic managers. Training is predominantly done on the job however operators must follow guidelines which ensures their decisions are always safe if adhered to. With the advancement of ITS applications, there is an expectation that operators' in the Netherlands will find tasks become easier. The focus of operators' work will shift from road traffic managers overseeing safety and traffic flow to information managers. In Finland, there is an expectation that working patterns of operators within the Traffic Management Centre may change because of the way information is received and processed faster, with operators required to exploit large amounts of data.	Human factors Driver behaviour Role of the traffic operator	The Netherland, Finland the UK

C. Interview Proforma

MOTT MACDONALD

CEDR Transnational Road Research Programme
Stopped Vehicle Hazards - Avoidance, Detection and Response (SHADAR)

Control Room Baseline - Interview Proforma

Background

Stopped vehicles on the highway network present a significant hazard with impacts 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. It shares knowledge on current effective practices, and by researching potential improvements that can advance the current state of practice.

A key component of the SHADAR project is exploring the incident management response to stopped vehicles through control room process mapping to identify the inputs, outputs, and processes, to develop an understanding of what supports an effective response.

Many control rooms are generally responders to an event rather than identifiers, reacting to the information they receive from stakeholders and through technology. Control room response is informed by many elements including the nature of the information received, timeliness of information and the internal processes that inform the decisions and activities that result in a response. As part of Work Package 3, we wish to explore this, to understand how events are detected and fed back to the control room, impact of driver behaviours and the response relationship with stakeholders.

National Road Authority Interviews

To develop an understanding of control room operations, we propose to initially undertake semi structured interviews with key stakeholders from National Road Authorities.

The initial interviews will take place virtually covering a range of topics as set out in the following proforma. Interviewees are encouraged to review the subject areas in advance, and we would be happy to extend the Teams invite to colleagues who may be better placed to comment on certain themes.

Interview Proforma

The proforma contains a series of organisational subthemes designed to provide the researcher with an understanding of how control rooms respond to stopped vehicles in live lanes, including the challenges and the necessary human factors which support an effective response.

Theme	Research questions
Strategy	1. What is your current strategy for detecting stopped vehicles in live lanes? 2. What are the Key Performance Indicators (KPIs) that this is measured against? 3. Does the control room have targets/key performance indicators to respond to stopped vehicles in live lanes? 4. How fast they are responding
-	5. Provide an overview of the process to managing stopped vehicles in live lanes within the control room o How is the control room alerted? Internally/externally o Who responds in the control room/what roles respond? o When/timescales o What technology is used software, detection technologies, social media etc. o Decision making process who does what. One operator does everything or is the work divided o Communications with stakeholders Police, emergency companies, news channels o When is the event closed off? 6. Are there any challenges/issues with this process? 7. What could be improved?
Resources	8. Can you talk me through the resources within the control room to respond to stopped vehicles in live lanes? o Dedicated resource how many operators, shift leader, social media operator etc. o Staffing levels, how they are doing with Covid 19-situation 9. Does this level of resource vary? o Are there periods when the level of resource to deal with stopped vehicles is an issue? (e.g. Covid restrictions) Bad weather conditions 10. What attributes/skills are required? 11. Are there any issues with resources? o Skills shortage o Training

Training /Development	12. Can you talk me through the training control room staff have relating to stopped vehicles? On the job training 13. How does this change over time? o Refresher training o Learning from reviewing incidents? How are they learning from previous incidents? o Mentoring? o Is there a process of continual improvement? o Collective/individual incident reviews? 14. Are there differences in ability/knowledge of control room technologies across operators? If so, what does this impact 15. How are new technologies introduced? 16. Could this approach be improved? new technologies!
Physical and external environments	17. How do the following affect the control room's response to stopped vehicles in live lanes? o Weather o Lighting o Time of day o Season o Road works/maintenance o Type of road e.g., quiet, open stretch, or busy e.g., junctions, motorway stops, bridges, lots of things that a driver has to attend to
Situational Awareness	18. How do operators develop situational awareness to stopped vehicle incidents? o How does the control room understand what is going on/what is unusual on the network? o Differences between the control room and external viewpoints (e.g. Traffic Officer, member of the public, emergency services) 19. How does this influence the decision-making process? 20. Is it fully process driven or are there opportunities for operators/stakeholders to make individual decisions?

Personality	21. Do operators have different approaches to dealing with stopped vehicles in live lanes? 22. Do control room operators perceive the issue of stopped vehicles in live lanes differently? o Does experience influence response?
Driver Behaviour	23. What behaviours do drivers display when they stop in a live lane? 24. What do you think influences their actions? E.g. time of day, traffic flows, type of motorway 25. Are there any common factors driving behaviours?
	26. Proportion of workload in control room with regard to stopped vehicles.

D. Case Study Proformas

Highways England
Interviewee/s Role/length of time in role
Background What geographical area does the control room cover? Who is in the control room? Operators/Roles/Numbers/does this change?
Technologies What tools do operators have within the control room to detect stopped vehicles?
Process How are they notified, who does what, when, when is the incident closed out. How does this change with/out detection?
Communications and Process Mapping Who communicates with who and when, how often. Technologies used to communicate Verbal communications within the room Factors that impact on communications Factors that help/assist communications Any issues/how could it be improved?
Link Analysis Document the relationships between inputs and outputs. Evaluate the relationship between the above and other factors in the control room response. What works well? What could be improved?

Scenarios

Test the previous tasks with operators using scenarios to explore what factors influence their response.

All lane running, 4 lanes, no hard shoulder, see image.

Without technology
With technology

	Condtions	Approach	Situation
Scenario 1	day	light traffic	stopped vehicle on 2nd lane
	good sight		stopped vehicle has no hazards lights on
	2 lanes		without driver next to the vehicle
Scenario 2	day	light traffic	stopped vehicle on 3rd lane
	light rain		stopped vehicle has hazards lights on
	3 lanes		driver is standing next to the car
Secnario 3	day	heavy traffic	stopped vehicle appears on 1st lane (no hard shoulder)
	good sight		stopped vehicle has hazards lights on
	3 lanes		driver is standing next to the car
Scenario 4	day	medium traffic	stopped vehicle on deceleration lane
	heavy rain, limited sight	HGV driving on th right lane	stopped vehicle has no hazards lights on
	3 lanes		without driver standing next to the car
Scenario 5	day	heavy traffic	stopped vehicle on 2nd lane
	good sight	drivers permanently change lanes	stopped vehicle has hazards lights on
	2 lanes		driver is standing next to the car

Situational Awareness

Explore their decision making and response performance in relation to the scenarios. How do they develop situational awareness?

Changes over time e.g., sign setting, decision making, stakeholders

Map the involvement and processes followed by other road response stakeholders.

Methods of communication, technologies and compatibility, timeliness of information.

What are the key challenges? How could this be improved?

Can we speak to police in the control room?

Resilience How do you manage resilience: Within the control room? With the technologies Outside of the control room? E.g., stakeholders What could this be improved? What are the key challenges?

Stakeholders
Interviewee/s Role/length of time in role
Background Organisation What geographical area do you cover?
Process How do you engage with the control room? Outline process, who does what/when/how How are incidents closed out? How do you find out about incidents Who oversees the process?
Communications, technology, and situational awareness
Process for dealing specifically with stopped vehicles in live lanes. - If Stakeholder identify first - Notified by control room

Success factors What supports the process Challenges Improvements
Driver behaviour How do drivers behave when they stop in a live lane How do other drivers behave - any differences in lane location?

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