Stopped vehicle Hazards – Avoidance, Detection, And Response (SHADAR)

Stopped vehicle detection and reporting – current methods

Deliverable D2.1

Revision C

21 July 2021

CEDR Call 2019: Safe Smart Highways

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D2.1 Stopped vehicle detection and reporting – current methods

Original due date of deliverable: 28/2/2021

Actual submission date: 07/05/2021

Submission date of this revision: 21/07/2021

Start date of project: 1/10/2020 End date of project: 31/7/2022

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Executive summary

Stopped vehicles on the highway network present a significant hazard with an impact on safety and the economy. The project "SHADAR" (Stopped vehicle Hazards – Avoidance, Detection, And Response) addresses the objective of "Preventing collisions with stopped vehicles in a live traffic lane", and this report is the output from SHADAR work package 2, which researches the state-of-the-art in stopped vehicle detection and reporting. Information was gathered from existing partner knowledge, from further literature search, and by eliciting further information from national roads authorities and their suppliers.

Stopped vehicles on live highway lanes appear to be a relatively common hazard, with Highways England recording over 40,000 annually due to breakdowns, and with much higher reported numbers of detected hazards to be investigated by operators.

Stopped vehicle detection equipment, systems, methods, or services can be characterised by several metrics. Important performance metrics that are widely used are: detection rate, false alarm rate and time-to-detect. There is commonly a trade-off between these metrics: by making equipment more sensitive, it may be possible to increase the detection rate, but possibly at the expense of false alarms, which may be decreased at the cost of increased detection time. For fixed equipment projection (spatial coverage) is also very important, with the average spatial coverage per detector determining the number of detectors and therefore the overall cost, which includes installation and maintenance. Different kinds of detection each have different properties that affect performance, reliability and life span. The performance of methods can be influenced by conditions including density of traffic, weather, lighting, infrastructure characteristics (including number of lanes, curvature of the road) and surroundings (including vegetation, thermal objects) or even the substructure of the road.

The reliability of a detection method is also important, for the influence on both overall system detection rates and cost. Properties including safe access, ease of use, privacy and security also affect the practicality of detection methods.

There is an increasing number of stopped vehicle detection methods. One category depends on human sight and includes reporting by bystanders, social media and navigation applications, and traffic officers and road inspectors. Another category depends on fixed sensors (roadside or in-road), such as induction loops, cameras, radar and LiDAR. A third category uses vehicle-based sensors, such as floating vehicle data, Cooperative ITS, and eCall.

Questionnaires were submitted to several NRAs via their CEDR research representatives to assess their use of stopped vehicle detection methods, including reporting, validation, and pros and cons of the methods in operation. Eight NRAs responded (Luxembourg, Netherlands, Austria, Belgium (Flanders), Ireland, England, Scotland and Denmark). Almost all NRAs have multiple methods that rely on human sight, and multiple types of fixed sensors installed to detect stopped vehicles. Detection through connected vehicles is less widely applied, although service providers (TomTom, BeMobile and INRIX) responded to a tailored survey by describing relevant products which alert on potentially dangerous traffic events.

While widely spaced traffic sensors can infer the possibility of stopped vehicles through indirect effects on traffic, they usually have longer detection times and reliance on minimum flow levels. The methods with highest detection rates and shortest detection times rely on direct observation of the stopped vehicle.

As illustrative examples, the significant facilities dedicated to stopped vehicle detection on

open highways in use by Highway England are described. These include extensive operational use of a rotating radar solution and successful trials of a camera-based solution with machine learning which have also led to further procurement. Detected stopped vehicle events are raised as alerts to operators in Highways England’s control centres, with aids for prompt verification by CCTV camera.

The possibility of stopped vehicle detection through eCall is described in more detail, since eCall is mandatory in Europe yet few countries use the associated data in traffic operations. Awareness of this method appears to be low, suggesting a need for education. Methods to integrate eCall data for traffic management operations would vary in detail due to the different patterns for Public Safety Answering Points (PSAP) in each country. eCall may not provide perfect coverage on its own, but combined with other methods it presents an opportunity for the other NRAs to improve detection.

A technology not yet widely used for stopped vehicle detection by national roads authorities is data fusion, which has been extensively researched for other traffic applications. Traffic data fusion is seen as important because of the increasing quantity and quality of information derived from vehicles and mobile devices while fixed detection infrastructure remains very expensive to install and maintain. A recent increased use of machine learning in traffic data fusion has been noted. Most traffic data fusion work has focussed on traffic state estimation, while for the application of stopped vehicle detection the most effective techniques have not yet been established.

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Glossary

Abbreviation/Term	Definition
ADL	Automatic Detection Loops
AID	Automated Incident Detection
ALR	All Lane Running
CCTV	Closed-Circuit Television
DR	Detection Rate
eCall	Vehicle Automated contact with emergency centre in the event of an accident, sending location and sensor information
ECC	Emergency Call Centre
ERT	Emergency Roadside Telephone
EU	European Union
EU EIP	The European ITS Platform
FAR	False Alarm Rate
FVD	Floating Vehicle Data
ITS	Intelligent Transport Systems
LiDAR	Light Detection And Ranging
Loop detection standstill	Detection by inductive loops of a vehicle that has stopped on the loop
Loop detection vehicle speed HD	Detection by inductive loops of slow-moving vehicles with short detection intervals (30-70 meter), High Density
Loop detection vehicle speed LD	Detection by inductive loops of slow-moving vehicles with long detection intervals (500- 3000 meter) Low Density
MIDAS	Motorway Incident Detection and Automatic Signalling
MTBF	Mean Time Between Failures
MTCC	Motorway Traffic Control Centre
MTM	Motorway Traffic Management
NAP	National Access Point
n.d.	No date (referenced source has no explicit year identified)
NRA	National Road Authority
PSAP	Public Safety Answering Point
PTZ	Pan/Tilt/Zoom
PVD	Probe Vehicle Data
QKZ	A method for traffic information quality assessment (always referred to as “QKZ” rather than any expansion).
RADAR	Radio Detection and Ranging
SRTI	Safety Related Traffic Information
SVD	Stationary Vehicle Detection/Stopped Vehicle Detection
TCC	Traffic Control Centre

Thermal camera	Camera using infrared radiation
TMC	Traffic Message Channel
TRR	Transport Research Report
V2X	Vehicle to everything
VMS	Variable Message Sign

1 Introduction

1.1 Purpose and scope

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

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

This report is the output from SHADAR work package 2, which researches the state-of-the-art in stopped vehicle detection and reporting. The work package gathered information from existing partner knowledge, from further literature search, and by eliciting further information from national roads authorities and their suppliers. It considers current detection and verification methods and technologies, and the reporting of alerts to operational staff and/or automated response systems.

1.2 Report structure

This report provides context by illustrating the scale of the hazard (section 2) and identifying how detection performance can be characterised (section 3). Current stopped vehicle detection methods and technologies are then identified (section 4). Results of surveys and interviews on how these methods and technologies are used by national road authorities or provided by service providers is given in section 5, with a focus on eCall in section 6. The bridge from detection into response – presentation of alerts to traffic control operators – is described using an illustrative example (section 7), and the state-of-the-art of related technology is section 8. Detail from the surveys is included in appendices.

References in this report

This report follows the CEDR research report template in which all references appear at the end of the report. References follow the common academic referencing scheme known as Harvard, specifically the "Leeds Harvard" guidance from the University of Leeds. Citations in the main text appear like (Author(s) surname(s), year) unless the sentence needs to refer to the author, in which case the author is outside parenthesis and only the year is inside. If a publication is not dated, that is signified by (n.d.). The list of references is sorted alphabetically by author, and then by year, so it should be easy to find a reference despite there being no hyperlinks or numerical identifiers.

An exception is made for international and national official standards which are identified directly in the text by their number e.g. EN 50110-1.

Where no reference is given, the information may come from the authors' experience working with road traffic systems.

2 Stopped vehicle events

This section provides context for the succeeding material on detection, by identifying the scale of the issue of stopped vehicle events. Data mainly from England is available and is presented here as an illustrative example, but figures in other countries may vary (European road deaths per million inhabitants vary from under 20 in Norway to over 85 in Romania, and UK is amongst the safest with 24; ETSC (2021) publishes road death figures for 32 European countries).

Breakdowns are one reason for stopped vehicles. The table shows numbers of breakdowns annually on motorways in England.

Breakdown type	Number of occurrences (annual average 2017-18)
Breakdown in live lane	41,067
Breakdown not in live lane	131,339
Breakdown unknown whether live lane	12,083
Total	184,489

Table 1: Breakdowns on motorways in England; derived from (Department for Transport, 2020a).

There are approximately 3100 kilometres of motorway in England, so the mean was close to 60 breakdowns per km per year, or 0.16 per km per day. However, an earlier breakdown rate stated in (Highways Agency, 2012) was (converted to km) 0.97 per km per day.

In the Netherlands (where there are 35 deaths per million inhabitants, below the European average of 42) incident recovery data indicates 81,000 breakdowns in 2019 on national roads (Stichting 2020), although it is not specified what proportion was on a live lane. The length of that network is similar to that of the English motorways, so either the breakdown rate is lower or the incident recovery dataset is not exactly comparable.

In Austria (where there are 39 deaths per million inhabitants, slightly below the European average) the numbers of breakdowns known to ASFINAG are lower still: 2,489 in a live lane and 3,947 on hard shoulder in 2020, on 2258km of road, but ASFINAG expects that there were other occurrences that they were not informed about. Apparent national differences in numbers of breakdowns may merit further research, but for the purposes of the SHADAR project the main point is that confirmed breakdowns in live lanes occur in significant numbers.

Confirmed breakdowns are not the only kind of stopped vehicle hazard – vehicles may stop for other reasons, including (from anecdotal evidence) collisions, obstructions, unsafe road surface, vehicle checks, and comfort stops and other personal reasons – even if illegal. Highways England analysis (2015) suggested that the number of vehicle checks and comfort stops may be *five times* the number of breakdowns, and data from a stopped vehicle detection system confirms a higher number of stopped vehicle alerts than would be expected from breakdowns. An analysis of one data set from a multi-lane motorway in England over several days showed an average of approximately 3 stopped vehicle alerts per carriageway km per day. The system requirements for stopped vehicle detection capacity are higher still – the requirement is to process a mean of 12 alerts per km per day. These figures include vehicles in refuge areas which do not present the same kind of hazard, and also a level of false alerts, but they imply that potential hazards are more common than illustrated by recorded breakdowns alone.

Analysis of collisions resulting in people being killed or seriously injured by Highways England (2015) showed stopped vehicles to the source of 1.6% of all fatal and serious accidents. There was a higher number of collisions arising from stopped vehicles in off-peak periods than in peak periods (but the proportion of the accidents that involved death or serious injury was slightly higher in peak periods). Sources such as Atkins (n.d.) assert that the hazard is greater outside peak periods, because speeds are higher, and it can be harder to detect the stopped vehicle.

A stopped vehicle event that leads to a collision obviously has a serious socio-economic impact. A UK assessment from 2019 data estimated an average cost of £2.3m from each fatal road accident (Department for Transport, 2020b).

3 Detection characterisation methods and metrics

This section identifies methods and metrics to characterise stopped vehicle detection equipment, systems, methods, or services. Different kinds of detection each have different properties that affect performance, reliability and life span.

3.1 Performance of detection methods

This subsection defines metrics characterising the performance of detection methods, identifies factors affecting performance, and elaborates some national standards as examples to indicate what performance is currently practical.

As reported in section 4, there are many potential methods and technologies for detecting stopped vehicles, each with different performance characteristics. Various metrics are useful to allow assessment of performance. Not only the accuracy of a method is important, but also its time to detect and its spatial coverage. This section therefore defines the metrics:

- Detection rate
- Time to detect
- Projection

While it is desirable to detect 100% of stopped vehicles, different technologies may detect different portions of the population of events, or may have more timely or more reliable detection, and so even a method with relatively low detection rate could be a useful additional source within an overall system (SHADAR plans to further explore this idea in workpackage 5).

3.1.1 Detection and false alarm rates

The Detection Rate and the False Alarm Rate are two performance metrics that can be used to directly assess the performance of a SVD technology.

Definitions:

- “stopped vehicle event” - an occurrence of a stopped vehicle in a defined area of road
- “alert” - a report of a stopped vehicle by a detection method
- “true positive” – where a stopped vehicle event is detected by the method, producing an alert
- “false positive” – where the method reports an alert but there is no stopped vehicle
- “false negative” - where a real stopped vehicle event is not detected i.e. there is no alert from the method

The Detection Rate can be defined as the ratio between true positive alerts and the total number of real stopped vehicle events (which could comprise of both true positives and false negatives) (Lasisi et al 2016) This can be summarised in the following formula:

$$Detection\ Rate\ (DR) = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

Two alternative formulations of false alarm rate have been used:

The formulation which we consider most useful is the proportion of alerts which are false positives:

$$False\ Alarm\ Rate\ (FAR) = \frac{False\ Positives}{True\ Positives + False\ Positives}$$

An alternative formulation is the total number of false positives over a given period.

$$False\ alarm\ rate\ over\ time\ = False\ positives\ (in\ time\ period)$$

Both metrics have been used with stopped vehicle detection; the latter formulation has been used in technology procurement in Europe with a period of 24 hours. Numbers calculated using the latter formulation depend on the amount of traffic on the road and the frequency of stopped vehicle events, whereas the former is independent from these factors.

The DR and FAR are important parameters to consider when assessing SVD technologies, as they can each have an impact on the other. By making equipment more sensitive it may be possible to increase the detection rate, but possibly at the expense of a higher false alarm rate. When optimising and calibrating SVD technologies with their environment, the overall aim is to balance these metrics to ensure the DR is sufficiently high in order to alert operators of all incidents on their road network, but with a FAR that is sufficiently low to enable reasonable operational efficiency.

3.1.2 Time to detect

Timely reporting of a stopped vehicle is extremely important, in order to respond quickly to avoid further incidents, especially in the case of a live lane. Delay in detection can lead to further accidents, increased congestion, and further secondary incidents.

The time to detect for a specific technology item or method is the sum of time required to detect, process, and report a stopped vehicle from that technology or method.

During the processing time, a detection system can perform an internal verification of the event to enhance confidence in the event. This will increase the overall Time to Detect but should also lower the False Alarm Rate (FAR) of the system. Therefore, similarly to the case of Detection Rate, tuning of the Time to Detect has an influence on other parameters.

The detection time of a system can be considered to consist of the following components:

$$Time\ To\ Detect\ =\ Initial\ detection\ time + processing\ and\ verification\ time + reporting\ time$$

Where:

- Initial detection time: duration from stopped vehicle event occurrence until the system recognises a potential event and triggers further action such as verification
- processing and verification time – duration of any additional time between the initial detection and deciding to report an alert, used to analyse/verify/compute a possible detection as being a reportable alert
- reporting time: duration for the detection system to relay the message to the system or user it reports to.

The processing time of a system can incorporate algorithms that can increase confidence of an event. Data-rich solutions can utilise machine learning and artificial intelligence concepts, such as detection curves, image processing, cross referencing, and pattern recognition.

The Time To Detect is used in metrics such as Mean Time To Detect (MTTD), where all measured Time To Detect are averaged, and Maximum Time To Detect (MaxTTD).

3.1.3 Projection

The term “projection” is used when discussing fixed infrastructure such as radar and cameras, where the coverage zone projects from the equipment location. It can also be used as a placeholder term to prompt consideration of spatial coverage more generally, although methods that move with vehicles will not describe their spatial coverage only in terms of projection.

Zone of detection can differ significantly per detection method, and since it can be varied by design or configuration it can be influenced by requirements of the road authority. The degree of risk occurring when a vehicle comes to a stop is considered when determining the requirements. For example on locations where there is no or little room for avoiding accidents with stopped vehicles, and on hazardous escape routes, the stopped vehicle detection requirements should be greater. The projection of the detection system is influenced by local and environmental conditions.

For the projection of cameras, radar and LiDAR[1], the position and angle for the target lanes and any potential obstacles must be considered.

3.1.4 Factors affecting performance metrics

Depending on the detection method, the following topics may affect performance and projection and may have to be considered in technology design depending on the technology chosen:

1. The effect of different levels of traffic flow
2. The number of lanes
3. The curvature of the road horizontally and vertically
4. The presence of vegetation (with variation seasonally and in vegetation maintenance levels)
5. The environmental conditions (low sun position, possibly nearby sources of smoke)
6. The weather conditions (fog, rain, snow, harsh winds)
7. The substructure of the road
8. The presence of thermal objects
9. The possibility of electrical interferences

For example, loop detection is not influenced by weather conditions, but the substructure of the road can influence the sensitivity of the loop detection. When reinforced concrete is used, as in tunnels or bridges, the sensitivity of the loop detection will deteriorate. Electrical interference from railway, tram or other sources can also influence the detection quality, so this must be considered when assessing the projection or spacing of the detection system.

3.1.5 Traffic information quality metrics

While metrics such as detection rate and mean time to detect, described above, are the most useful and direct metrics for stopped vehicle detection, the following subsection briefly considers the application of metrics used for traffic information quality assessment, because they could provide alternative ways to present and consider the quality of a stopped vehicle detection system.

The CEDR research project UNIETD summarised several traffic information quality assessment methods and metrics (Heinrich et al, 2015). None of these is for stopped vehicle detection, but the closest metric with the most chance of relevance is “QKZ” (Bogenberger, 2003), which assesses the quality of traffic information reporting whether there is or is not a significant traffic event. For QKZ the event is normally any congestion, rather than a stopped vehicle event specifically. QKZ has been used to measure the performance of various incident detection methods or services (Ackaah, 2016). Interesting features of QKZ for assessing incident detection are described below; SHADAR WP5 may consider whether there is a benefit in applying these for stopped vehicle detection.

Associated visualisations

Which is better – a service with 80% detection and 0% false alarms, or a service with 85% detection and 15% false alarms? That might be argued. The QKZ method includes visualizations which can help such consideration.

QKZ is based on the superimposition of the incident detection output (incident / no incident) with a known ground truth source (i.e. a source that is trusted to be an accurate reference), in time and road space dimensions. In the two-dimensional superimposition, there are regions where both sources agree, regions where a real incident is missed, and regions where an incident is falsely reported. This initial presentation in time and space can be useful on its own, but QKZ derives two numeric quality indicators, both percentages between 0 and 100%, similar to true positive rate (QKZ1) and false positive rate (QKZ2). These are visualized in a two-dimensional quality diagram with discrete quality bands suggested (Figure 1).

[1] This report uses the capitalised acronym LiDAR while using the lower case word “radar” because only the latter has become a familiar word without capitalisation.

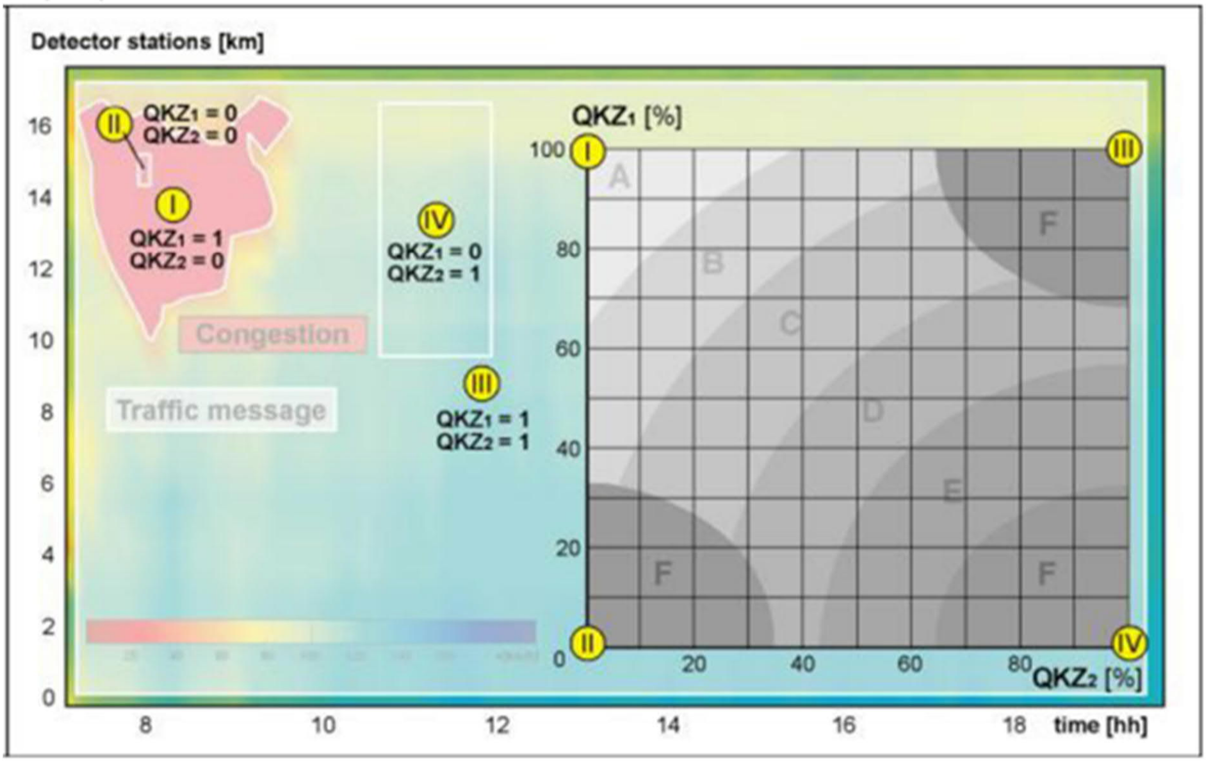


Figure 1: QKZ quality diagram with quality levels (Bogenberger, 2003)

Assisting calibration

In cases where detection systems are being calibrated to balance between detection rate and false alarm rate, by altering sensitivity parameters, QKZ quality diagrams can assist in choosing a preferred setting from the range of possibilities.

Built-in assessment of timeliness

Which is better – a system that detects incidents with an 80% success rate after 10 seconds or a system that detects incidents with a 90% success rate after 2 minutes? Again, this might be argued. QKZ metrics include time-responsiveness of the detection methods in the same metrics as detection rate and false alarm rate, rather than having a separate quality. This may not be an advantage for stopped vehicle detection, but it provides a comparison of alternatives using fewer metrics with simple visualisations.

3.1.6 **EU EIP**

On the initiative of The European ITS Platform (EU EIP), a framework for the quality of safety-related and real-time traffic information was setup (Kulmala et al, 2019). The definition of the criteria, as well as the requirements, is backed up on experience in quality frameworks including validation and stakeholder consultation. For Safety Related Traffic Information (SRTI) the following quality criteria are formulated.

- Timeliness (start of the event and detection)
- Timeliness (update)
- Latency (time between detection and provided at the CAP/NAP)
- Location accuracy
- Classification correctness
- Event coverage (detection rate)

For SRTI a distinction is made in wrong-way driving and all other events. The requirements for the criteria are divided into Basic, Enhanced, Advanced and Future technologies (not specified yet). When characterising the metrics and methods these criteria form the framework can indicate the impact on the requirements and may be used as reference in the upcoming work in SHADAR project. In Table 2 and Table 3 the quality criteria are displayed.

	Quality Criterion	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)	★★★★ (Future technologies)
SRTI (Wrong Way Driver)	Timeliness (start) [1]	**Best effort**	For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 5 min[1]	For 95 % of all events: Detection & acceptance < 2 min after event occurrence	
	Timeliness (update) [1]	**Best effort**	Best effort	For 95 % of all events: Detection & acceptance < 5 min after event change/end	
	Latency (content side) [1]	**For 80% of all events: < 5 min**	For 80% of all events: < 2 min	For 95% of all events: < 2 min	
	Location accuracy - Road	**For 95 % of all events: affected road segment not longer than 50 km or road number with destinations (city names) nearby**	For 95 % of all events: Correct link between intersections[2]	For 95 % of all events: Correct link between intersections[2]	
	Classification correctness	**> 75%**	> 85%	> 90%	
	Event coverage	**Best effort**	Best effort	> 80% of all occurring events	

[1] For the first two levels (basic and enhanced), it is only necessary to measure timeliness and latency at the beginning and end of an event.

[2] A tolerance zone of 500 meters to both directions from the geographical centre point of the intersection can be applied (e.g. to address differences in georeferencing systems). Ramps leading to rest areas only are not defined as intersections.

Table 2: Level-of-Quality Requirements for SRTI type: Wrong Way Driver (Kulmala, R et al, 2019).

	Quality Criterion	★ (Basic)	★★ (Enhanced)	★★★ (Advanced)	★★★★ (Future technologies)
SRTI (all SRTI events/ conditions except wrong way driver)	Timeliness (start)[1]	**Best effort**	For 95 % of all events: Time between event occurrence and first detection: Best effort Acceptance after first detection < 10 min[1]	For 95 % of all events: Detection & acceptance < 5 min after event occurrence	
	Timeliness (update)[1]	**Best effort**	Best effort	For 95 % of all events: Detection & acceptance < 10 min after event change/end	
	Latency (content side) [1]	**For 80% of all events: < 10 min**	For 80% of all events: < 5 min	For 95% of all events: < 5 min	
	Location accuracy - Area	**For 95 % of all events:** **Correct administrative region**	For 95 % of all events: Correct geographic area; 10 km accuracy	For 95 % of all events: Correct geographic area; 5 km accuracy	
	Location accuracy - Road	**For 95 % of all events:** **Correct link between intersections**	For 95 % of all events: Correct link between Intersections AND off-set < 4 km [3]	For 95 % of all events: Correct link between Intersections AND off-set < 2 km [3]	
	Classification correctness	**> 85%**	> 90%	> 95%	
	Event coverage	**Best effort**	Best effort	> 80% of all occurring events	

[1] For the first two levels (basic and enhanced), it is only necessary to measure timeliness and latency at the beginning and end of an event.[2] For an event with a length, like many road works, both the start point and the end point must fulfil the given criteria.

[3] A tolerance zone of 500 meters to both directions from the geographical centre point of the intersection can be applied (e.g. to address differences in georeferencing systems). Ramps leading to rest areas only are not defined as intersections. The off-set requirement is not applied when only link-to-link information (i.e. without coordinates) is provided.

Table 3: Level-of-Quality Requirements for all SRTI types except Wrong Way Driver (Kulmala et al, 2019).

3.1.7 Requirement standards examples

In this subsection, examples that have been collected to show what kind of requirements are currently used for stopped vehicle detection by some national roads authorities. (The documents identified are not publicly available but may be provided by the authorities to authorised individuals. Other countries may have similar specifications, but these are not known to the authors of this report.)

The Netherlands – tunnel context

The tunnel standard of the Netherlands (Rijkswaterstaat GPO, 2021) specifies false positives and negatives including detection time. The prescribed method is detection by inductive loops with an average spacing of 60 metres. The requirements are:

- BSTTI #17513: Detection of under speeding or standstill must be done as soon as possible, but no later than 10 seconds.
- BSTTI #17513: Of the 100 SOS (under speeding system) reports in a lane, at least 99 reports must be valid.
- BSTTI #17513: Out of 1000 incidents in a lane where the speed of a vehicle is below the road's speed limit value at least 999 must be reported.

[In other words, DR at least 99.9%, FAR at most 1% - demanding requirements for this tunnel context.]

Highways England – open motorway context

The detection rate and false alarm rate in the relevant specification of Highways England (TR 2642) are formulated as follows:

- The detection rate for Stopped Vehicle Events that trigger an SVD Alert shall be at least 80%. The detection rate is defined as the true positive rate, i.e. the proportion of Stopped Vehicle Events which are correctly reported within the performance limits specified …. [e.g. within 20 seconds]
- The false detection rate shall be lower than 15% of all SVD Alerts raised. The false detection rate is defined as the proportion of all SVD Alerts reported incorrectly, either because an SVD Alert does not relate to a true Stopped Vehicle Event, or because the SVD Alert data is not within the performance limits specified, e.g. longitudinal location greater than 25 metres from true location, wrong carriageway.
- The longitudinal detection location accuracy for any Stopped Vehicle Event shall be ±25 metres or better, measured from any part of the stopped vehicle(s).
- The detection location shall be attributed to the correct carriageway.
- The system shall be able to differentiate between a vehicle stopped in an Emergency Area and within a running lane and be able to send alerts differentiating between the two.

Belgium (Flanders)

The road authority representative reported that they no longer use formal requirements because, based on experiences, in practice, the requirements were not feasible. The current approach is to adjust and combine different systems as well as possible to arrive at a workable level of false positives. The biggest problem is SVD in a traffic jam. This is also related to the detection time (the shorter you set it, the more false positives). The road authority is working on a pragmatic balance.

3.2 Reliability of detection methods

In this context, we refer to reliability of the equipment or method being operational, as opposed to reliability of the truth of an alert (which is expressed by false alarm rate).

The reliability of a detection method is as important as its performance in normal circumstances. While unavailability of detection due to an equipment or service failure could be factored into the overall mean detection rates, it is informative to express the reliability as a separate metric. Relevant concepts include:

- Reliability
    - Technical lifespan
    - Functional lifespan

- Recurring maintenance interval
- Availability of parts/components
- Safe access to system and components
- External influences (such as damp or dirt affecting detection equipment)
- Ease of use

In public tenders, the technical and functional lifespan, availability of replacements, protection against external influences, and maintenance needs are often expressed in requirements for the system.

3.2.1 Reliability

A common reliability measure is the Mean Time Between Failures (MTBF). This measures the rate at which a product will fail and therefore can form an assessment of the operating life of a technology. For equipment installed at the road, this is an important metric to consider since road closures to fix units at fault is an expensive and time-consuming activity.

The (MTBF) of an individual component and for the system overall, and is calculated by:

$$MTBF = \frac{\sum(time\ of\ failure - installation\ time)}{number\ \ of\ failures}$$

This calculation however may not always reliably predict failure characteristics in the future since for example manufacturing processes and internal components can differ between batches. It provides a measurement of past performance which can be indicative of future performance of similar equipment.

The technical and functional lifespan of components and the total system is relevant in combination with a preventive maintenance interval which influences the MTBF results.

Another metric used, especially in service contracts, is availability, usually expressed as a percentage

$$Availability = \frac{total\ of\ time\ periods\ in\ which\ equipment\ or\ service\ was\ available}{total\ assessment\ time\ period} * 100\%$$

Suppliers meeting a service requirement can include redundancy of individual equipment items, knowing their MTBF, to meet a target availability level.

Technical lifespan

Lifespan may be specified separately for different types of components. For example a technical system could have the following minimum required life spans for components:

- 15 years for the electronics
- 25 years for outdoor enclosures/cabinets
- 50 years for cables and pipes.

Functional lifespan

The term “function lifespan” of a detection system has been used to denote the period in which the performance continues to meet functional requirements i.e. when equipment performance deteriorates but still meets required performance levels it is still within its functional lifespan, but deterioration beyond those performance levels means the functional lifespan is over. Since deterioration over time is common for physical equipment, it may be appropriate to run tests periodically to ensure the system still meets the specifications.

3.2.2 Recurring maintenance interval

Detection equipment often requires recurring maintenance – so the interval between maintenance activities is of interest. Tenders often include maintenance in competitively assessed price, but if the maintenance has any impact on the road or 3rd party service providers then it can be an important factor for a roads authority to also know separately.

3.2.3 Availability of parts

This may affect the practical lifespan of equipment. Procurement of equipment should ensure availability of parts for at least as long as the required technical lifespan.

3.2.4 Safe access to systems

In many European countries there are national safety regulations which govern work on systems and components, and a hazard assessment from the supplier is typically mandatory.

3.2.5 External influences

Requirements related to external influences are identified in European (IEC 60394) and national standards. Requirements for influences like climate, mechanical load, animals, electrical voltage, frequencies, electromagnetic fields, seismic influence, Ionisation, earth potential when touching etc. are included. Examples of these national standards are:

Austria

- Regulation on safety, normalization and typing of electrical equipment and electrical systems (BMDW, 2020)
- EN 50110-1, operation of electrical systems
- ÖVE / ÖNORM E 50110-4-44, Completed electrical production facilities

https://www.ris.bka.gv.at/eli/bgbl/II/2020/308

The Netherlands

- Standard NEN 1010:2020 on electrical installations

England

- Highways England TR 1100 (Product Acceptance Process and General Requirements for Motorway Products, Materials, Equipment and Systems)
- Highways England MCH 1600 (Product Acceptance Procedure)

3.2.6 Ease of use

The ease of use is a qualitative requirement. This considers how straightforward the interaction with the detection method is, from the separate perspectives of operators and maintainers.

The signals presented by the system for the operators should be easy to interpret. A dashboard is not always part of the detection system and could be a central system that presents the information to the operator. The design of the user interface is important.

For maintenance, the layout of the system and its components must be easy to interpret and work with. Documentation and a clear layout of components in cabinets, enclosures and server racks are essential. A list of items that should be available:

1. Service/ maintenance guideline
2. Drawing/scheme of the system
3. Product and component specifications
4. Component list
5. Naming list components
6. Enclosure, server, cabinets drawings and schemes
7. Cable numbering list
8. I-O list
9. Communications list
10. Test specifications

Some technologies may not require maintenance, and inherently this reduces the difficulty in maintenance, so long as the reliability meets this expectation.

3.3 Costs

When conducting cost analysis on ITS technologies, it is important to consider all associated costs over the full lifespan, which include:

- capital expenditure
- operating costs (including maintenance)
- roll-out costs – installation, commissioning, traffic management, decommissioning.

The roll-out costs are related to the method in which an ITS technology is deployed on the network. The method will influence how much traffic management is required to keep the road network clear, and the resource and impact it will have on road infrastructure.

Operating costs can come in the form of maintenance activities required for these technologies. As well as this, reliability of each technology should be taken into consideration. A technology with a shorter Mean Time Between Failure will be subject to more maintenance activities, and hence an increased operating cost.

Previous reviews such as Parkany and Chi Xie (2005) have noted the relatively low hardware cost of induction loops, but the higher installation and maintenance costs: 2-3 times higher than for roadside sensor systems.

The SHADAR project invited roads authorities to share any information on costs experienced, but no figures were provided other than the study from the German Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV) (2019) which gives cost ranges for each of ten traffic detection technologies, with estimated annual maintenance as a percentage, and associated costs such as mounting poles and power and communications connections. The study does not reflect the relative difference in installation and maintenance costs of loops noted by Parkany and Chi Xie. Anecdotal experience of the SHADAR authors is that the need for traffic management for installation of loops for example does contribute to such a difference. The FGSV study is not for detectors specialised for stopped vehicle detection, and does not state the service level achieved for the estimated maintenance costs. The costs identified are from 2014, since when the costs (and capabilities) of some types of stopped vehicle detectors have evolved.

Cost-benefit analysis can quantitatively compare the costs to the benefit arising from the reduction of negative socio-economic impacts of stopped vehicles (an analysis of socio-economic benefits of incident avoidance is outside the scope of this report on detection).

3.4 Privacy and security

Security risk analysis methods following ISO 27001 consider confidentiality, integrity and availability of the information assets. All are important for ITS systems, and risks should be assessed for specific systems and contexts, with appropriate controls and mitigations introduced to provide acceptable risk levels. Each network operator typically has its own specifications and standards for cyber security.

Confidentiality in particular should be a prominent consideration for stopped vehicle detection equipment because ITS technologies will generate concerns amongst the public if seen to have an impact on privacy. Experience in deploying monitoring technology has shown that elements of the public are sensitive to perceived "big brother" issues (i.e. invasion of privacy), which may weaken the acceptability of a detection solution. There may even be legal constraints, for example if a detection system can be considered to hold personal data then GPDR applies in Europe.

The authors have encountered ITS solutions being proposed without full consideration of privacy, for example vehicle registration numbers to be communicated over the Internet in an unencrypted form, and/or stored in a system unnecessarily.

Mitigation of these concerns is a relevant consideration for any detection method. Methods that capture images or data that can identify individuals should avoid unnecessarily transferring or storing these. For technologies that do not store or communicate any personally identifiable information this is less of an issue, but assessments should be aware that individuals can sometimes be identified even from a set of individually anonymous observations.

3.5 Environmental footprint

Responsible organisations are concerned with sustainability and therefore the environmental impact of detection methods is relevant. The environmental impact of a road improvement scheme should be calculated, and these calculations should include the impact of significant items of technology, albeit the carbon cost of the technology is generally very small compared to any changes to the road itself.

For example Highways England data collection pro-forma supporting their carbon calculation tool includes a section for “Street Furniture & Electrical Equipment”, with rows for standard technology items including variable message signs, cameras, cable, and cabinets, although specialised detection equipment does not yet appear in the list.

The environmental cost of manufacturing and installing the technology can usually be justified by the environmental gains that the technology will achieve through improving traffic flows, amongst other benefits.

4 Stopped vehicle detection methods

This section summarises existing stopped vehicle detection methods. The information sources included the SHADAR project partners' existing knowledge from working with roads authorities, and further literature search. (A survey of NRAs on the topic is reported in section 5).

This report does not attempt to provide lists of suppliers of these technologies, which in most cases would be extensive, but suppliers may be named in connection with unique capability or relevant trials.

This report does not attempt to give a survey of traffic detection methods in general (a useful and recent reference for that is (FGSV, 2019)) but rather a focus on the relevant characteristics for stopped vehicle detection specifically.

4.1 Detection methods

4.1.1 Bystander

Someone like a bystander, public service, etc. contacts the emergency services, for instance by calling 112 or a local used reporting point for incidents. The handling of an incoming call is handled via different channels in the different countries in the EU.

4.1.2 Social media and navigation applications

The possibility of the use of social media and navigation apps for the traveller is an increasing source for incident detection. In some Traffic Management Centres (TMC) in EU and abroad the notifications/messages from sources like Twitter, Waze, Flitsmeister, etc. are displayed on the video walls/screens. Apps like Waze are dedicated to traffic, and the user can report incidents on the road and give feedback on reported incidents by other users which enhances the quality of the source. The degree of trust in the users is identified based upon feedback from posted notifications. Amin-Naseri et al (2018) assesses crowdsourced reports such as Waze as invaluable, yet there are challenges to overcome regarding redundancies, inaccuracies, and mismatches. Therefore, pre-processing and validation are necessary.

Use of Waze in NL

In the last decade the use of Waze as a crowd-sourced source of information was promoted by MAPtm. For several customers, the TMCs of Rijkswaterstaat, Municipality of Amsterdam and Nijmegen and Verkeercentrum Flandre a dashboard (Figure 2) was developed showing Waze notifications in the area of interest. For faster orientation, road number and hectometre are added to the notification. The notifications are grouped by stranded vehicles, accidents, dangerous situations and also filtered and sorted by time and reliability. The reliability is based on the esteem of the user who creates the notification and the number of likes he receives. A function was added where the TMC and/or road inspectors can create a notification and add a picture or short film to show the traffic operator more details about the incident.

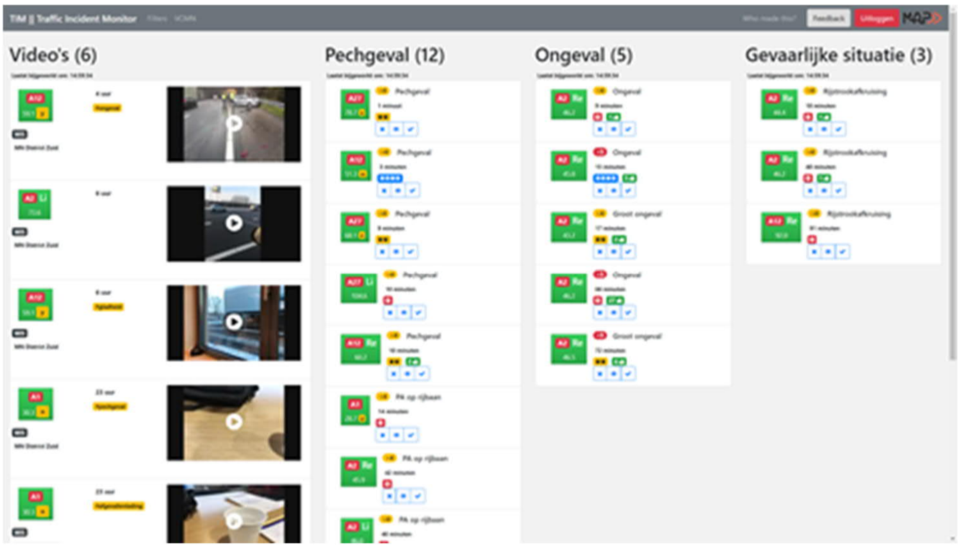


Figure 2 Waze dashboard IM-viewer (MAPtm)

Amsterdam ran a one-year pilot with traffic officers on motorbike undertaking surveillance of the arterial and main roads in the city and using the IM-viewer together with a logging tool available on a smartphone. After evaluation the deployment was extended for two years. The experience of the users is that it is a valuable contribution to support the work of the traffic officers, road inspectors and traffic operators. The anecdotal experience of MAPtm is that the Waze community provides a fairly reliable source for stopped vehicle detection and other road incidents.

Textual social media

In the UNIETD project the use of Twitter messages for deriving speed from geographical information and analysing textual content to trace traffic-related information was investigated on major roads around the city of Leeds (Grant-Muller, 2015). The analysis demonstrated that pairs of successive geo-tagged tweets can be used to estimate speed along highways, but with low coverage of road space and time. The analysis also showed that tweets contain potentially relevant content for traffic management, and that this can be automatically detected, not with perfect accuracy but with enough accuracy (up to 85% success in classification of relevance for traffic management) to enable a practical filtered feed for human interpretation. The automatic classification used an ontological scheme that included the concept of vehicle breakdowns and hazards.

UNIETD noted: It is illegal to use a mobile phone when driving. Studies show that drivers using a mobile phone are slower at recognizing and reacting to hazards. Any exploitation of social media content must not be predicated on use by drivers, and should be accompanied by continued awareness campaigns such as the “Think!” campaign by the UK Government.

Twitter data can also be analysed via the "Sprinklr" commercial software service which correlates individual reports to indicate potential problems. It can detect stopped vehicles once enough people pass, but it is more likely to detect congestion.

4.1.3 Traffic officers, road inspectors

Incident detection is a part of the task of the traffic officers, road inspectors, police, national roadside assistance companies, and in some countries the salvage companies. Typically they also form the parties that secure the incident in regard to traffic safety and follow-up of the incident. The reliability of reports by this group of officials is ~100%.

4.1.4 Induction loops

Induction loops are widely used for measuring traffic conditions. They are not thought to be significantly hindered by weather conditions and are considered reliable during their lifespan provided that the road surface remains in good condition. The distance between loops and the presence of metal surfaces like bridges, reinforced concrete, and even tram and railway objects, can all have a significant influence on the performance of induction-based detection.

Loop detection: local standstill

Standstill detection with induction loops is mostly used on hard shoulders and emergency refuge areas. The area to be monitored is equipped with one or more induction loops and monitored by one or more induction loop detectors. Normally the loop detector is set to the ‘presence’/‘permanent’ output mode, in which the signal from the loop detector remains active during the occupation of the loop (as opposed to the ‘passage’/’pulse’ mode where a pulse is sent).

Loop detection: low vehicle speed and other traffic property changes

Another broadly used detection method is the detection of slow driving vehicles. Using two loops in conjunction with a fixed layout and distance, for instance, 1 meter in between, characteristics like speed, length, and even a vehicle’s electrical signature can be registered. The pulse output mode (sending a signal within a fixed frequency) is typically used for detecting moving vehicles.

When low speeds of passing vehicles are detected on a detection location using a predefined threshold (for instance below 45 or 30 km/h) combined with a predefined flow threshold, an incident is inferred. These detection loops are commonly installed at fixed distance intervals. The incident detection is often integrated with automatic signalling, as in MIDAS (Motorway Incident Detection and Automatic Signalling) in England, MTM (Motorway Traffic Management) in the Netherlands and RSS (rijstrooksignalisatie) in Flanders.

Distances between the detectors differ per country. In the United Kingdom (Tucker et al, 2006) and the Netherlands (Rijkswaterstaat, 1999) 500m is common. Distances are shortened on risky locations and locations where the visibility of road users is shorter. Due to the distances between the cross-sections these detectors mostly register slow-driving vehicles forming a queue due to an incident ahead on the road.

Other incident detection algorithms have been developed (frequently discussed are the McMaster, HIOCC and California algorithms) to consume loop-based traffic measurements and look for significant changes (Parkany and Chi Xie, 2005), (Nikolaev et al 2017). Assessments from experienced traffic management users noted lengthy or difficult calibration, and variable levels of reliability, but for stopped vehicle detection their biggest drawbacks are the length of time to detect and reliance on levels of flow. Nikolaev et al reported up to 100% incident detection rate (in limited study) from two algorithms but detection times from 41 seconds to 4 minutes.

Loop detection: missing vehicles

Loop detection focussed on detection of incidents (including stopped vehicles) is also used in tunnels with closer spacing. In the Netherlands, the average distance for loop detection is set in the National Tunnel Standard to 60 meters, see (Rijkswaterstaat GPO, 2021).

The electrical profile of a vehicle produced by passing an induction loop is used to recognize an individual vehicle. By comparing these electronic signatures gathered from the loop detection an individual vehicle can be traced during its travel. Systems exploiting this to provide stopped vehicle detection include:

- IDRIS, for example on A55 in Wales (Pietrzyk, 1997) – developed in the 1990s, featuring data processing to improve loop detection performance, and potentially enabling detection of stopped vehicles anywhere on the carriageway. 100m spacing between loop pairs is recommended by the originators, with support for up to 200m spacing. No information on detection times or detection rates was found.
- From 2000 a system called TunSafe was implemented in Norway tunnels (Sovik, 2018). By using this electronic signature combined with camera images a check-in and check-out system was realized. The TunSafe system was not maintained and removed from the last tunnel in 2011.
- AVE Verkehrs- und Informationstechnik has developed a detection system (“Mave-Tun”), based on loop detection for detection of incidents that provide travel time, density and using also a

check-in check-out system, based on the vehicle's signature, per defined tunnel section to detect incidents and stranded vehicles.

4.1.5 Cameras

Video cameras

Video cameras are used in two different ways for incident/stopped vehicle detection. Most commonly, cameras are used for human observation of traffic flow, road condition (weather impact) and, if observed, stopped vehicles. For stopped vehicle detection, these cameras are typically used to validate reported alerts.

The video stream of cameras can also be used for video analytics producing automated detection of stopped vehicles. Video cameras use visible light. The light circumstances and weather conditions differ during the day and during the year. Problems can arise from bright sunlight, sun-facing the camera, fog, and a dirty lens (Ogier Electronics, 2021). The performance of some machine learning solutions can be affected by slightly altered image e.g. a slightly viewpoint arising from wind conditions. It is more challenging to maintain successful detection from a PTZ (pan/tilt/zoom) camera than a fixed camera because the angle between the camera and the road can differ as well as the zoom factor.

Video processing methods for stopped vehicle detection have been published (Bevilacqua and Vaccari, 2007), (Alpatov and Ershov, 2017), as have many more general vehicle detection algorithms which could presumably be adapted or extended for stopped vehicle detection specifically.

Video-based automatic incident detection products have been advertised for many years, and several reported. Early trials and deployments of video-based stopped vehicle detection tended to focus on the fixed environment of a tunnel. Trials on open highways had mixed results (noted in our NRA survey) and the solutions have not yet (in 2021) become common on open highways but the most recent results have been successful and Highways England recently awarded framework contracts for the potential future provision of video-based stopped vehicle detection.

Examples of recent trials

A test was executed in the Netherlands on a rush-hour lane on Highway A2 (Beck, 2017), with existing cameras to identify vehicles on the road. The initial results were positive. Rijkswaterstaat planned the next steps to examine the possibilities. On Highway A13 high-resolution cameras are deployed with image recognition (Taale et al, 2019). The reason to proceed in this direction is that Rijkswaterstaat has an installed base of 3000 cameras on the highway network of which only a part can be displayed on the video walls in the different TCCs, so there is added value by using a detection system on the image-feed of these cameras.

In Belgium, an evaluation was done in 2018 regarding the AID system operated in 5 Ten-T tunnels, after previous experience of high false alarm rates. Optimization of the existing systems was procured, and a project was started to enable several providers to perform a proof of concept using imagery from the Kennedytunnel. One of these used neural networks. The percentage of detected objects that were indeed vehicles was over 90%. The percentage of recognised vehicles was around 50% due to vague imagery and vehicles being only partially in view. The false alarm rate was significantly better than that of the existing AID camera system. The maximum time-to-detect was 7 seconds.

The video analytics of supplier Vivacity Labs were trialled on the open highway using existing traffic cameras of Highways England, in a systems integration provided by Costain (Costain, 2020). 32 CCTV feeds were selected to be analysed during the trial period and a dashboard at the traffic control centre displayed alerts related to events detected. The video analytics engine could identify speed, occupancy, traffic flow, stopped vehicles, and whether the camera has moved, from each CCTV feed, and provided live alerts when certain threshold conditions are met. When an altered camera position is detected and alerted, the system avoids generating further alerts until the camera position is restored, to avoid false positives. The system showed 94% accuracy for stopped vehicle alerts of which 58% were vehicles stopped in emergency refuge areas, 6% were vehicles stopped on a dynamic hard shoulder, 19% were vehicles stopped on conventional hard shoulder, 4% were individual vehicles stopped in live lanes and 14% were stopped road maintenance vehicles. Performance was less effective on PTZ cameras than fixed cameras due to wind affecting the home positions of the former.

False positive alerts were due to the following occurrences:

- Sun glare, lens flare and shadows
- Water or dirt on the camera lens
- Lights and reflective markings
- Road markings and water patches

In 2019 the Vivacity Labs system was tested in the Southwick tunnel testbed (Bradford, 2019). This system uses special camera-based detectors with artificial intelligence that can detect, classify, and track vehicles within a field of view. The software identifies instances of vehicles (and pedestrians) and their location within the field of view, then classifies these, and tracks instances from frame to frame. If a vehicle stops in the tunnel in a zone that has not been designated as a parking area, but is not blocked by another vehicle in front of it (as would be the case in congestion), this can be flagged as either a breakdown or collision. The system requires a period for machine learning and tuning before operational use. The system was evaluated on its ability to capture slow vehicles, stopped vehicles and vehicles driving in the wrong direction. With a requirement to detect within 120 seconds, 187 out of 188 incidents were correctly detected, with 1 incident missed and no false alarms, i.e. a detection rate of 99.5% and false alarm rate of 0%. Further detail on the Vivacity trials is provided in Appendix A Recent trials of optical detection in England.

Thermal cameras

Thermal cameras detect temperature differences between objects in the field of view. As stated by Ogier Electronics (2021), thermal cameras suffer mainly from similar problems to those of video cameras.

Strom (2017) discusses the pros and cons of the use of thermal cameras. Thermal cameras can perform without visible light. In the same article the supplier FLIR explains that these cameras can detect excessive heat by fire or a malfunction of a vehicle without the need of contact with flames, heated gasses, or smoke. ‘This can be a life-saving feature in smoke-filled tunnels’ and ‘can provide valuable information to firefighting teams about the possible location of people’. In the same article the supplier Dahua Technology suggests: ‘The advantage of thermal cameras does not justify its higher price nor its lack of intelligent recognition and analytics capabilities, thus thermal cameras are not widely applied in traffic management.’

Thermal cameras have been used where their primary purpose is fire risk detection (e.g. Mont Blanc tunnel entrance) rather than stopped vehicle detection.

Fu et al (2017) investigates the performance of thermal video sensors in comparison with regular video data with existing computer vision methods for automated data collection for detection, classification, and speed measurement under varying lighting and temperature conditions. During the daytime, regular and thermal detection were comparable. The regular detection narrowly outperformed the thermal camera in terms of detection and classification during the daytime. The regular camera detects and classifies vehicles adequately during night-time, but the detection of bicycles and pedestrians deteriorates. The thermal camera shows stability across the day and night conditions. Measurement of speed by the thermal camera was more accurate.

4.1.6 Radar

Radar has been used in traffic detection for many years. Radar for traffic detection can be classified in two main types – rotating 360° radar and staring radar.

Rotating Radar

In parts of Europe, notably on the strategic road network in the UK, stopped vehicle detection is performed with rotating FMCW (frequency modulated continuous wave) radar. This has continuous coverage of each lane in both carriageways for up to a few hundred metres from a sensor.

Rotating sensors transmit varying frequency radio waves that reflect back to the sensor when they hit an object, as illustrated in Figure 3. The time for the signal to return determines the distance to the target. This allows detection of both stationary and moving objects, which can be highlighted when compared to a known background, or ‘clutter’ map.

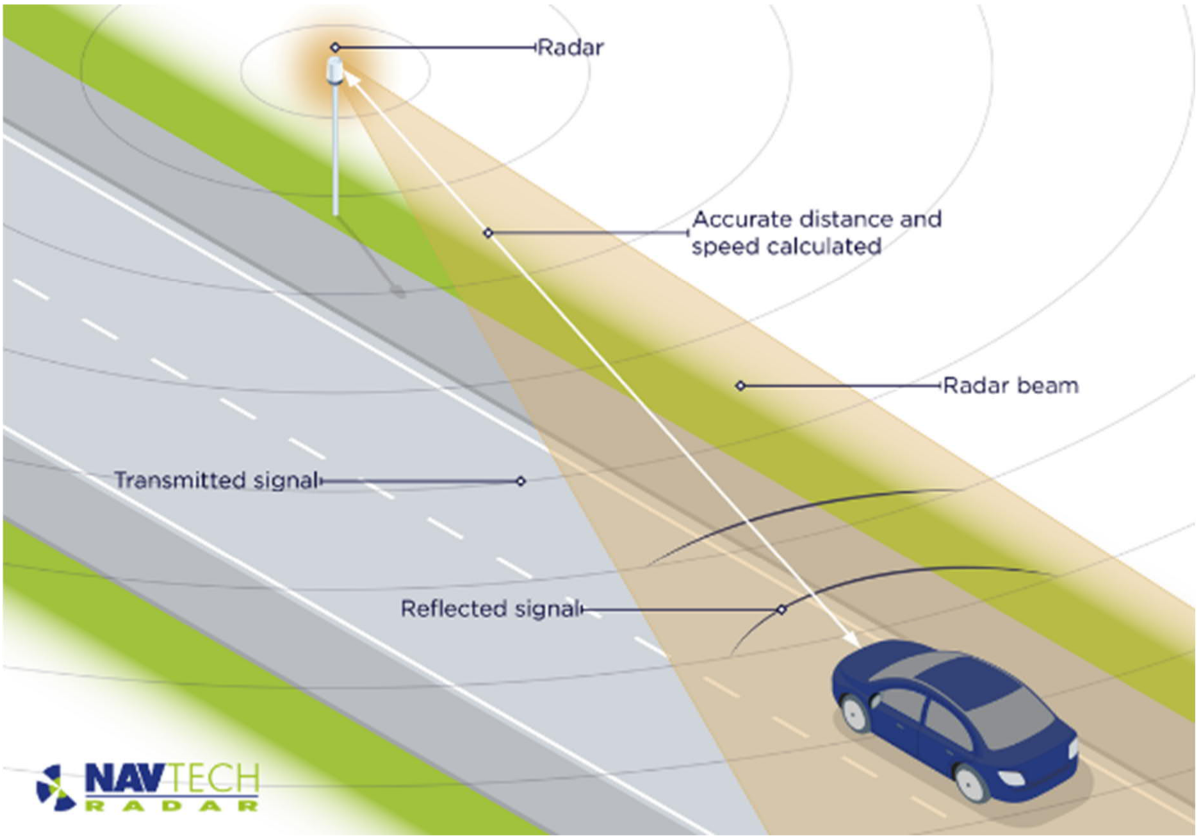


Figure 3 Schematic illustration of rotating radar (Source: Navtech Radar)

The high coverage range from one sensor (although this can be limited by sharp bends) means relatively few sensors are needed to cover a large area. Individual vehicles can be detected, rather than relying on queueing traffic or algorithms (Athow, 2013) to infer stopped vehicles. Radar is relatively unaffected by weather or light conditions, allowing detection in low visibility conditions, when it is needed most. Furthermore, privacy is maintained by being unable to identify specific vehicles in the way that thermal and visual cameras do.

The wavelength of radio waves used in radar determines limits of resolution, which is coarser than that of visible light. For example, detection resolution from Navtech Radar devices is specified to be 17.5cm. This should not impact stopped vehicle detection but can limit detection of debris and small animals. The capital costs of radar equipment can be expensive; however this is often offset when compared to other technologies by the limited maintenance and installation costs.

On the M25 in the United Kingdom, a stopped vehicle detection trial was performed in 2016 on a stretch of road where a hard shoulder lane was converted to a permanently live traffic lane in an "an "All Lane Running" (ALR) regime. Emergency refuge areas were added but the risk of a stopped vehicle on the lane was one of the most important risks considered. To mitigate this risk, especially during off-peak hours, Highways England commissioned a trial with Navtech Radar's Clearway using rotating radar (Navtech Radar, 2019). Initially 13km then 38km of motorway carriageway were covered by the schemes. Stopped vehicles were detected within 10 seconds, the operator could investigate and verify the alert within one minute, and incident response could be deployed much quicker. Road coverage was planned using a 3D model (SNC Lavalin, n.d.). The detection system considered logical sections of 100m – in each section at most one alert is raised at one time, even if 2 or more stopped vehicles are detected, or if a stopped vehicle is detected by more than one radar device. This gives better alignment with the role of the human traffic management operator than if alerting on all detections. Alerts can be suppressed if there are upstream signal settings restricting the traffic, or on operator request (during roadworks for example). Highways England is in the process of expanding this detection system to a large proportion of the motorway network where there is no hard shoulder.

The system's ability to detect stationary objects is illustrated in the schematic Figure 4 where the stationary yellow car in the image can be detected and an alert raised. The technical specifications for the radar devices state an operating range of up to 500m (for vehicle detection) and a rotation frequency of 4Hz.

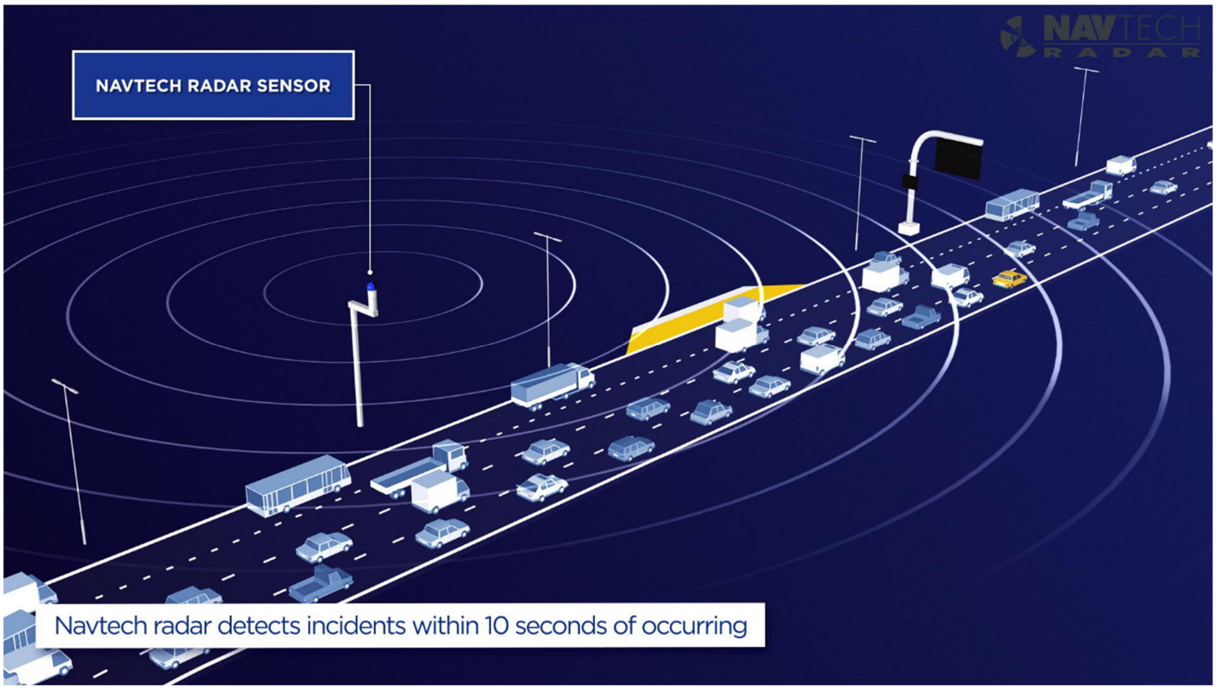


Figure 4 Rotating radar detecting stopped vehicle (Source: Navtech Radar)

Analysis of the M25 trial (Highways England, 2016) showed a Detection Rate between 0.82 and 0.90 and a False Alarm Rate of 8.6%. Highways England also undertook trials of other detection products including other radar devices but no details are available and they have not led to operational use.

Staring Radar

Staring radar, or panel radar, uses similar technology to rotating radar. Radio waves are transmitted from a sensor and reflected off an object. The difference to rotating radar is that the transmission is only in one direction from the sensor. This reduces moving parts, creating a lower cost sensor, but reduces total coverage area. Camera integration can be easy with staring radar as a camera doesn't need to move to see the full area covered by the radar.

The advantages of staring radar are similar to those of rotating radar. In particular, the technology works in all weather conditions and requires minimal maintenance. However, staring radar loses some effectiveness through having to be orientated directly along a carriageway. This removes a dimension from the data acquired, reducing the accuracy of speed sensing as Doppler techniques are generally used. (By comparison, the coverage in rotating radar means tracks are long enough to determine speed from position variation.) Staring radar has a higher potential for a vehicle to be hidden by moving traffic as the detection direction does not change.

The range accuracy of an example staring radar from SmartMicro is 25cm. The angular resolution (and therefore the ability to determine the lane of a stopped vehicle) is not quoted.

In the Netherlands, the Falcon Doppler radar detector is used for AID on highways, as part of the Motorway Traffic Management/MTM2 system, especially at locations where detection loops cannot be installed e.g. on bridges. The radar can measure speed and classify passing vehicles but the classification is less accurate as investigated in a field test (Rijkswaterstaat, 2002): the system approached the results of loop detection at best, with a specific focal point on the road to emulate loop detection.

4.1.7 **LiDAR**

LiDAR sensors transmit pulsed laser light that is reflected back to the sensor when it hits an object. This time is measured for each pulse, which then allows for the sensor to create a three-dimensional image of its surrounding environment. Objects such as vehicles, pedestrians and cyclists can then be classified (Guerrero-Ibanez et al, 2018). As with radar, it can be used in rotating and fixed-view devices, and it is considered useful for automated vehicles (Khader and Cherian, 2020).

A key advantage of LiDAR is high resolution imaging, with low installation costs. Compared to radar, the granularity provided by LiDAR is an advantage for some purposes and can help improve classification.

Disadvantages include relatively high capital costs of the technology (especially at higher resolution) but as LiDAR module volumes increase (especially if it is used in mass-market automated vehicles) the cost is dropping to more practical levels (Verge, 2020). Although Ogier (2018) describes its range as “very short”, suppliers such as SICK and Luminar promote devices with ranges over 300m, and the latter are designed for automated recognition in vehicles. Practical detection range is likely to be less than that of radar due to different absorption rates. LiDAR performance deterioration in rain, fog and snow is more significant than that of radar. LiDAR has not been prominent in roadside or infrastructure installations at large volumes, and its potential for stopped vehicle detection not fully yet explored.

4.1.8 Floating Vehicle Data

Data reported by multiple connected vehicles can represent the overall traffic state on a location on the network. Van Vianen (2017) researched floating vehicle data (FVD) for the detection of stopped ehicles. The research investigated methods/algorithms for detecting stopped vehicle location and ran simulations to test a new algorithm. The tested algorithm has problems with infrastructural changes and could not detect an incident when there is no congestion (the most dangerous situation). A new algorithm was designed using lane change as an input – this information is not always available from connected vehicles, but its availability is expected to increase.

Houbraken et al (2017) reported a large-scale field trial of FVD for incident detection on two highway sections in the Netherlands (A27 and A58). The average coverage of FVD was around 6%. The FVD-based incident detection used the same incident detection algorithm as the existing system (MTM2) which used induction loops with 500 metres spacing. Performance results were considered promising.

Highways England researched the use of FVD for incident detection in 2019 (no publication is known). The loop-based MIDAS system was used as a baseline for comparison – it generates queue alerts on motorways which result in queue warning messages and reduced mandatory speed limits. This project investigated whether floating vehicle data could provide an alternative data source instead of roadside traffic detectors. If so, this would allow significant reduction in roadside technology infrastructure with associated cost savings (although with operational costs for data purchase instead). Data from existing products (Traffic API, TomTom) and one development product (Dangerous Slow Down 2, INRIX) were compared with MIDAS queue alert logs from robustly operating network sections. The development product showed very good correlation with MIDAS alerts; the existing product shows some good correlation but more variable performance. This is to be expected because the FVD suppliers’ existing products were not developed with queue detection in mind. Both TomTom and INRIX are continuing to develop further innovations to improve performance; the project concluded FVD could be used for queue protection in future.

Further information is provided from the inputs of mobile/connected vehicle service providers in section 5.2.

4.1.9 Cooperative ITS

In addition to using information from service providers, road authorities can also detect stopped vehicles more directly if they collect standardised cooperative ITS (C-ITS) messages. ETSI TR 102 638 defines a class of applications for “active road safety”, with use cases including “Stationary vehicle warning“.

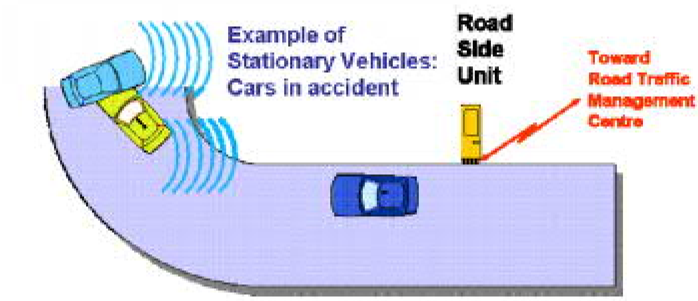


Figure 5 Stationary vehicle warning scenario (ETSI TR 102 638)

Given limited information available on implementations, support cannot yet be assumed to be high in the general vehicle population. An implementation for road maintenance and emergency vehicles is noted in Hessen, Germany (C-Roads n.d.). The influential CAR 2 CAR Communication Consortium has defined "Triggering Conditions and Data Quality: Stationary Vehicle Warning“ (CAR 2 CAR, 2020), confirming specific requirements for use of "DENM“ messages (Decentralized Environmental Notification Message, see ETSI EN 302 637-3) which are already widely implemented in C-ITS components for various use cases. "CAM“ messages (Cooperative Awareness Messages, see ETSI EN 302 637-2) also provide relevant information including speed and acceleration.

An important initiative for safety-related connected vehicle data in general is the "Data for Road Safety“ initiative (Data Task Force, 2020). This initiative should increase the availability of stopped vehicle alerts available to roads authorities, gathered through C-ITS and other proprietary methods.

4.1.10 eCall

As eCall is a specific focus of SHADAR, it is described in detail in section 6.

4.1.11 Bluetooth

Although Bluetooth is normally used for journey time applications, Margreiter (2016) investigated incident detection based on Bluetooth in a four-year experience in Northern Bavaria. His paper describes the application of an automatic incident detection algorithm for real-time use, avoiding false alarms. Incidents were inferred from detected traffic properties (rather than individual missing vehicles which would clearly not give perfect detection rates due to limited use of Bluetooth in vehicles). The technology as well as the algorithms showed their feasibility in practical use. This incident detection algorithmic processing work seems transferrable to the alternative technology of Wi-Fi detection which similarly detects passing vehicles at two or more successive points, albeit with incomplete coverage of the vehicle population.

4.1.12 Acoustic detection

In tunnels acoustic monitoring is used to detect anomalies such as the crash of a vehicle against the tunnel wall, two vehicles crashing, dropped of cargo (Joanneum Research Digital, n.d.). When the system detects an anomaly, it is assigned to the nearest microphone. An alarm is set in the tunnel control room with the incident category and associated camera image.

Acoustic detection is also offered for smart city applications (Sorama, 2016), and the suppliers claim that their technology can detect, classify, and track vehicles, but no use of these sensors for stopped vehicle detection is known.

4.1.13 Hybrid detectors

Hybrid detectors have been produced, combining CCTV and radar in one sensor (ITS-UK, 2021). These combine the strengths of the two alternative methods. Stopped vehicle detection was one intended application of an initial trial deployment of one sensor on a motorway in UK. Incidents detected by radar lead to targeting of the CCTV (smartmicro, 2018). Whether this technology includes any automated detection from the CCTV and potential fusion from the two methods is not specified.

4.2 Comparison

This section compares detection methods using metrics defined in section 3. A method which has poor performance on one or more metrics may still be useful in combination with other methods.

Detection rate

Detection rates achieved by recent camera-based solutions and radar are high, while anecdotal evidence on induction loop detection suggests a relatively lower rate. Methods that sense effects on traffic are dependent on minimum flow levels, so they produce lower average detection rates across all flow conditions. Methods exploiting connected vehicles for direct detection currently have relatively low coverage in the vehicle population so produce relatively lower detection rates. Human reporting of bystanders, social media and traffic officers obviously have lower overall detection rates due to their lower overall spatial coverage on the road network, although individuals may have perfect detection rates within their own spatial coverage.

False alarm rate

Methods using processing of signals from equipment typically require a period of calibration or learning to reduce false alarms to a practical level – then trials show that their performance is good. False alarms can occur in eCall through inappropriate manual activation, which should be reduced if education is increased.

Time to detect

Methods that detect directly are typically faster than methods that detect indirect effects (induction loops and floating vehicle data) and methods that rely on human reporting (bystander, social media).

Projection

It is difficult to compare different categories of methods: covering a field from a fixed point / covering via successive cross-sections / moving with vehicles. The largest projection identified from a fixed point appears to be from rotating radar, while LiDAR has a shorter range. Ranges quoted for automated detection from cameras from one leading supplier (200-280m, with higher individual examples) are slightly lower than for radar. Induction loops, even with denser spacings, have a much smaller direct spatial coverage, but as noted can also detect indirectly through effects across successive cross-sections, as can Bluetooth and Wi-Fi-based detection. For C-ITS using ITS G5 communications, the maximum range from vehicle to roadside unit has recently been quoted as 1.8km.

Reliability

No data is available to suggest any significant difference in overall availability, but the methods relying on roadside or in-road equipment require ongoing maintenance to maintain the system availability. Maintenance costs for induction loops are relatively higher – one study suggested 2-3 times higher than for roadside equipment. Since radar is currently used in smaller volumes than CCTV cameras and induction loops, the availability of parts may be lower. All electronic methods obviously depend on the reliability of the communications networks used to transfer their data.

Independence from weather and lighting

Camera-based solutions are potentially more affected by weather and lighting, although it should be possible to mitigate this to an extent by extensive training in a range of conditions. Thermal cameras do not require visible light, but their performance can degrade in certain weather conditions. Wind can knock PTZ cameras away from their home positions for which they are trained to recognised stopped vehicles. Radar is less affected by environmental conditions, but there can still be effects in severe conditions. Induction loops and C-ITS are assumed to be relatively unaffected by these factors.

Independence from other influences

Induction loops can be affected by nearby structures but this should be taken into account in design for deployment. Thermal cameras will be affected by unusual heat sources such as fire, but these should be relatively rare. Induction loops can be affected by electrical interference but this is not commonly cited as a significant practical problem. Methods using line of sight (humans, CCTV & thermal cameras, radar, LiDAR) are all affected by vegetation – a more common problem on local roads but which can even occur on highways.

Ease of use

Ease of use is not an inherent property of the detection method – it depends on the system constructed around the technology.

Privacy and security

Methods capturing data that can identify individuals include cameras, floating vehicle data, social media, and Bluetooth. These privacy concerns can be mitigated (in different ways), as noted. Otherwise the security characteristics are not inherent in the technology but in specific system implementations.

Environmental footprint

Methods that require in-road or roadside installation will have a more direct environmental cost of installation than methods that use connected vehicles that are traveling anyway. In addition to the cost of materials required for equipment and its installation, roadside equipment may require clearance of vegetation, and could have some adverse visual impact for residents and in cultural locations. Unless it is installed during other works, in-road equipment (loops) would have significant environmental cost from the road surface materials. The use of advanced algorithms with existing multi-purpose equipment (such as using AI on existing cameras) avoids installation costs although there is still carbon from the computing services. Assessment of the environmental cost of detection via connected vehicles is difficult as some or all components of the service come from third parties. While further research could enlighten the comparison, the environmental costs may be low compared to the potential environmental savings from improvements in traffic flow (amongst other benefits).

Summary

To represent the discussion in a single table requires simplification of multi-facetted issues, and the representation of fundamentally different concepts on a single axis, but an attempt is made below. Rows representing services or third-party data consider the overall service at current coverage levels. Assumptions have been made, and the full discussion above should be consulted for a more complete view. No scientific comparison of methods in the context of stopped vehicle detection has been found.

	Detection Rate	Time	Projection	Maintenance	Conditions-independence	Privacy	Environmental footprint
Bystander	Low	High	Low	Low	Medium	Care	Low
Social media	Low	High	Low	Low	Medium	OK	Low
Traffic officers	Low	High	Low	High	Medium	OK	High
Loops	Medium	Medium	Medium	High	Medium	OK	High
Cameras (+automatic detection)	High	Low	Medium	Medium	Low	Extra care	Medium
Radar	High	Low	High	Medium	Medium	OK	Medium
LiDAR	High	Low	Medium	Medium	Low	OK	Medium
FVD	Medium	High	Medium	Low	Medium	OK	Low
C-ITS	Medium	Medium	Medium	Medium	High	Extra care	Medium
eCall	Medium	Low	Medium	Low	High	Care	Low
Bluetooth (& WiFi)	Medium	Medium	Medium	Medium	High	Extra care	Medium
Acoustic	Medium	Low	Low	Medium	Medium	Care	Medium
Hybrid/fusion	Highest	Low	Highest	Medium-high	High	Extra care	Medium

Table 4: Simplified comparison of detection methods against metrics

5 Stopped vehicle detection by national roads authorities and service providers

This section reports the results of surveys of national roads authorities and service providers.

Contact with NRAs was made via the identified contact points provided by the CEDR 2019 Programme Executive Board. Those contacts or their delegated representatives provided information by email and phone conversations. 9 countries were invited, and 8 countries responded (in one case via 2 separate organisations).

The results reflect the knowledge of those individuals and may not fully represent complete information about the road authorities. The survey contents included:

1. Current vehicle detection methods
2. Working of each method
3. Stopped vehicle alerts reporting
4. Stopped vehicle alerts verification
5. Pros and cons of each method
6. Future stopped vehicle detection methods

Contact with service providers was through connections of the authors. 3 service providers were invited and all responded.

The full survey questionnaire of 20 questions is included in Appendix B, and the direct or transcribed responses are presented in Appendix C.

5.1 Detection methods by NRAs

First, the organization's current methods of detecting stationary vehicles and an estimation of the prevalence of these technologies was requested. These results are summarised in Table 5. It is important to note that entries include estimation provided by individuals. The table can be used to provide insight into the current operational means of stopped vehicle detection in each country but does not necessarily provide complete and accurate information on all installations in these countries.

NRA	LUX	NLD	AUT	BEL	IRL	ENG	SCO	DNK
Phone call	Private calls	Private calls	Emergency roadside telephone		Private calls	Emergency roadside telephone	Emergency roadside telephone	Private calls, 112 relay
Social media	Waze for verification	Waze on desk TMC		Waze 100% of the network			Waze, Twitter via Sprinklr	
Traffic officers road operators	Police ECC	ECC	Traffic officers, police	Police 100%	Blue-light Route patrolling 3rd parties	Traffic officers, police		Police Radio stations
CCTV Video cameras	Motorways 80% CCTV verification	CCTV verification tunnels	CCTV verification	20-25% CCTV verification	M50 98% verification Tunnels	Monitoring 100% on smart motorways	CCTV verification	5% CCTV for verification
AID cameras	Video analyses in tunnels 100%	AI PoC 5 km	Video detection (tunnels) Pilot 50 km (open)	Ring roads, tunnels <10%		In trials, and procured for further rollout	Two past trials	
Thermal cameras	Some in main tunnels		Dual cameras: Pilot site				Used locally as alternative to loops	
Loop detection Standstill			Breakdown bays in tunnels				Hard standings Bus lanes 5%	
Loop detection (High Density)		Rush-hour lanes & tunnels every 60-70m			3 High-speed tunnels 1% of network			
Loop detection (Low Density)	Motorways, 2-3 km interval	AID (MTM)	Tunnels	AID 20%	On M50 ADL 100%	MIDAS	Yes	
Radar						100% on ALR locations by 2023	Used locally as alternative to loops	
LiDAR								
Acoustic Detection			In tunnels			Past trial		
Floating vehicle data			(C-ITS deploying)			INRIX data used in national information service	INRIX service	Trial conducted.
eCALL	directly to national emerg. Centre	eCall	Through police + direct studies	Through police	Channelled thru MTCC	Through police + direct studies		

Table 5:Survey results: detection methods reported to be used by NRAs

Darker shading indicates methods with a specific purpose of detecting stopped vehicles.

Lighter shading indicates methods that detect more indirectly e.g. basic cameras requiring human recognition of a stopped vehicle, or widely spaced loops which can detect indirectly through associated congestion.

5.1.1 Notes on reported methods

Bystander

Four NRAs mention private calls as a method for retrieving information about stopped vehicles. Probably this is also the case in other countries but not mentioned by the NRAs.

Social media/Navigation applications

In the BeNeLux and Scotland data of Waze is used in the TMC for detecting possible situations of stopped vehicles. Denmark is investigating the use of reports from service providers like Waze. In Scotland notifications on Twitter are analysed via the "sprinklr" product which can detect incidents including stopped vehicles once enough people pass.

Traffic officers, road inspectors

Not all the NRAs mention the means of notification by police, road inspectors, etc. Maybe this is not elaborated by the NRAs due to the focus of the questionnaire on stopped vehicle detection.

Cameras

CCTV/video cameras

CCTV (PTZ) is mostly used for human verification of stopped vehicles and other incidents on the road network. In the Netherlands and Flanders, the NRA is investigating or applied field tests to use the CCTV images for data analysis for incident detection. Scotland has undertaken two trials of video-based detection, but these were not sufficiently successful to lead to operational use. In 2008 a field test was done with a solution which had achieved good results on fixed cameras in New South Wales, Australia, but did not work so well in Scotland with PTZ cameras. The solution required the operational staff to continue to classify incidents as true positive or false positive, to allow the system to continue to learn, but this was not always done, limiting the potential performance. A further trial of a different video-based product was performed in 2019 but again was not sufficiently successful to lead to operational use. Transport Scotland is nevertheless still considering the future use of alternative video-based solutions.

AID cameras focussed on incident detection/stopped vehicle detection are in use by three NRAs but only in tunnels. This could be due to rather stable environmental conditions and of course the need of having a detection system in operation in a high-speed tunnel. The NRA of Luxemburg indicates a weekly reporting of true/false incident detection in tunnels. In general, false detection mainly occurs in the tunnel portal areas due to changing light conditions.

Thermal cameras

Two NRAs specified that thermal cameras are used in some locations in tunnels. One site uses dual cameras. The NRA of Luxemburg indicates that the current systems in tunnels are end of life and will be replaced by IP-cameras, where thermal cameras will be used in the portal areas.

Loop detection standstill

Standstill detection is mainly used in break-down bays and on bus lanes. (A note of the authors is that standstill detection in the Netherlands is used at locations where the safety risks for the stopped vehicle, other road users and emergency services are high. This is the case around and in tunnels and locations where no hard shoulder is available and brake down bays are present.)

Loop detection low vehicle speed

Low vehicle speed detection is used in two types of configuration. On main highways where traffic is dense, and risks of congestion/traffic jams loop detection is used with an interval of round about 500 metres mostly in combination with traffic signalling (MTM in the Netherlands, ADL on the A50 in Ireland and MIDAS in the United Kingdom). With the use of algorithms, the signalling will automatically show a speed restriction as a warning of congestion up ahead. As a bycatch, the congestion can be a result of an incident/stopped vehicle.

By creating a dense detection field there is an increased statistical chance of detecting a vehicle that will come to a standstill or an upcoming vehicle that will reduce speed due to a stopped vehicle or other obstacles. Spacing may be from 30 to 70 meters. In tunnels in the Netherlands, the speed discrimination is set with two thresholds and generate two kinds of warnings. The thresholds could be something like 30 km/h and 15 km/h. This configuration is mostly used in tunnels and on rush hour lanes. As shown in the table this is the case in Ireland and the Netherlands

Radar

Highways England uses radar detection for stopped vehicle detection on all-lane-running sections of the strategic road network. There is a commitment for every section of all lane running to be covered by 2023. This use is expanding to include some areas with roadworks where there is no exit from live lanes, with an initial system being deployed on the A46.

Rotating radar is used for incident detection on bridges and tunnels across many parts of Europe, including Sweden, Norway, Austria, and Switzerland.

LiDAR

In the survey, the use of LiDAR as a detection method is not mentioned.

Acoustic detection

In Austria, the AKUT-system (Acoustic Tunnel Monitoring) is used in tunnels to detect anomalies within the noise of the tunnel. For example, crash, tire burst, door banging. In the brochure (Joanneum Research Digital. n.d.) the setup and operation of the system are described. Microphones are placed by cameras every 100-150 meters. Detected sounds are classified by algorithms. Critical incidents are accompanied by characteristic concurring sounds by which an incident can be detected. An alarm is sent to the control room and accompanying cameras can be turned on automatically on the screen (like other detection systems in a tunnel SCADA system).

Floating Vehicle Data

In Denmark a trial with floating vehicle data has been conducted. In 2021 another trial will take place with more focus on the operational aspects in the traffic centre.

Other known uses of floating vehicle data not identified by the NRA surveys include the more indirect use through cooperation with connected vehicle service providers for traffic management, such as in the SOCRATES2.0 European project (socrates2.org), and the supply of safety-related data by participants in the “Data for Road Safety” initiative (www.dataforroadsafety.eu).

eCall

In Europe, all 112 centres started using eCall from 2018. In most countries, eCall is routed through a national access point like an emergency centre and from there rerouted to the TMCs. The number of eCalls will increase as it has been obligatory for new cars and vans from April 2018.

5.1.2 Verification process

The incident management process can be considered to consist of several phases. It starts with the detection phase, which is followed by the verification phase, since all detection methods may suffer in one way or another from a misinterpretation of the acquired information/data. In the verification phase, it is checked whether the detection/report is correct, and action needs to be taken; if yes, the next phase will start (traffic management phase and/or approach phase by emergency services).

The questionnaire asked about the process of arriving at a verified incident and which methods are used. All NRAs have a control room (TMC) from where traffic/incident management and control is coordinated. The detected incident is handled through an operator at an equipped desk. In most cases, the operator verifies the report using CCTV before the incident report is passed on to the traffic officers, road inspectors, the police and/or a salvage company. If the incident area has no CCTV coverage, the incident report is verified on site by police, road inspectors or a salvage unit.

The incident report contains as much information as possible about the incident like the position on the carriageway, seriousness, and circumstances of the incident like how many vehicles are involved, are there victims, damage to infrastructure and the remaining duration. The NRAs indicate that these data are logged in the TMC. Different systems are used for this. The logging supports the potential for subsequent audits.

The sharing of incident information to operational staff is mainly done by phone and/or e-mail although some NRAs also share this information through a traffic management system. In the Netherlands, the information is also shared in a data feed through the national access point (NAP), the NDW.

The TMC also deploys the traffic measures necessary to warn traffic that a vehicle is stationary. It is stated that these measures depend on the available resources. Where available, message signs and signals are used, in the case of tunnels also warning lights, or the tunnel is closed entirely. Road users are also informed by radio and possibly through service providers that use the provided data feed from the NAP.

In addition to visual verification of the detection of a stopped vehicle, other means of verification are possible, such as data fusion, which can verify not only that positive detections are correct, but also negatives. No details were supplied in the surveys.

5.1.3 Benefits and shortcomings

In the questionnaire, the NRAs were asked to give their opinion on the benefits and shortcomings they encounter in daily practices regarding stopped vehicle detection.

Benefits mentioned are:

- The reduction of collision risk.
- To carry the involved persons (in danger) into security.
- Reduction of supplementary traffic jams.
- When automatic detection is done with smart cameras, less staff needed in traffic centre.
- With camera detection immediate verification is possible.
- Detection with cameras is cost-effective because the hardware is also used for visual monitoring. Not much additional equipment is required.
- Safety and efficiency value is added.
- Police as a source are always reliable.
- Waze: cheap and wide coverage.
- Loop detectors are less weather dependent.
- Multiple ways of detection are used to reduce risk of reliance on just one.
- The primary measure is to ensure visibility of the vehicle for approaching motorists and therefore to increase the advance warning with the placement of traffic cones to the rear of the vehicle.

Shortcomings mentioned are:

- Problems with video detection: For bad weather conditions (fog, snow), there are additional moisture sensors necessary (differences for dry and wet road surface).
- Problems with video detection: The light should always be even, problems with different weather situations and day/night.
- Camera detection: the number of false alarms due to weather, light, and traffic conditions.
- Loop detectors: good quality outside tunnels, expensive in deployment and maintenance.
- Relaying on detection by police or traffic officers has risk of latency.
- The reliability of Waze.
- Lack of camera coverage for verification when incident detected by other means
- Inability of an actor to be legally entitled to remove vehicles from the network unless this is instructed by the police or local authority.

Little quantitative evaluation information seems to be available. The only detailed information provided or found is the radar trial analysis by Highways England (2016) identified in section 4.1.6.

5.1.4 Indication of the costs of operated systems

Our contacts at the NRAs have, for themselves, no information on the costs of the systems they use. This is mainly due to that most of our questioned NRAs are associated with the operational use of the system in the TMC, with other departments responsible for the procurement, realisation and maintenance of systems and infrastructure. Furthermore, the various procurement contexts across the different NRAs are likely to be so different that comparison of costs would be difficult.

5.1.5 **Summary**

The survey has shown that all countries take advantage of detection and reporting by humans, and can also exploit the capabilities of existing induction loops, but few authorities have sensors dedicated to stopped vehicle detection on open roads, except in limited trials of radar or video analytics. Two countries have operational video analytics on parts of their highway network, and Highways England has pledged to deploy dedicated stopped vehicle detection radar coverage on all of its “all-lanes running” motorways by 2023. Despite this deployment, the technology seems at an early stage of maturity, with the available evaluation data coming from earlier limited trials.

5.2 Stopped vehicle detection by service providers

This subsection reports responses from connected vehicle/mobile service providers.

SP	TomTom	BeMobile	INRIX
Detection method	Fusion including GPS data sent at 5-10s intervals	Fusion of FVD + event data (notification by community)	Detection of major speed changes at specific points on highways
Type of detection	Mainly detecting slow down. Jam tail warning.	Incidents including stopped vehicles	Dangerous slowdowns
Coverage	5-15% of vehicle fleet (in Central Europe) (=> high coverage of highway network may be assumed)	100% of NL highway network	Implied full coverage of highway network.
Response process	Confidential	On notification verification by FVD, if positive report to traveller & stakeholders	AI engine scans for large speed change, alerts generated.
Report	To users of TomTom traffic	To traveller and SIMN service for incident support	To any customers of “Dangerous Slowdowns” product.
Alerts	Depends on end solution (visual/audible), and as data	Travellers visual & audible, to SIMN as data.	Up to end user
Verification	Matching with another source may be attempted including TomTom moderation team by camera	Confirmation by user community.	Not on individual level
SP opinion on used method	GPS is cost-efficient and accurate	Improves driver awareness and high coverage	Functions in all conditions, no reliance on infrastructure
Developments	Participant in Data for Road Safety initiative.	eCall/messages by stopped vehicles themselves Detection by FVD alone.	Vehicle detailed data (hard braking) neural networks to enhance detection

Table 6:Summary of survey inputs from service providers

The service providers gather and use data from connected vehicles through various sources and channels, which may provide position, speed, heading, and potentially a wide range of other internal vehicle data.

BeMobile collects data in the Netherlands using their Flitsmeister app. TomTom (n.d.) uses the probe vehicle data from multiple sources including anonymous measurements from GPS navigation devices, in combination with traffic information feeds from road authorities. INRIX (Athow, 2013) collects data form transport authorities, stationary sensors, fleets of connected vehicles etc, including the users of the INRIX application.

The high volume of data gathered allows analysis to determine traffic state. The service providers do not specifically focus on stopped vehicles but on incidents, and (for TomTom and INRIX at least) steep speed drops that indicate dangerous situations.

All these service providers incorporate the feedback loop between floating vehicle data and notification of the users of their applications/services.

6 Current state of eCall

6.1 eCall overview

6.1.1 eCall is working is across Europe

eCall based on the single emergency number of 112 has been operational in Europe and the UK since the 31st March 2018.

In addition, the standards, (communication and operation) on which eCall is based are now used in Turkey and the Middle East. The current eCall standard only applies to cars and light trucks but there are pilots for goods vehicles and powered two-wheeled vehicles and after-market fitment to the existing vehicle fleet being trialled across Europe.

6.1.2 eCall Deployment options

As well as the eCall based on the single emergency number of 112/999 which is a legal requirement for all new types of vehicle manufactured after 31st March 2018, there is also a private eCall system (TPS eCall) which is a subscription service. TPS eCall can be requested by the vehicle owner when the vehicle is first purchased. The system will usually only operate if the subscription is valid, though many service providers convert the TPS eCall into eCall based on 112 where there is no contract in place. The data and method of activation are the same as the mandated eCall system.

6.1.3 All countries use it for emergency services

eCall activations throughout Europe are passed to the emergency service for the correct response depending on the nature of the emergency. Most countries still transfer the data to the emergency services via voice. Few have a complete electronic transfer system for the Minimum Set of Data (MSD) as well as the transfer of the voice call from the vehicle occupants.

6.1.4 NRA use was always planned

The original concept of eCall, when defined in 2002, foresaw the requirement to provide the eCall data, once validated, to road authorities who are responsible for managing the roads in that member state.

As pressures on the emergency responders have increased throughout Europe, with increasing workload and reduced numbers, the role of the road authority in providing active assistance in the management of the scene of incident has become more important.

Hence the data contained within an eCall allows the road authority to provide advance notice to the road user of an incident up ahead. This is used to protect the scene during the rescue phase, and to then manage the restoration of normality once the incident has been resolved.

6.1.5 National Road Authority use of eCall to date

Whilst the use of eCall data by road authorities was always foreseen, to date only the Czech Republic, Denmark and Finland make full use of the data in the event of an eCall activation. Other member states are aware of the potential to use the data, but do not yet fully understand the provenance of the data. The restrictions placed on the use of the eCall data by GPDR is seen as a barrier, however specific exemptions exist if the eCall data is used within the as part of the emergency responder deployment. The dispensations are granted under the European Electronic Communication Code. The penetration of eCall in Europe means the data set has potential high value.

6.1.6 eCall data transmission

The data generated by the eCall the Minimum Set of Data (MSD) was specifically designed by the emergency services, for the emergency services, only providing the key data required for the mobilisation of a rescue.

In designing the eCall system, it was envisaged that the data could be transmitted electronically, thus saving minutes compared to voice transmission. Trials have shown that eCall data is well suited to electronic transmission, and can be transmitted seamlessly between different emergency authorities and where necessary member states, saving time and ensuring an accurate transfer of data. Whilst the data was primarily designed for the emergency services, the design of the data set provides valuable data for National Road Authorities if used as described in the necessary eCall data protection policies. When allied and fused with other data from infrastructure, it offers opportunities for incident detection.

6.1.7 Awareness of the eCall system

eCall systems have been in existence since 2002 in the TPS eCall format. The eCall system entered general use in 2018. However, the penetration of eCall across Europe and beyond is not uniform. The vehicle refresh rate for each member state differs significantly, especially when the accession countries in Europe are added, and the provision of associated infrastructure there is well behind the rest of Europe.

Currently only the member states involved in the development of eCall through the HeERO, HeERO2 and I_HeERO projects[2] have provided any information to their citizens over what eCall is. No member state has issued any guidance to its citizens on how and when to use eCall. Overall, user education about eCall at the driver level seems somewhat lacking.

6.1.8 Summary

- eCall is now working across Europe
- Mandatory fit in all cars and vans
- Different deployments but same protocols
- All countries use it for emergency services
- NRAs' use was always envisaged
- Few countries so far make full use at NRA level
- Little evidence of rapidity of data and automatic feed being used in stopped vehicle detection – opportunity for NRAs
- Awareness is poor – need for education
- Allied with other data offers further potential

6.2 How eCall works

6.2.1 End-to-end summary

eCall is an emergency call (using the pan-European 112 service) generated either manually by vehicle occupants or automatically via activation of in-vehicle sensors (such as airbags), following a collision. The service is free for all the citizens of Europe.

When activated, the in-vehicle eCall system will establish a voice connection directly with the relevant PSAP (Public Safety Answering Point). At the same time, a small data set called the Minimum Set of Data (MSD) is sent to the PSAP operator receiving the voice call, providing the location and other vehicle data.

Road safety is one of the major elements of the European Union's transport policy. eCall is designed to contribute significantly to the reduction of road fatalities and alleviation of the severity of road injuries.

[2] The countries involved: HeERO Czech Republic, Finland, Germany, Greece, Italy, the Netherlands, Romania and Sweden and Croatia. HeERO2 Belgium, Bulgaria, Denmark, Luxembourg, Spain and Turkey. I_HeERO Bulgaria, Cyprus, Czech Republic, Finland, Germany, Greece,
Ireland, Italy, Luxembourg, Portugal, Slovenia

The harmonised implementation of an interoperable EU-wide eCall service has been on the agenda of the European Commission since 2005 and has now become a priority action for the improvement of road safety and the deployment of ITS in Europe.

6.2.2 Key elements of eCall

Using 112 means that the generation of an eCall is free at the point of use where eCall is fitted to a vehicle. In contrast, private eCall (called TPS) is usually a subscription service so if the subscription is not renewed by the owner, then the system could be disconnected, or revert to a 112 eCall.

Whilst the provision of the 112 service has been a major achievement, it still requires the caller to have some idea where they are located and to be able to communicate. eCall differs in that there are two distinct methods of activation:

1) Automatic, this is a machine activation, no human intervention, with the vehicle activating through a sensor and a confirmatory process that there has been an event which requires emergency intervention.
2) Manual, this is human intervention requiring the SOS button in the vehicle to be pressed. Currently this method of activation has the highest number of false activations, but much of this is down to poor education of the vehicle occupants

Whether the activation is manual or automatic, the same process in contacting the Public Safety Answering Point (PSAP) will happen. The 112 call receives high priority on the network, so no matter which networks are present, the call will go through. Once the call is received, the vehicle will then transmit the minimum set of data. It is the data which makes the key difference to a normal 112 call.

6.2.3 eCall data set

The information on the vehicle type and location is in the minimum set of data that is transmitted to the PSAP after the eCall has been activated either manually or automatically via sensors.

Block No	Name	Description
1	MSD ID	Variant of MSD type
2	Message Identifier	Sequence of message
3	Control information	Manual or Auto, test or Emergency, Location Trusted, Vehicle Type
4	VIN Number	According to ISO 3779
5	Propulsion Type	
6	Time Stamp	When event occurred
7	Vehicle Location	Latitude and Longitude
8	Vehicle Direction	May be revised
9	Vehicle last positions	Bread Crumb x 3
10/11	Optional fields	Passengers and Additional Data

Table 7: eCall data set (Source: EN 15722:2020)

6.2.4 eCall legislation

In August 2010, Directive 2010/40/EU of the European Parliament and of the Council of Ministers adopted the framework for deployment of Intelligent Transport Systems for road transport and for interfaces with other modes of transport, with the 'harmonised provision for an interoperable EU-wide eCall' as one of the six priority actions identified.

According to EU legislation, all new M1 and N1 vehicle (cars and light vans) manufactured after the 31st March 2018 and submitted for type approval shall have eCall based on 112 fitted as standard equipment. However, as European PSAPs are equipped to receive eCall, it is anticipated that many existing vehicles will be retrofitted with after-market eCall devices. This initiative is being supported by member states and the European Commission

6.2.5 eCall advancement

The project "sAFE - Aftermarket eCall For Europe" is to define the standards and specifications to pave the way for deployment of aftermarket systems for eCall. The deployment aims to reduce the required duration for successful full deployment of after-market 112 eCall in the EU.

To guarantee the functionality, compatibility, interoperability, continuity, and conformity of after after-market across Europe the existing eCall, specifications will be used in establishing criteria, with the aim of limiting the number of false eCall to PSAP. All vehicle types will be considered, not just those defined in the eCall legislation.

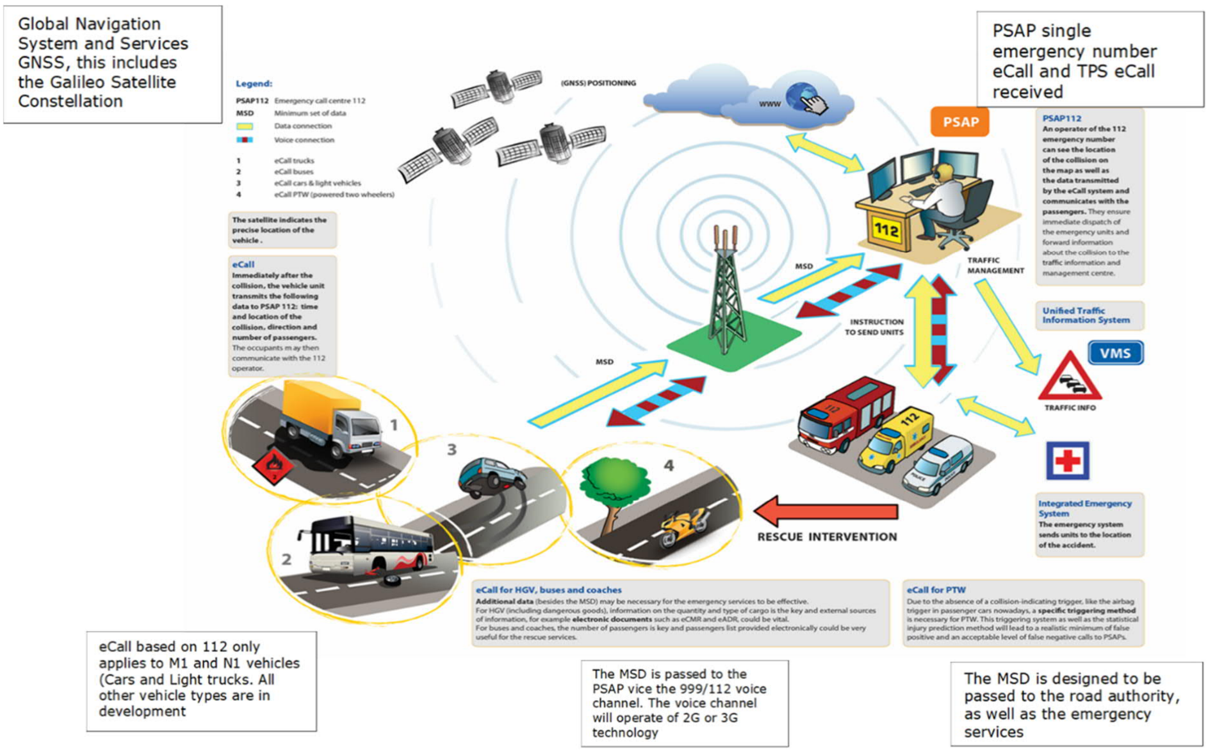


Figure 6: eCall based on 112 high level architecture (Source: I_HeERO)

6.3 PSAP architecture in Europe to handle eCall

The deployment of eCall in Europe is now complete: the European Commission has confirmed that all member states are now capable of receiving eCall based on 112. Most member states can receive private eCall (TPS eCall) activations. Member states are not obliged to handle private eCall, but the majority do.

During the implementation phase of eCall, each member state was required to make a strategic decision on how many PSAPs would be required to process eCall in that member state. With notable exceptions of France and Germany, the majority chose to limit the number of PSAPs that could receive eCall.

France opted to introduce an intermediate PSAP to answer all eCall (Public and Private) owing to the age of the existing PSAP system in France. Germany as a federated state has more than 262 PSAPs; each region in Germany is responsible for providing 112 services. For these reasons Germany equipped a significant number of PSAPs to receive eCall. This was done mainly to limit the cost of conversion, but it was anticipated that for the first 5 years, the numbers of eCall received would be low, which posed training implications for PSAP operators.

In understanding eCall, there is a need to understand how each member state PSAP is configured especially as each member state has chosen to limit the number of PSAPs that can receive eCall.

The European Emergency Number Association (EENA) has defined the high-level architecture for each member state. This defines the possible points that eCall data could be directed towards national and other road authorities.

6.3.1 eCall architectures[3]

To understand how each member state configures eCall, it is necessary to understand the architectures defined for Europe. All can receive and process both public and private eCall. The variations are due to legal, strategic, and operational limitations in each member state or region.

Model 1

Calls to national numbers and 112 are redirected to an Emergency Response Organisations (EROs). If the intervention of a different ERO is required, the call and/or data about the emergency situation are forwarded to the most appropriate ERO. Dispatch from the intervention resources is carried out by the ERO operators. This variant can also occur where two EROS are co-located and contacted via the same number. An example of this is in France, where there are legacy numbers still in use.

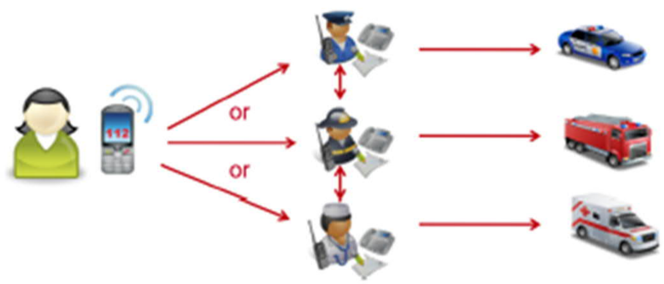


Figure 7: PSAP Model 1

Model 2

An independent first stage PSAP receives all emergency calls and then forwards them to a local ERO. The call-takers only ask the caller with which emergency service they want to be connected to. The stage 1 PSAP forwards the call to the appropriate local ERO. Detailed data gathering and dispatch of the intervention resources are done by the emergency response organisation. The PSAP may connect to one ERO. If further EROs are required, then the first ERO is responsible for contacting the other required resources. This is the model utilised in the UK.

[3] Source: PSAP models European Emergency Number Association (EENA) Compendium 2020

Figure 8 PSAP Model 2

Model 3

Similarly to model 2, there are two levels. The difference is the role played by the independent organisations at PSAP level 1. Civilian call-takers will classify the call and make a parallel dispatch of the calls to EROs. In some cases, police, EROs' specialists are available to support the call-takers. The dispatch of the rescue intervention resources carried out by an ERO.

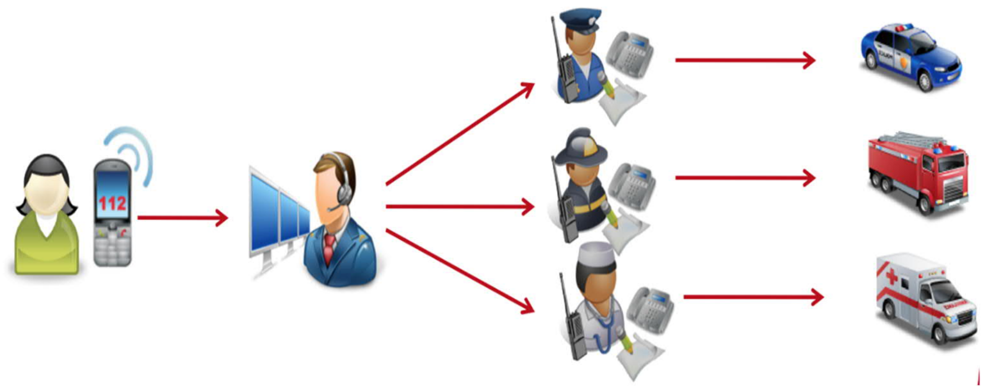


Figure 9: PSAP Model 3

Model 4

This model is also in two levels but the civilian call-takers and ERO are in the same place. Civilian call-takers oversee classifying the call and make a parallel dispatch of the calls to the most appropriate EROs if needed. In some cases, ERO specialists are available to support the call-takers. Dispatch of the intervention resources are carried out by the ERO. This architecture is used in Turkey.

Figure 10: PSAP Model 4

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Model 5

Civilian call-takers handle both call-taking and the dispatch of intervention resources. In some cases, ERO specialists are available to support. The same PSAP oversees classification of calls, data collection and dispatching the intervention resources to the incident. This system is operated in Romania.

Figure 11: PSAP Model 5

Model 6

PSAP from different regions can be interconnected. If no call taker is available, the call will then be redirected to another PSAP. This is an optimal architecture for a member state as the demand is constantly managed, thus allowing for a fast response from ERO.

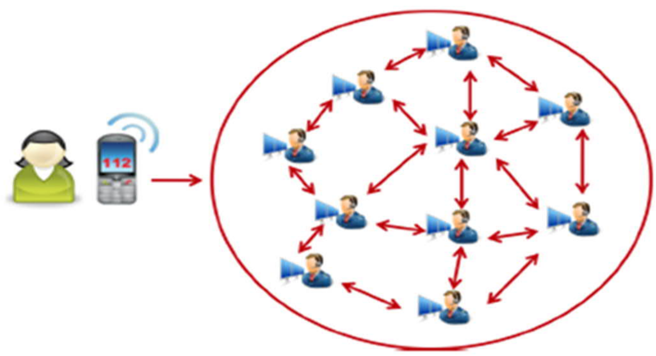


Figure 12: PSAP Model 6

6.4 Member state eCall implementation

With all member states having deployed 112 eCall, all PSAPs can receive both the voice and data content of an eCall. eCall for the first time has provided an automated geolocation of an event that requires a response from the emergency services.

As pressures on the emergency responders have increased throughout Europe, with increasing workload and reduced numbers, the role of the road authority in providing active assistance in the management of the scene of incident has become more important.

Hence the data contained within an eCall allows the road authority to provide advance notice to the road user of an incident up ahead, protect the scene during the rescue phase, and then manage the restoration of normality once the incident has been resolved.

The member states below who form part of the SHADAR study have been approached to detail how they process data generated from an eCall alert.

6.4.1 Denmark

Member State PSAP architecture

The use of 112 in Denmark is governed by the geo-location of the caller. There are two PSAP maintained by the National Police, one in the north of the country and one in the south. There is also a PSAP located in Copenhagen, which is operated by the Greater Copenhagen Fire Department.

All three locations now have the capability to receive and process eCall.

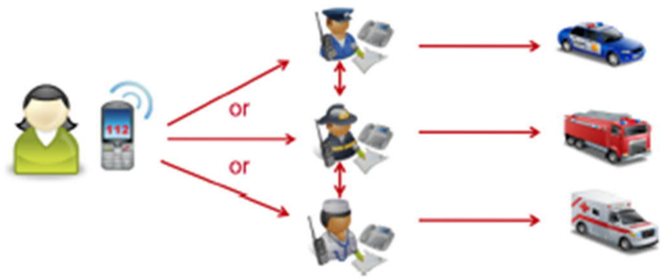


Figure 13 PSAP Architecture Denmark

Connection with Road Authorities

The Danish Road Directorate receives a data feed from the Danish National Emergency Centre. This data feed is integrated into the GEWI-provided TIC Incident Management System and is used as both incident generation and management.

6.4.2 Finland

Member State PSAP architecture

Finland maintains six PSAP located throughout the member state. Call takers are highly trained with a Diploma in Police Studies or ERC Operator (Call taker). Call-takers initiate tasks by giving them directly to field units, however, task support and task monitoring is separated from call taking.

Figure 14 PSAP Architecture Finland

Connection with Road Authorities

Data including the MSD is passed to the traffic control centres electronically, where it is processed, and the appropriate control measures activated.

6.4.3 **Germany**

Member State PSAP architecture

Germany is a federal republic consisting of 16 states which each have responsibility for immediate hazards. They oversee Emergency Medical Services (EMS), Fire and Rescue Services (FRS) and Police. Each state has its own legislation as well as its own organisation. As far as the organisation of FRS is concerned, the states make use of the existing local and regional authorities. Without exception, 112 calls are routed to the PSAPs operated by the fire brigade or rescue services. In total there are 263 PSAP in Germany all varying capabilities. 110-calls are received by the Police. Emergency calls are separately processed in these two kinds of emergency response and control centres. Requests for help in medical conditions are assessed for urgency:

• Medical service is processed in own competence

• Non-emergency medical requests are redirected into the health system

If necessary, emergency calls from the two areas (Police and non-Police) are transferred to the Emergency Medical Dispatch (EMD) and other rescue services. Control centres of Police and non-Police organisations cooperate. Germany uses a model like Model 1.

The operator asks the caller a set of questions according to a fixed pattern and then decides which rescue services must be deployed, for instance fire brigade, emergency physician, ambulance vehicle. In general, the operator is supported by a computer-aided operation control system. The fire brigade is alerted as soon as the operator that has received the emergency call has finalised the operational arrangements. Some of the German PSAPs are interconnected to exchange data, others are interconnected only via voice.

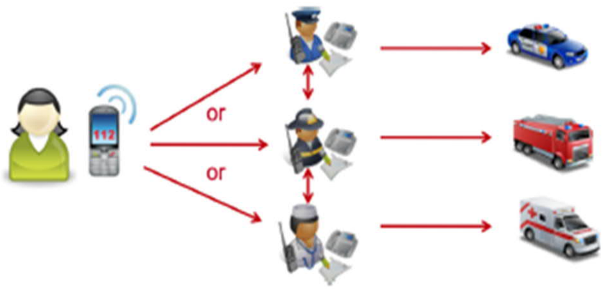


Figure 15 PSAP Architecture Germany

Connection with Road Authorities

Due to the unique circumstances of Germany, many PSAPs operate a cloud-based eCall solution provided by OECON. This system can receive and transmit data to the road authorities, which would emanate from an eCall activation. The data generated is passed to the Federal police who have a responsibility in managing incidents on the strategic road network.

6.4.4 **Ireland**

Member State PSAP architecture

The Emergency Call Answering Service (ECAS) is the stage 1 filtering PSAP service for Ireland; this service is operated by BT Ireland on a similar model to the UK. All Emergency calls and SMS are routed to the ECAS which in turn connects the caller to the requested stage 2 service: Police, Fire, Ambulance, and Coast Guard. PSAP are not interconnected.

Figure 16 PSAP Architecture Ireland

Connection with Road Authorities

There is no direct connection to the road authority currently

6.4.5 Netherlands

Member State PSAP architecture

The 112 calls are handled in one national stage 1 PSAP and a diminishing number of regional stage 1 PSAPs. The call-takers identify, validate, and locate the call and forward it to the applicable regional emergency organization (stage 2 PSAP). The process of the national stage 1 PSAP is executed on two locations and fully redundant. The national stage 1 PSAP is interconnected on a redundant dedicated digital network with 15 regional stage 2 PSAP for Fire and Rescue Services, EMS, and Police.

Figure 17 PSAP Architecture Netherlands

Connection with Road Authorities

No information on connection with road authorities was available.

6.4.6 United Kingdom

Member State PSAP architecture

The section of this report as well as England also covers Scotland, Wales, and Northern Ireland as a general overview. The 999 single emergency number system covers all these countries. The emergency services in the UK all have the same strategic bodies. In the management of eCall there are currently no specific differences in how eCall, whether eCall based on 999 or TPS eCall, are handled.

The UK PSAP has two levels. The Level 1 Public Safety Answering Point (PSAP) is provided by BT. BT provide this in a sub-contracted arrangement with the major mobile network providers; Three, EE and Vodafone pay BT for the provision of the service. The service provided by BT ensures that the mobile network providers discharge their liability to ensure that all 999/112 calls are transmitted to the emergency services free of charge to the caller. There are six call centres located across the United Kingdom. The centres do not receive 112/999 calls through geo-location, instead call taking is balanced, so that the 999 call goes to the next available call taker in one of the six centres.

Call volumes are in the region of 33 million calls per year, on average 98% of all calls are answered within 5 seconds. BT, in handling 999/112 calls, screens the calls, completes an initial call log, geo-locates the caller and then transfers the call and any data available to the first emergency service that the caller requests, at the level two PSAP.

999 eCall

BT declared itself ready to receive eCall in March 2018. Since that date BT have used a "Tactical Solution". This solution which has reduced functionality will remain in place until the new 999 system is operational, this should be in 2021, however this report understands that this has now been delayed due to COVID-19.

BT receives all eCall based on 999/112 at several dedicated positions located across the six 999 centres.

The 999 eCall is screened is the same way as any other 999 call, with the call being placed with the first emergency service that the caller requests, and the MSD data being made available via Enhanced Information Service for Emergency Calls (EISEC).

The first emergency service receiving the eCall is responsible for transferring the eCall data and the call to any other emergency service that may be required. Any data that is associated with the 999 call, or the eCall, is made available to the relevant emergency service via EISEC which is a data storage facility with a push /pull data transfer capability between BT and the emergency services.

The fields in EISEC are strictly defined and were originally designed to transmit eCall data only. The solution currently in place with BT cannot fully decode the MSD. Missing from the MSD will be the last two positions of the vehicle and the direction of travel for the vehicle.

The data is available in the system, it is just that BT cannot see it.

Private eCall (TPS eCall)

TPS eCall is generally a subscription service, paid for by the vehicle owner. The eCall is first routed via a service centre which can be in any country. Once the eCall is verified as genuine, the voice call and the data are transferred to BT. Currently there are no TPS eCall providers who have the capability to transfer the MSD data electronically from the TPS service centre to BT.

All data is transferred verbally, this has a significant impact on the level of time taken to transfer both the voice call, and the data associated with the emergency call. The average time to transfer a call and data is seven minutes per leg of the call.

Figure 18 PSAP Architecture UK

Connection with Road Authorities

There is no direct connection between the PSAP level 1 and Highways England Regional Operations Centres (ROC), nor their equivalents in other parts of UK. Contact is made via the regional police control centre to the ROC. This connection is via voice not data.

SHADAR consortium member Chiltech undertook a research project for Highways England (HeCall Project), in 2019. The resulting report illustrated a clear benefit in integrating eCall data with Highways England's operational systems and detailed the benefits when augmenting SVD on all-lane running motorways and when used on non-instrumented roads.

7 Reporting stopped vehicle alerts to operators

Highways England’s facilities are described here as an illustrative example.

For stopped vehicle detection monitoring on Highways England’s trunk road network, a web-based SVD alert management tool, the SVD Alerting Tool, has been developed. The tool uses modern web technologies to present users with a reactive web page displaying current and recently cleared alerts.

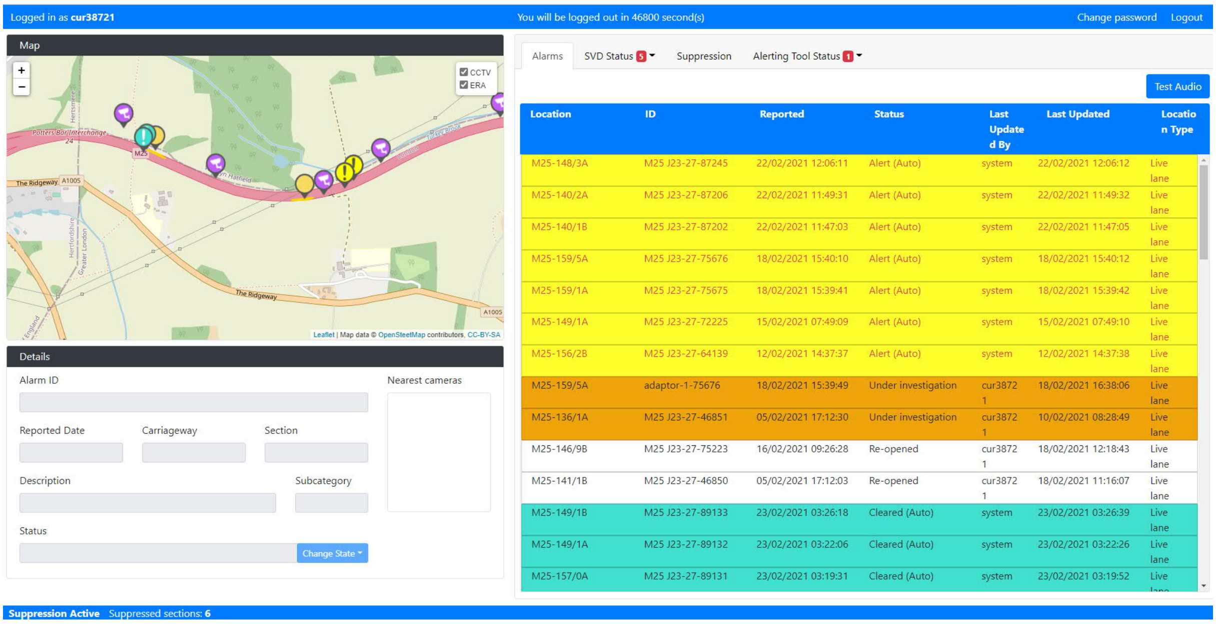


Figure:19 Highway England SVD Alerting Tool (source: Mott MacDonald)

Features

The SVD Alerting Tool gives operators the following features to help them promptly manage stopped vehicles:

- Audible alarms when a new stopped vehicle is detected and displayed on the user interface
- A list of nearest cameras to the stopped vehicle to improve response times in identifying the CCTV camera with best visibility of the stopped vehicle
- Distinction of live lane and emergency refuge area 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
- Health status information of the source SVD system, to help identify breaks in coverage or availability

Notifying the operator

Alerts originating from the source SVD system appear on a tabular and map-based display. New alerts are accompanied by an audible notification to attract attention if an operator is away from their workstation. Operators are also made aware of new alerts visually, through flashing rows on an alert list.

The tool described above is an interim solution between two generations of Highways England’s traffic management systems. The older generation of Highways England traffic management systems has similar functionality for presenting alert data, without a dedicated map. Operators have said that the addition of the map is a significant benefit. In the longer term the alerting will be fully integrated into Highways England’s newer generation of traffic management systems. In the fully integrated systems there are further features:

- Automatic suppression of alerts in queuing traffic conditions
- Automatic upstream sign setting

Response of the operator

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. Stopped vehicle operational response is more fully described in the companion report D3.1 “Current practices in response to stopped vehicles”, due for delivery in 2021.

8 Related technology – data fusion

This section briefly identifies the state-of-art of a technology that may be important in our subsequent research: data fusion. Although data fusion is not widely used for stopped vehicle detection by national roads authorities, it has been extensively researched for other traffic applications.

Multi-sensor data fusion aims to combine individual data to produce a result with increased accuracy, confidence and robustness, enhanced spatial or temporal coverage, or potentially lower cost. Traffic data fusion is seen as important because of the increasing quantity and quality of information derived from mobile devices while fixed detection infrastructure remains very expensive to install and maintain (Cornwell et al, 2016). Since the CEDR review of (Cornwell et al, 2016) there have been many further research works on traffic data fusion, and updated reviews of the field including El Faouzi and Klein (2016), Klein (2019), and most recently Cvetek et al (2021).

The CEDR review noted that despite dozens of projects there was still no clear consensus or standardization on approaches. It has been shown that accuracy can be improved by fusing data from fixed sensors with floating vehicle data, and that certain advanced methods have better accuracy than naive methods, but there is little or no published objective comparison of results of different advanced methods. It has also been shown that floating vehicle data and data fusion can reduce but not remove the need for fixed detectors. The choice of fusion method depends on the data sources available and the application. In 2016 an increasing focus was noted on traffic theory to fuse individual vehicle and detector measurements, with rule-based techniques becoming less frequent. In 2021, Cvetek et al noted an increasing focus on fusion through deep learning, which they expected due to the recent popularity of deep learning across many domains.

The CEDR review also noted that fusion for incident detection used two contrasting kinds of fusion: (i) fusing the raw data to improve a single detection process (ii) allowing multiple detection algorithms to reach a conclusion and then fusing their outputs. The subsequent fusion work identified in the 2021 review appeared to focus on traffic state estimation and did not directly inform the state-of-the-art for incident detection, where the most effective techniques are not yet known – a gap for further SHADAR project research to consider.

9 Conclusions

Stopped vehicles on live highway lanes appear to be a relatively common hazard, with Highways England recording over 40,000 annually due to breakdowns, and with much higher reported numbers of detected hazards to be investigated by operators.

Stopped vehicle detection equipment, systems, methods, or services can be characterised by several methods and metrics. Different kinds of detection each have different properties that affect performance, reliability, and life span. Important performance metrics that are widely used are: detection rate, false alarm rate and time-to-detect. Spatial coverage is also very important, with the average spatial coverage per detector determining the number of detectors and therefore the overall cost, which of course includes installation and maintenance.

There is an increasing number of stopped vehicle detection methods. One category depends on human sight and includes reporting by bystanders, social media and navigation applications, and traffic officers and road inspectors. Another category depends on fixed sensors (roadside or in-road), such as induction loops, cameras, radar, and LiDAR. A third category uses vehicle-based sensors, such as floating vehicle data, Cooperative ITS, and eCall.

Ideally a detection method should have high spatial coverage, high detection rate, low false alarm rate, low time-to-detect and high availability. Once in operation, the ideal method should have a long recurring maintenance interval, high availability of parts or components, high environmental independence and high privacy and security standards. However, the choice for procurement of an SVD method does not solely depend on these characteristics: it also depends on the budget available – not only for capital expenditure, but also for maintenance.

While traffic sensors such as widely spaced induction loops can infer the possibility of stopped vehicles, they usually have longer detection times and reliance on minimum flow levels because they usually detect the indirect effects on traffic. Although such systems can also detect vehicle signatures and therefore infer missing vehicles, that mode of operation has not become widespread in the decades since its invention, which may be an indicator of unsatisfactory performance. Floating vehicle service providers also provide indirect detection through effects on traffic. The methods with highest detection rates and shortest detection times rely on direct observation of the stopped vehicle.

Eight NRAs responded (Luxembourg, Netherlands, Austria, Belgium (Flanders), Ireland, England, Scotland, and Denmark) to our survey on use of detection methods. Almost all have multiple methods that rely on human sight, and multiple types of fixed sensors installed to detect stopped vehicles, although dedicated stopped vehicle detection on open highways is limited, with some coverage of radar and video analytics. Use of video analytics on traffic cameras is seen as attractive by road authorities because the cameras also perform other functions for traffic management, but there are concerns over its performance in unfavourable conditions. Detection through connected vehicles is less widely applied, although service providers offer relevant products as shown by responses from TomTom, BeMobile and INRIX. Notably, Waze is used operationally by several countries.

Highways England appears to have the most significant dedicated facilities for detecting stopped vehicles on open highways, so their approach may be instructive for other roads authorities. Highways England has performed various trials of various technologies. It has completed extensive operational pilots of a rotating radar solution and is in the process of deploying this solution to a large proportion of the motorway network where there is no hard shoulder. Success of trials of a camera-based solution with machine learning have also led to Highways England procuring this technology for further potential deployment. Detected stopped vehicle events are raised as alerts to operators in Highways England’s control centres, with aids for prompt verification by CCTV camera.

Despite trials and some operational use of dedicated stopped vehicle detection, published evaluation data for this technology is limited. Further study of the performance of multiple technologies with reliable ground truth from human observation would be expensive but would clarify the benefits of further uptake.

Although eCall is mandatory across Europe, awareness is low, and only 3 countries (of those considered) use the associated data in their NRA’s traffic operations. eCall may not provide perfect overage on its own, but combined with other methods it presents an opportunity for the other NRAs to improve detection. The low awareness of eCall suggests a need for education.

Although this report focussed on the current state-of-art of stopped vehicle detection methods, the technology of data fusion appears to offer the potential to increase stopped vehicle detection performance by combining two or more of the many available methods, and this will be considered further in our subsequent research.

Appendix A Recent trials of optical detection in England

Several organisations have researched or developed incident detection capability based on video analytics; a solution that has been applied directly to stopped vehicle detection on open carriageways as well as tunnels is the technology from Vivacity Labs.

One trial (in Southwick Tunnel, England) used Vivacity's own camera sensors as well as their detection analytics, while a trial on the open highway used the analytics with existing traffic cameras of Highways England, in a systems integration provided by the supplier Costain.

Trial on open highways

The Video Analytics Service Platform (VASP) used video analytics on existing CCTV feeds to detect and classify incidents (Costain, 2020). 32 CCTV video feeds were selected to be analysed during the trial period and a dashboard at the Regional Operation Centre (ROC) displayed alerts related to events detected by the VASP.

The figure shows the system architecture, which is instructive in identifying the kinds of components required in such a solution.

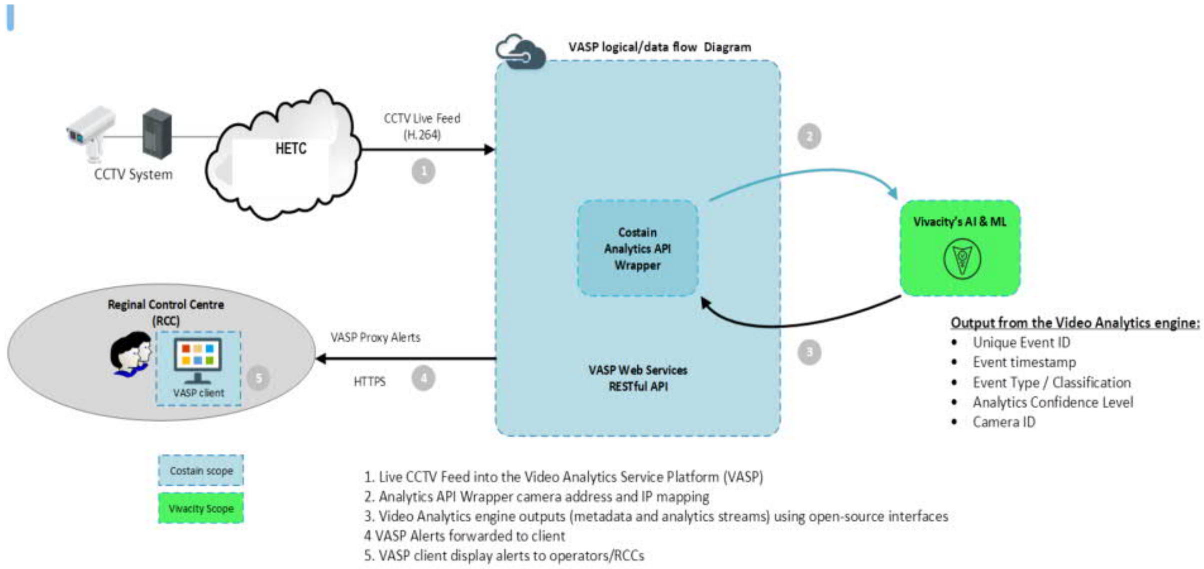


Figure 20 System architecture of VASP stopped vehicle detection trial system

HETC: Existing Highways England Traffic Cameras (HETC) system which provides access to most of the cameras on the network and does not require any additional hardware to be set up for accessing the streams.

Vivacity's Analytics Engine: The analytics engine performs video analytics on video streams to detect the agreed-upon events. On detection of these events, it will raise alerts to VASP and clear them as appropriate.

VASP Application: Coordinates. Passes video stream URLs to the analytics engine, manages and prioritises the analytics from each camera by making a start and stop API endpoints call on the analytics engine. That will be achieved by providing API endpoints for raising and clearing of alerts. Serves the interface that displays alerts to the operator.

VASP Client: User interface that displays alerts detected and raised by the VASP system. Displayed on a web page on a desktop PC located in the ROC or on one of the videowall monitors.

The video analytics engine can calculate speed, occupancy, traffic flow, stopped vehicle detection, and an indication of whether the camera has moved, from each CCTV feed, and provide live alerts when certain threshold conditions are met.

To estimate the speed of each vehicle as it travels through the camera's field of view, a GPS-based perspective transform maps points within the camera view into a real-world latitude/longitude reference frame. An average speed per zone is reported, allowing alerts to be set based on speed thresholds.

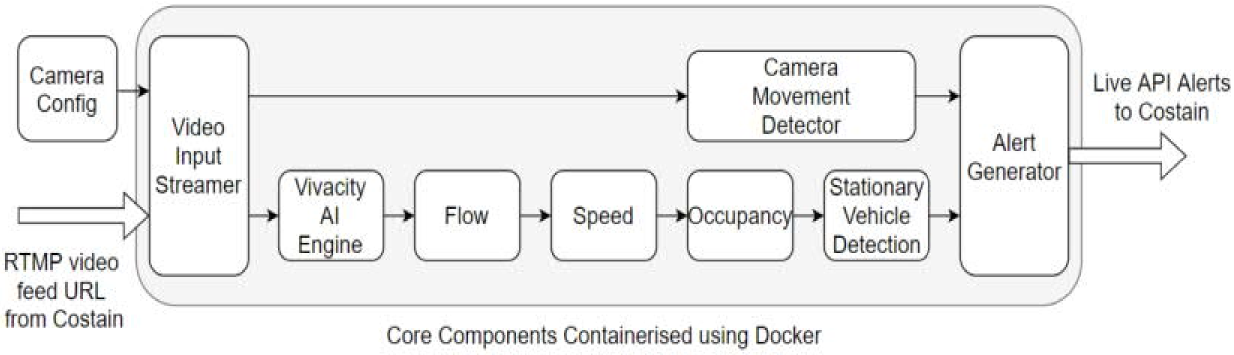
Occupancy is measured through the number of vehicles detected within each zone at any given moment in time. This is averaged across time to derive an average occupancy for each zone. Occupancy zones can also be configured in emergency refuge areas where any object detection in this region triggers an alert.

The stopped vehicle detection alert is derived from the above metrics with appropriate filtering logic to indicate the presence of a stationary vehicle in any given zone.

The video analytics engine analyses the current images being received from the CCTV feed and checks if the video feed has moved from the pre-set position. If above a certain threshold is measured, a "moved camera" alert is triggered. After this, no subsequent alerts will be sent until the moved camera alert is cleared by the camera returning to the pre-set view.

The alerts dashboard presents stationary vehicle alerts and other incidents detected in two separate columns.

The system architectural flow diagram below indicates the process that takes place from the video capture to the end receiver alert.



Performance results

Performance evaluation distinguished three different cases:

1. **True Positive**: where the cause of the alert was clearly visible in the video and was verified as genuine.
2. **False Positive**: where the system triggered the alert incorrectly.
3. **External Issues**: where external technical issues with the CCTV stream may have caused the alert to be triggered.

The system showed 93.7% accuracy for stopped vehicle alerts of which 57.7% were vehicles stopped in emergency refuge areas, 6% were vehicles stopped on a dynamic hard shoulder, 19.1% were vehicles stopped on conventional hard shoulder, 3.7% were individual vehicles stopped in live lanes and 13.6% were stopped road maintenance vehicles.

Regarding the false positive alerts, it was identified that these were caused due to the following categories:

- Sun glare, lens flare and shadows
- Water or dirt on the camera lens
- Lights and reflective markings
- Road markings and water patches

True positive example

False positive example

Additional limitations recorded during the trial were:

- Blank, faulty or inaccessible video feeds
- Existing camera feed URL switching to a different camera
- Intermittent loss of video
- Repeated identical frames
- Corrupted video frames
- Video quality dropping to low frame rate

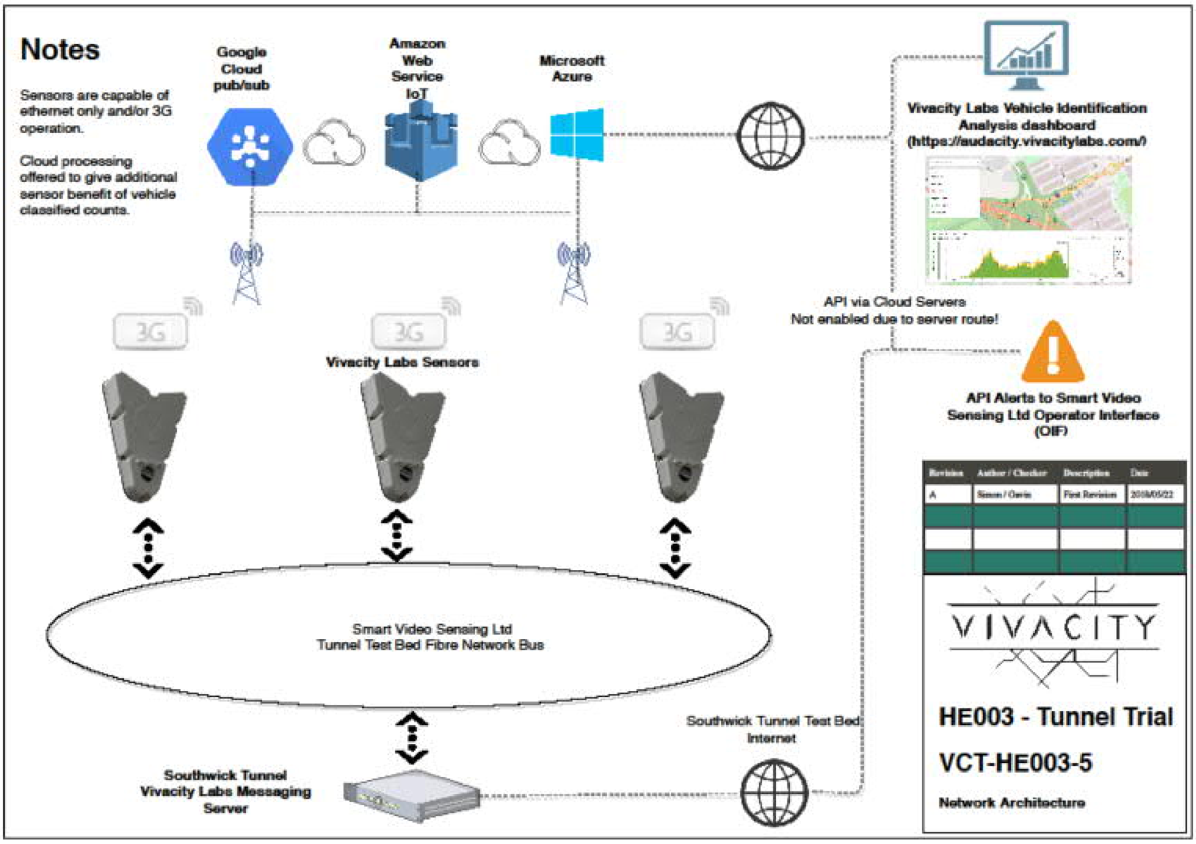
Feedback received from the traffic operations centre mentioned that the application is simple and functional and provides clearly displayed information that operations can utilise. Performance was less effective on PTZ cameras than fixed cameras due to wind affecting the home positions of the former.

Tunnel trial with dedicated video equipment

A separate trial (Bradford, 2019) using the Vivacity video analytics technology for stopped vehicle detection took place at the Southwick Hill Tunnel which is a 490-metre twin-bore road tunnel in Shoreham-by-Sea, West Sussex, England. Four Vivacity V-City detector units were installed, co-located with independent fixed cameras for verification for the trial only.

The Vivacity system uses a special CCTV camera-based detector unit with artificial intelligence techniques to understand road transport movement, including the detection of stopped vehicles, slow moving, wrong way and congestion. Vivacity's traffic sensors detect, classify and track vehicles within a field of view. The software identifies instances of vehicles (and pedestrians) and their location within the field of view, then classifies these, and tracks instances from frame to frame. If a vehicle stops in the tunnel in a zone that has not been designated as a parking area, but is not blocked by another vehicle in front of it (as would be the case in congestion), this can be flagged as either a breakdown or collision.

A system architecture overview is provided below.



The system ran in an evaluation period from February to June 2019, after a period for machine learning and tuning.

The Vivacity system was evaluated against its ability to capture slow vehicles, stopped vehicles and wrong direction vehicles. Detection was required within 120 seconds. The results reported are as follows:

Incidents correctly detected	187
Incidents missed	1
False alarms	0

This represents a detection rate of 99.5%, false alarm rate of 0%.

Appendix B Survey questions

Background information

This task will collect and review **current practices** of a group of European NRAs incident management operations, stopped vehicle detection *methods* and their *impact on risk of collisions events*.

This will include identification of **how stopped vehicle alerts are reported to operators** through *computer user interface features* or *other means*.

We will identify **whether any data fusion is used** for stopped vehicle *detection* or *validation* in the surveyed operations.

Research topics

- Current vehicle detection methods
- Operation of each method
- Stopped vehicle alerts reporting
- Stopped vehicle alerts verification
- Pros and cons of each method
- Future stopped vehicle detection methods

Estimated time necessary to answer the questions

It takes approximately 1-2 hours to answer the questions if the respondent(s) knows / has access to the necessary data to answer the questions. Below you can find an estimation for each topic:

Topic	Estimated time
1. Current vehicle detection methods	< 5 minutes
2. Operation of each method	15 minutes for each method
3. Stopped vehicle alerts reporting	20 minutes
4. Stopped vehicle alerts verification	< 10 minutes
5. Pros and cons of each method	20 minutes for each method
6. Future stopped vehicle detection methods	If applicable, 20 minutes

Topic	Survey Question
1. Current vehicle detection methods	1. What kind of stopped vehicle detection methods does your organisation have?
	2. Can you roughly estimate how many percent of the highway network is covered by each method individually?
2. Working of each method	1. Could you please describe the process step by step from detection of a stopped vehicle to the response?
	2. What is the source(s) of detection (e.g. inductive detector loops / radar / a combination)? Also 112 call, dedicated emergency phone, eCall?
	3. What kind of hardware (e.g. road(side) systems) is used?
	4. What kind of software (e.g. video analytics) is used?
	5. How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? Is a common data standard used?
3. Stopped vehicle alerts reporting	10. To whom (and/or which automated system) are alerts reported?
	11. How are alerts reported (e.g. visual or audible)? If you receive eCall messages are they voice and/or data?
	12. What kind of information is being shared with receivers (e.g. operational staff or automated response systems)?

	13. In which format is information being shared with receivers (e.g. operational staff or automated response systems)?
	14. Which information about stopped vehicle alerts are logged by the receivers (e.g. operational staff or automated response systems) and in what kind of system?
4. Stopped vehicle alerts verification	1. How are stopped vehicle alerts verified (e.g. what is the process, what is the architecture & is data fusion used)?
5. Pros and cons of each method	1. What are in your opinion the most important benefits of each method? (e.g. less collision risks (safer), cheap, always functioning, reliability)
	2. What are in your opinion the biggest shortcomings of each method? (e.g. expensive, not functioning in specific weather conditions)
	3. Have you researched the impact of stopped vehicle detection methods on the risk of collision events? If yes, could you please share the results/report(s)?
	4. Could you (roughly) estimate both operational and implementing costs of each method?
	5. If two or more methods are used: Which method do you consider most valuable and why (e.g. on which aspect)?
6. Future stopped vehicle detection methods	1. What kind of other/new stopped vehicle detection technologies/methods is your organisation interested in? Are you aware of eCall?
	2. Is your organisation involved in the development of new detection technologies/methods? - Which technologies/methods? - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? - How would you describe the current state-of-the-art of this technology/method? - (When) do you expect to implement this technology/method?

In addition, SHADAR will also look into detection rate, mean time to detect, and false alarm rate. Therefore, we are interested in any research that considered detection performance. If any results or reports are available, could you please share these?

For our analysis we are also interested in logfiles about stopped vehicle alerts and follow up actions. If possible, we would really appreciate it if you could send us the logfiles of the year 2019.

Appendix C Survey Q&A

The following are either transcriptions of conversations or direct written responses from the roads authority and service provider representatives.

In a small number of cases, further information to supplement these answers was provided after the initial survey and has been included in section 5 of the main body of this report.

Results survey questions		Luxembourg	Netherlands	Austria
		Adminsitration des ponts et chaussées / National Road Administration	Coordineren/specialisisch adviseur Verkeersmanagement & Smart Mobility	ASFINAG
		07/01/2021		21/01/2021
	Question	Answer	Answer	Answer
1.1	What kind of stopped vehicle detection methods does your organisation have?	The motorways (+/-170km) of Luxembourg are covered up to 80% with video surveillance (CCTV) (24/7 CITA-surveillance team, cf. www.cita.lu) and the main tunnels of the motorways are equipped with 100% standstill detection devices (video analysis and some thermal cameras). For the motorways the detection is mostly done via detection via phone from either from police, emergency call center, private calls, emergency phones or the teams on the road and is than verified by the CITA-operators via the cameras and the informatic tools (such as traffic conditions, Waze, ...)	1) Loop detection at rush-hour lanes, among others, 2) Loop detection in Tunnels 3) Proof of Concept with AI and CCTV cameras 4) Probe vehicle data 5) Social media like Waze data in the front ofice 6) Ecall alerts (via 112, also cellphone alerts, and private)	In Tunnels: loop detection in breakdwon bays; video detection whole tunnel (camera distance 125 - 250m); noise dection system (indirect dection of stopped vehicle: AKUT -acoustic detection in tunnels: detection of anomalies within noise of the tunnel. For example crash, tyre burst, door banging, ...); pilotsite with dual camera (visual and infrared-thermic) Open land (outside tunnel): video detction pilots in one conurbation and within one projekt of hard shoulder running
1.2	Can you roughly estimate how many percent of the highway network is covered by each method individually?	cf. 1.1	1) Loop detection at rush hour lanes, 360km 2) Loop detection on tunnels, all tunnels 3) Proof of Concept cov AI and CCTV cameras, 5km 4) Probe vehicle data, national roads in NL 5) Social media as Waze data in the front office, national highways in NL.	at the moment: ca. 11% of the network equiped with automated detection systems: Total length of Network: 2249 km; Length of Tunnel detection: ca. 200 km; dection Pilots in open land: 50 km;
2.1	Could you please describe the process step by step from detection of a stopped vehicle to the response?	Detection (video surveillance, call, ...) reaches the CITA control center, operator checks video cameras and informatic tools, if security problem, alerts the police/emergency call center, and alerts the NRA traffic officers/response team, which will drive to the incident, regulate the traffic, secure the vehicle and in case eliminate the damage to the infrastructure. If there are variable message signs on the concerned section of the motorway, users are informed about the presence of the stopped vehicle. In tunnels, the lane in which the stopped vehicle is located is blocked. Otherways, the motorway users are informed by radio messages, RDS-TMC or via the national access point.	Too detailed to describe here, RWS has very comprehensive specifications for this.	Stop vehicle is detected by video detectionssystem, incident is reported to scada in control room, 3 different cameras automatically switch on the video wall, acoustic sound and alarm message is reported in scada system. Operator is inspecting the incident and depends, close the tunnel, switch flashing lights, public address announcement, radio announcement. (when a vehilce stand in the breakdown bays, traffic lights flashing yellow); AKUT: acustic detection of a nois anomalies by AKUT, reported to scada in control room, 3 different cameras automatically switch on the video wall, acoustic sound and alarm message is reported in scada system. Operator is inspecting the incident and depends, close the tunnel, switch flashing lights, public address announcement, radio announcement.
2.2	What is the source(s) of detection (e.g. inductive detector loops / radar / a combination)? Also 112 call, dedicated emergency phone, eCall?	Sources are mainly 112 call, 113 call (police call center), ACL (automobile club), intervention teams on the road, private calls, The whole motorway is equipped with different traffic equipements (detector loops, radar, etc.), but a detection of a single stopped vehicle by these equipements is rather difficult, if there is no traffic jam Automated detection via cameras in motorway tunnels	I-WKS, WKS, HD CCTV, fibre optics, computer service with AI in the traffic centre, etc.	In tunnel video detection, on portal and breakdown bays loops (Induktionsschleifen), only few kilometer radar and thermal camera (only few tunnels und test highway).
2.3	What kind of hardware (e.g. road(side) systems) is used?	Two différent types of systems are used: 1) Dedicated microcontroler processing cards, which are processing black and white video streams 2) Standard x86 Servers	I-WKS, WKS, HD CCTV, fibre optics, computer service with AI in the traffic centre, etc.	video camera, (Thermal cameras, dual cameras in few tunnels), server infrastructure, inductive loops, microphones
2.4	What kind of software (e.g. video analytics) is used?	Dedicated video analytics software	Machine learining, Artificial Inteligence, background detection	video analystics: Algoritm for detecting stopped vehicle (zone detection), slow vehicle, traffic jam, wrong way driver. OS windows and linux, Flir Software.
2.5	How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? Is a common data standard used?	Both systems make picture comparison with pixel contrast change measurement Blackbox system, as far as we know, no common data standard is used	Very detailed question, see specifications	video picture/pixel detection; analysis of noise pattern; no sensor fusion in full operations; pilots for sensor fusion in tunnel
3.1	To whom (and/or which automated system) are alerts reported?	To the traffic control center operators by the traffic management system	to the road traffic controllers in the traffic centres	To operator in traffic management center
3.2	How are alerts reported (e.g. visual or audible)? If you receive eCall messages are they voice and/or data?	eCall messages aren't sent to the NRA/CITA dispatching, but go directly to the national emergency call center. It seems that eCalls constitue a very few part of the detected incidents.	visual, data (gong announcement in traffic centre has been terminated, too many announcements and also false announcements)	visual and/or audible (configurable); no ecall from vehicle implemented yet to road operator (just to rescue service); if detection in breakdown bay: alarm using data, video is displays on TMC video wall automatically, voice connection automatically established
3.3	What kind of information is being shared with receivers (e.g. operational staff or automated response systems)?	mainly location, direction on the motorway (or other road), type and description of incident, type of vehicles and amount of persons involved and hurt, damage to the infrastructure, estimated time for the evacuation of the incident	This is shared in advance in the operational process of traffic centres, i.e. to the road traffic controllers, and possibly to the road inspectors. Incidents are also shared with service providers via NDW.	kind alarm of (stopped vehicle, slow vehicle, wrong way driver) with concrete position; information is shared with operational staff and used for semi-automated measures
3.4	In which format is information being shared with receivers (e.g. operational staff or automated response systems)?	at the moment mainly via phone, a solution via text messages is in pre	Via a user interface in the front office, or at the tunnel desk or other workstation present in the traffic centre associated with the notification.	visual and / or audible alerts; video display on video wall and control system (scada)
3.5	Which information about stopped vehicle alerts are logged by the receivers (e.g. operational staff or automated response systems) and in what kind of system?	mainly location, direction on the motorway (or other road), type and description of incident, type of vehicles and amount of persons involved and hurt, damage to the infrastructure, estimated time for the evacuation of the incident, time of call, time of alert of other respons teams, evolution of the incident, until elimination of all damage and reopening of the road, VMS activations	Logging is done in various systems, from tunnels or in the uniform dry logging system	date, time, position, kind of event, short videostream; Maintenance log in scada, video storage
4.1	How are stopped vehicle alerts verified (e.g. what is the process, what is the architecture & is data fusion used)?	every alert (call) is verified via video surveillance, if no detection possible and traffic safety is in cause (danger for the persons involved or the other road users, f.e. lane blocked), an NRA intervention team is send out to check the incident in situ	Usually by road traffic controller using camera images in the traffic centre, or aditional information sources.	manual verification by operator in TMC using video cameras
5.1	What are in your opinion the most important benefits of each method? (e.g. less collision risks (safer), cheap, always functioning, reliability)	reduction of collision risk, carry the involved persons (in danger) into security, reduction of supplementary traffic jams	safety and efficiency (automatic detection with smart cameras, fewer FTEs needed in traffic centre)	infrastructure for video detection in tunnel is already available and necessary for monitoring, not a lot of additional equipment for automated detection required; differences of quality (detection rate, rate of false alarms) within the different methods (video, noise, loop)
5.2	What are in your opinion the biggest shortcomings of each method? (e.g. expensive, not functioning in specific weather conditions)		too much detail	video detection in tunnel: cost benefit because hardware necessary for monitoring; outside tunnels: problems with video dection: For bad weather conditions (portal fogg; snow form outside in the tunnel, snow/ice from trucks), there are additional moisture sensors necessary (differences for dry and wet road surface). The light should always be evenly, problems with different weather situations and day/night; noise pattern recognition only in tunnel available; loop detectors: good quality outside tunnels, expensive in deployment and maintenance
5.3	Have you researched the impact of stopped vehicle detection methods on the risk of collision events? If yes, could you please share the results/report(s)?	No detailed analysis available	this requires some more searching, but is available	no detailed resarch results concernig the impact of detection methods to the risk of collision events.
5.4	Could you (roughly) estimate both operational and implementing costs of each method?	N/A		-
5.5	If two or more methods are used: Which method do you consider most valuable and why (e.g. on which aspect)?	N/A	?	the combination of different methods gives the best result (loop, video, noise); at the moment video detection is more used then noise pattern recognition (due to avalaible camera infrastructure for traffic monitoring); in the future noice will also be equiped during tunnel renewing
6.1	What kind of other/new stopped vehicle detection technologies/methods is your organisation interested in? Are you aware of eCall?	cf. 3.2 The actual systems cover the most ot the motorways. There some initiatives to use automated technologies furthermore.	AI, yes we are familiar with ecall (see 1)	C-ITS technology will be deployed during the next years; All possibilities to increase detection rate is interesting (part of incident management), especially outside tunnels; Sensor fuison is important topic; Ecall data are important, we are aware of it and it will be deployed in the next years; The cost / benefit relation is very important
6.2	Is your organisation involved in the development of new detection technologies/methods? - Which technologies/methods? - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? - How would you describe the current state-of-the-art of this technology/method? - (When) do you expect to implement this technology/method?	NRA is an process to develop in order to replace the core of the traffic management system of CITA. In this process all the functions are going to be revised and it will be possible in the futur to add new technologies and methods.	Yes including AI at rush hour lanes and incident management	- Which technologies/methods? LiDAR (technology evaluation) AKUT (acustic detection in tunnels; indirect) CAM detection (corporate awareness messages) - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? sensor fusion is tested in one tunnel; one pilot also in open area - How would you describe the current state-of-the-art of this technology/method? (When) do you expect to implement this technology/method? LIDAR: research project AKUT: in operation, unde deployment C-ITS: will be deployed in the next year, start 2021 Sensor fusion will be a central part to optimize detection rate

CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

Results survey questions		Belgium (Flanders)	Ireland	Ireland
		AWV - Verkeerscentrum	M50 Concession Ltd	Egis Lagan Services
		05/01/2021	20/01/2021	19/01/2021
	Question	Answer	Answer	Answer
1.1	What kind of stopped vehicle detection methods does your organisation have?	in operation: AID-camaras, cctv PTZ, Waze, Police. under investigation/in developement: algorithms based on induction loops, SRTI, enhanced image recognition based on AI	On the M50 Project Road, stopped vehicle detection is via CCTV and also identified via automatic detection loops(ADL) in the wearing course. These are monitored by the Motorway Traffic Control Center. Detection methods also include route patrolling and 3rd party reporting from relevant stakeholders including public in general and blue-light services. (Note that ADL's do not detect an inividual vehicle stationary on the carriageway, only resulting traffic queing)	On the primary motorway networks, stopped vehicle detection is via route patrolling and 3rd party reporting from relevant stakeholders including blue-light services. Within the 3 high speed road tunnels in the country, stopped vehicles are identified via loop based detection and CCTV monitoring.
1.2	Can you roughly estimate how many percent of the highway network is covered by each method individually?	AID-cameras: Antwerp ring road, Brussels ring road, tunnels (total: < 10%), CCTV: 20%-25%, Loops: 20%, Police&Waze: 100%	The M50 Project Road is 100% covered by ADL and approx 98% by CCTV(limited parts of the road are not able to be viewed by CCTV). One set of cameras is managed by TII and the cameras managed and monitored in the MTCC and there are cameras that are managed and monitored by Dublin City Council. Both parties have access to each others cameras.	Loop based detection <1% (tunnels). Patrolling and stakeholder reporting >99% on the southern high speed road network.
2.1	Could you please describe the process step by step from detection of a stopped vehicle to the response?	operator gets 'alarm' of possible event (e.g. camera-detection, Waze notification, notification by Police officer, ...) and tries to verify with other means (e.g. camera's, police, ...), If event is true, activate red cross on lane signalling (if applicable), notify police-officer (liaison present 24/7 on operator room) who will further notify emergency services, put event into system, resulting in automatically included in traffic information stream (Datex-II, website, RDS-TMC) and automatically proposed VMS message	On the identification of a stopped vehicle on the high speed network, the incident will be reported to the Motorway Traffic Control Centre. The M50 Incident response vehicle will be contacted and will attend the location. The Garda will be informed also who will attend and manage the closure/diversion. The M50 Vehicle Recovery will be called to remove the vehicle.	On the identification of a stopped vehicle on the high speed network, the incident will be reported to the Motorway Traffic Control Centre. The road O&M contractor will protect the stopped vehicle by placing 3 consecutive rows of traffic cones 25metres apart to the rear of the vehicle. The owner of the vehicle will organise the removal of their vehicle typically through their insurance provider. The road contractors are not legally empowered to remove the vehicle. Only the police and the Local Authority (County Councils) are authorised to instruct the removal of the vehicle.
2.2	What is the source(s) of detection (e.g. inductive detector loops / radar / a combination)? Also 112 call, dedicated emergency phone, eCall?	see 1.1, Depending on which source(s) produce first alarm(s)	Sources of detection are by a call from the public (either to emergency services, to the M50 free phone number, to the MTCC number) and then a call is placed to MTCC to manage the response from their end. The network is also equipped with emergency roadside telephones. This connects the stranded motorist to the MTCC. The MTCC will provide safety information to the driver to stay behind the barrier etc. Alternatively, the ADL may inicate queing due to stopped vehicle at the MTCC and the control room operator will use the CCTV to observe and identify is a stopped vehicle is the issue. Alternatevely, a patrol driver or member of staff may observe the stopped vehicle and will contact the Motorway Traffic Control Centre (MTCC) via telephone to advise.	The route patroller will contact the Motorway Traffic Control Centre (MTCC) via telephone to advise of an abandoned vehicle on high speed network. The network is also equipped with emergency roadside telephones. This connects the stranded motorist to the MTCC. The MTCC will provide safety information to the driver to stay behind the barrier etc and also offer local recovery service contact information should the driver wish to avail of this.
2.3	What kind of hardware (e.g. road(side) systems) is used?	see 1.1, Depending on which source(s) are available on the specific spot	CCTV cameras, ADL, Emergency roadside telephone.	Emergency roadside telephone.
2.4	What kind of software (e.g. video analytics) is used?	AID-Cameras: video analytics (FLIR). Other: own developments	M50CL have access to the CCTV images from MTCC and Dublin City Council	Not applicable on the southern motorway and high speed dual carriageway network.
2.5	How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? Is a common data standard used?	Data fusion is not yet being used, but it is cuurently unther investigation. Every system has its own ettings (predifined trigger points). No intergration between systems yet.	We cannot provide that information as the ITS systems are not operated by M50CL	Not applicable on the southern motorway and high speed dual carriageway network.
3.1	To whom (and/or which automated system) are alerts reported?	Police liaison officer present in the operator room + Own developed central traffic information system	Alerts are reported to the MTCC based at the Dublin Tunnel.	Alerts are reported to the MTCC based at the Dublin Tunnel.
3.2	How are alerts reported (e.g. visual or audible)? If you receive eCall messages are they voice and/or data?	depending on the source: camera, Waze are visual, Police (including e-call through Police) is audio	Alerts are reported to the Incident Support Unit by telephone and an email is sent to all parties with updates sent as the incident progresses. We cannot provide information on how the ITS systems alert the MTCC operator as these are not operated by M50CL. We don't receive eCall messages and we cannot tell if the MTCC receives them.	eCall is offered through certain vehicle retailers, but is not part of the publicly provided network management system. All emergency telephones are channelled through the MTCC.
3.3	What kind of information is being shared with receivers (e.g. operational staff or automated response systems)?	verified alarms (true events) are put into central system and therefore shared (open data). Non verified alarms could be shared with police (possible verification on site). Communication with emergency services trough police liaison officer	Email with Unique Reference from MTCC, Time, Date and person issuing the notification. The Road ID, Carriageway Direction and Location and status of the carriageway. Incident Type/nature and the name of the caller reporting and the category of the incident 1-4. Type: The nature of the incident, including how many vehicles, buildings and so on are involved, Hazards: Both present and potential, Access: Best route for emergency services to access the site, or obstructions and bottlenecks to avoid. Numbers: Numbers of casualties, dead and uninjured on scene Emergency services: Which services are already on scene, and which others are required	ETHANE - Exact location: The precise location of the incident, Type: The nature of the incident, including how many vehicles, buildings and so on are involved, Hazards: Both present and potential, Access: Best route for emergency services to access the site, or obstructions and bottlenecks to avoid. Numbers: Numbers of casualties, dead and uninjured on scene Emergency services: Which services are already on scene, and which others are required
3.4	In which format is information being shared with receivers (e.g. operational staff or automated response systems)?	see 2.1	The M50CL incident support are being communicated to be mobile phone. All interested parties are being emailed with the details of the incident.	ETHANE - Exact location: The precise location of the incident, Type: The nature of the incident, including how many vehicles, buildings and so on are involved, Hazards: Both present and potential, Access: Best route for emergency services to access the site, or obstructions and bottlenecks to avoid. Numbers: Numbers of casualties, dead and uninjured on scene Emergency services: Which services are already on scene, and which others are required
3.5	Which information about stopped vehicle alerts are logged by the receivers (e.g. operational staff or automated response systems) and in what kind of system?	verified alarms (true events) are logged as all traffic information output is logged. No systematic logging of non-verified alarms	A log of all incidents which will include stopped vehicles is kept and reported to the client monthly. We use the RMMS system to log them and report them	Location, vehicle description and registration.
4.1	How are stopped vehicle alerts verified (e.g. what is the process, what is the architecture & is data fusion used)?	see 2.1	Information is confirmed verbally from Incident Support Unit drivers on site to the MTCC contact centre personnel.	Information is confirmed verbally from route patrollers to the MTCC contact centre personnel.
5.1	What are in your opinion the most important benefits of each method? (e.g. less collision risks (safer), cheap, always functioning, reliability)	camera detection: pro: immidiate verification possible (video), con: amount of false alarms due to meteo, light and traffic conditions. Police: pro: reliable, con: latency. Waze: pro: cheap and wide coverage, con: reliability (especially unsubscribe incidents) Loop detectors are less weather dependent, but have not (always) visuals.	Multiple ways of detection to reduce risk of reliance on just one. Besides, once the accident is detected the response is quick to make the place safe (e.g. average response times from our ISU are less that 12 minutes)	The primary measure is to ensure visibility of the vehicle for approaching motorists and therefore to increase the advance warning with the placement of traffic cones to the rear of the vehicle.
5.2	What are in your opinion the biggest shortcomings of each method? (e.g. expensive, not functioning in specific weather conditions)	see 5.1	None of the methods or systems currently in place in the M50 allow for an automatic and real time detection of the vehicle stopped on the carriageway. This can lead to relevent delays in detection depending on the circunstances (e.g. Fatal accident on 11/11/2015, see LA16 report attached and article on the subsequent investigation https://www.irishtimes.com/news/crime-and-law/courts/criminal-court/driver-who-caused-woman-s-death-on-m50-gets-suspended-sentence-1.3762842 : A car broke very down on lane 1 early in the morning with heavy rain and was undetected by all the methods for 17 minutes until the fatal collision took place). Secondly, once the vehicle stopped is detected, none of the current methods allow for an inmediate and effective advance warning and messaging to the road user of an incident ahead, until the ISU or the mergency services arrive onsite	The biggest shortcomings are the inability of the client or the road contractors to be legally entitled to remove vehicles from the network, unless this is instructed by the police or local authority.
5.3	Have you researched the impact of stopped vehicle detection methods on the risk of collision events? If yes, could you please share the results/report(s)?	no	No research carried out by M50CL	We have quantified the frequency of hard shoulder collisions however this has not been formally researched. Regrettably there have been fatalities arising from collisions between stationery vehicles on the hard shoulder and approaching vehicles that veered off the lane 1 carriageway.
5.4	Could you (roughly) estimate both operational and implementing costs of each method?		As we are only responsible for a portion of the whole activities involved in each method we cannot provide cost estimations for them	
5.5	If two or more methods are used: Which method do you consider most valuable and why (e.g. on which aspect)?	ideally a detector that has a broad coverage and is more or less weather independent, combined with the actual traffic state (filter out stopped vehicles in congestion) and some kind of (visual) verification	CCTV detection in combination with ADL is the most valuable as cameras are monitored 24/7 and if a call is received the cameras can identify location quickly and direct the response.	The primary method of detection is via route patrolling. This is effective as it can provide human assistance to the stranded driver, and enables the installation of safety measures at the same time (placement of warning cones).
6.1	What kind of other/new stopped vehicle detection technologies/methods is your organisation interested in? Are you aware of eCall?	E-call information is provides through police in tuch with e-call response operator rooms. Currently looking at SRTI (including e-call), investigatiing loop detection and data fusion	Our major shareholder, Globalvia, is involved in the research and develoment of a solution based on intelligent road studs (see below details). Regarding ecall, yes, we are aware of eCAll	There are a number of phone applications available with e-call, but they are not widely used.
6.2	Is your organisation involved in the development of new detection technologies/methods? - Which technologies/methods? - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? - How would you describe the current state-of-the-art of this technology/method? - (When) do you expect to implement this technology/method?	Currently under investigation/in developement: algorithms based on induction loops, SRTI, enhanced image recognition based on AI and looking at data fusion (correlations between existing sources) First implementations to be expected 2021 (step by step)	Our major shareholder, Globalvia, is involved in the research and develoment of a solution based on intelligent road studs called Smart45. The technological partner is Valerann. The solution consist of smart lane beacons installed in the pavement as road studs along the lanes. The road beacons are capable of detecting the trayectory and speed of every single vehcile in the road on real time. Besides they can provide visual information to the road users by changing thier colour. They will also allow for V2i communications with the connected vehicles. Globalvia has already implemented a trial of this solution in a section on the M45 motorway in Madrid, Spain with very good results. The solution not only detects stopped vehicles on real time and allows for inmidiate warning to the rod users of the incident, but also provides for a full range of traffic monitoring services including counting, measuring speed, locating debris on the road, detection of low temperatures and ice formation in the pavement, warning users and suppor TM arrangements by indicating close lanes, wrong dway driving detection, queue formation, and with connectivity to connected vehicles. if you want more information please tell us	Our shareholding company (egis) has developed an e-call phone application some time ago through their electronic tolling bran Eazytrip, but this has not been rolled out extensively to the market.

Results survey questions		Denmark Danish Road Directorate	England Highways England	Scotland Transport Scotland
		25 March 2021	15/01/2021	17/02/2021
	Question	Answer	Answer	Answer
1.1	What kind of stopped vehicle detection methods does your organisation have?	Currently, DRD has no automatic detection in operation. We rely on several sources to have such incidents reported to the traffic centre: Phone calls from drivers, copies of 1-1-2 calls from external emergency reponse centres, reporting from the police and radio stations etc. We also have camera coverage on some sections of the road network but there is no automatic detection via cameras - they are used by the operators in the traffic centre to verify incidents reported by drivers or other sources that are not considered fully reliable.	Regional Operations Centres (ROC) operators have numerous methods for Stopped Vehicle Detection including CCTV monitoring, Phonecalls from ERT or police, our MIDAS system, or our bespoke SVD system, currently installed on two sections of the M25, with a national rollout currently underway. The SVD system we use currently utilises Navtech Radar. I will talk exclusively about the SVD system for the purposes of this questionnaire.	Road surface magnetic Sensors (detector loops) for Hard Standings/bus lanes, CCTV for crosscheck. Road surface detector loops - but of course these are practicaly for queue detection as opposed to individual stopped vehicle detection. A few special places in the network have exta loops for better queue detection. Also infrared ("Kingston") as alternative to loops. Also radar (wavetronics) at Queensferry Crossing as alternative to loops, not as dedicated SVD. CCTV for manual crosscheck (and detection seems possible but not guaranteed). Have made some additional trials: ISDS iSentry video-based detection trial around 2008-10 - reported to have worked very well in NSW with fixed cameras but did not work so well in Scotland with PTZ cameras. "It was a promising solution, but in the end for us the trial was a failure." [due at least partly to operational staff not reviewing the incidents to train the system to learn from positive and negative alerts] "It also was hampered by the fact that it was running on pan and tilt cameras which never quite re-aligned themselves back to the exact same home position. I understand that this was successfully deployed in Sidney's control room on fixed CCTV cameras." 2019 trial, again video-based, "Saturn Eclipse", not sufficiently successful. TS has Bosch cameras which enable analytics, so far that is untried but its use is under consideration. Use Waze and Inrix 3rd party data for incident detection in general.
1.2	Can you roughly estimate how many percent of the highway network is covered by each method individually?	With the exception of cameras, the above mentioned methods cover all of the state road network which is the responsability of the DRD. Camers are located mostly on dense-traffic sections, but even there not with full coverage. A rough estimate is, that 5 percent of the road network can be seen using either fixed or PTZ cameras by the traffic centre.	All Smart motorways have 100% CCTV coverage, full MIDAS complement to the standards, and all All Lane Running (ALR) sections will have SVD fitted by 2013.	5%
2.1	Could you please describe the process step by step from detection of a stopped vehicle to the response?	The DRD traffic centre will send out vehicles with warning trailers to assist in cleaning up the area and will make any repairs needed to safely reopen the road. But the DRD is not part of emergency response with respect to sending an ambulance, police, fire arms etc. Therefore, if the traffic centre receives a report of an unknown accident from a driver, the first response is to alert the emergency response parties, and then DRD's own contracters are called and a traffic message is sent out to warn drivers. If the traffic centre receives information about a new incident from the 1-1-2 system or the police, the relevant DRD contractors are called and traffic messages are created.	Vehicle stops - SVD detects - Alert raised to operator - Operator searches via CCTV to confirm - appropriate action from operator if confirmed - Control works populated.	Detection through loops ---> Alert to Traffic Scotland System ---> This is crosschecked through CCTV --> Decision made based on situation---> Red X over hard shoulder ---> Police arrives on site
2.2	What is the source(s) of detection (e.g. inductive detector loops / radar / a combination)? Also 112 call, dedicated emergency phone, eCall?	At present, the only non-manual source is 1-1-2 information passed on from the 1-1-2 call centres. This is integrated into our existing traffic management system (GEWI TIC3). We are preparing a trial with incident detection based on real-time floating car data.	For the dedicated SVD, it is a scanning Radar - Navtech product.	Inductive Loops/ Automated bus service trial (V2X) / ERTs / Radar Queensferry crossing
2.3	What kind of hardware (e.g. road(side) systems) is used?	No roadside equipment is used.	Navtech Radar currently.	Inductive Loops / Radar / CCTV
2.4	What kind of software (e.g. video analytics) is used?	Except for the exchange of data feeds to and from TIC3 from GEWI, no software solutions are in use. The trial of floating car data is expected to take place using a stand-alone system. If this source is found to be of value to the traffic centre, it would need to be integrated into the traffic management system.	The SVD system integrates into our Traffic Management System, currently COBS. A new TMS is being rolled out nationally as part of the CHARM programme, which will replace COBS with a new TMS called DYNAC. SVD will feed into a temporary software tool n the interim until DYNAC can be upgraded to accept the SVD alerts.	Crowd source data / Trial SVD system (2019 - not active)
2.5	How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? Is a common data standard used?	This is not relevant it this point.	The SVD System is required to meet Highways England's comprehensive list of standards and specificaitons.	(1. Crowd Source data using fused data / taking into account historical information) (2. One source data used for the rest of the system/network)
3.1	To whom (and/or which automated system) are alerts reported?	This is not relevant it this point.	To the ROC operator, via COBS currently. (Control office Base System)	Traffic Scotland System --> Everyone in the control room
3.2	How are alerts reported (e.g. visual or audible)? If you receive eCall messages are they voice and/or data?	1-1-2 incidents are shown as alerts to the operators in the traffic centre in TIC3.	Both audible and visual. The audible alarm does not stop going off until an operator actions it.	Visual
3.3	What kind of information is being shared with receivers (e.g. operational staff or automated response systems)?	Information is only shared manually at the moment, usually via phone calls.	Alert type, time, location, which carriageway, Emergency area or running lane, nearest cameras.	Location / point to CCTV on location/ incident site
3.4	In which format is information being shared with receivers (e.g. operational staff or automated response systems)?	The 3.3.	Text based via the COBS.	Predifined reports, need to be acknowledged from the operator
3.5	Which information about stopped vehicle alerts are logged by the receivers (e.g. operational staff or automated response systems) and in what kind of system?	All reported incidents are logged in TIC3.	The ROC staff have access to two main systems - COBS, to manage the roadside equipment, and Control Works, to log events. The information gathered includes SVD event information, action taken by operator, and timestamps are automatically recorded by all systems in case audit is required.	All logged into Traffic Scotland System (time, location, action, etc.)
4.1	How are stopped vehicle alerts verified (e.g. what is the process, what is the architecture & is data fusion used)?	In most cases, 1-1-2 calls are consiered reliable and thus not verified before actions are taken. Other sources are verified by looking at cameras if available or waiting for another report of the same incident.	Once an alert comes into the ROC, the operator will use CCTV to verify. Where SVD is installed, there is 100% CCTV coverage from PTZ cameras.	CCTV verification or Police Scotland/ Operators
5.1	What are in your opinion the most important benefits of each method? (e.g. less collision risks (safer), cheap, always functioning, reliability)	The benefit of 1-1-2 calls are that they are verified by the 1-1-2 call centre. Cameras have the benefit of giving a precise location or lane information. Phone calls have benefit of covering the entire road network but are not very precise or reliable.	We only use one dedicated method currently.	Safety value added, reliable in general
5.2	What are in your opinion the biggest shortcomings of each method? (e.g. expensive, not functioning in specific weather conditions)	Except for cameras, there is some "latency" with every method, a self-reported locations from drivers who call the traffic centre is not very precise.	We only use one dedicated method currently.	Manual part of the system creates additional notifications/actions
5.3	Have you researched the impact of stopped vehicle detection methods on the risk of collision events? If yes, could you please share the results/report(s)?	No.	Hoping these two documents answer the question. They contain the original hazard assessment and log which shows that Hazard 135 (Vehicle stops in running lane off peak) increases significantly (on a logarithmic scale). This was always considered as part of the overall risk and made up just 5% of overall risk total. The Manhattan charts in the document show this change (reduction) in cumulative risk from D3M to ALR. SVD was considered as a mitigation to this specific risk at the roadside but clearly much other work has gone into this in the last several years – vehicle checks campaign, New EA signs and orange surfacing etc https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/2011-13-knowledge-programme/MM-ALR_Generic_Safety_Report_(Final_23-03-12).pdf https://s3.eu-west-2.amazonaws.com/assets.highwaysengland.co.uk/specialist-information/knowledge-compendium/2011-13-knowledge-programme/Demonstration_of_meeting_safety_objective_report_(Final_23-03-12).pdf	No research has been made on the subject
5.4	Could you (roughly) estimate both operational and implementing costs of each method?	It woul take us some time to provide this. Regarding the trials with floating-car data, I think the analysis and evaluation were more expensive than the acquisition of data and the system development and operation. This could look different in the future when we have more knowledge before introducing af new source of incident detection.	I will obtain and forward.	N/A (2 different contract for Operations and Traffic Scotalnd System)
5.5	If two or more methods are used: Which method do you consider most valuable and why (e.g. on which aspect)?	We are not able to answer this.	N/A	Manual CCTV monitoring considered effective but not perfect. As the same applies to any automated system (with positives and negatives for aeach one)
6.1	What kind of other/new stopped vehicle detection technologies/methods is your organisation interested in? Are you aware of eCall?	We have conducted a trial using floating-car data and another trial will take place this year with more focus on the operationel aspects in the traffic centre. We have been looking into real-time camera detection or incidents reported by outside service providers' customers such as driver-reported incidents from Waze. We think eCall alerts should go directly to the emergency response call centres but it could be beneficial to the traffic centre to know of such events immediately in any case. The use of several different sources at the same time is also an issue: An incident reported by a less reliable source may be verified using another source, but some automatic methods may report the same indicent in ways that make it unclear, if it is one incident or two unrelated incidents because of differences in location referincing, detection methods etc.	As part of the SVD Procurement exercise, we have opened up to the whole market to bring options to us. We are aware of Ecall, and have undertaken some initial studies on its potential use by HE.	Yes but not any specific ones (possibly SVD). Aware of e-Call but not integrating yet to the system.
6.2	Is your organisation involved in the development of new detection technologies/methods? - Which technologies/methods? - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? - How would you describe the current state-of-the-art of this technology/method? - (When) do you expect to implement this technology/method?	Currently, we are working on incident detection using floating-car data. In this trial, we have asked the company supplying the data to do the computations, data cleaning etc. and present us with alerts for use in the traffic centre. We may conduct further trials using other technologies and try to compare how they work with respect to reliability, location precision, usability in the traffic centre etc. Experiences from other countries presented at the ITS congresses and several collaboration forums are of interest to us. We think that other countries have shown that automatic incident detection can be made to work, at least under certain conditions. The only fixed schedule at the moment is our second trial of floating-car data in the autumn of 2021.	We currently have a procurement exercise underway, so am limited in what we can say.	Not aware of any developments at the moment. TBC

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Results survey questions

		TOMTOM	Be-mobile	INRIX
		03-Feb	15/02/2021	24/02/2021
	Question	Answer	Answer	Answer
1.1	What kind of stopped vehicle detection methods does your organisation have?	•We use GPS probe data transmitted in real-time (<= 2 min latency). •GPS log intervals of vehicles: 5 - 10 sec. •Probe penetration rates of the total fleet depend on country. Central Europe 5 - 15%. •We are mainly interested in detecting slow downs and stops of traffic, not of individual (broken) cars. •Dangerous slowdowns are reported as Jam Tail Warnings in our traffic service.	Stopped vehicle detection based on FCD + event data (notifications on incidents & accidents by our community).	"Dangerous Slowdowns" - detection of major speed deltas at specific points on limited access roads. Aggregate rather than individual vehicle stop / slowdown detection
1.2	Can you roughly estimate how many percent of the highway network is covered by each method individually?	N/A	We cover 100% of the Dutch highway network.	Limited access roads (eg motorways, dual carriageways) - typically 10% of total national road networks
2.1	Could you please describe the process step by step from detection of a stopped vehicle to the response?	Detailed info is confidential - high level summary above	When we get a notification on a stopped vehicle, we collect floating car data in the surrounding area. Both inputs are used to verify whether this is truly a stopped vehicle. If this is positive, we report the incident to our travellers and other stakeholders.	Our AI Traffic engine continually scans the limited access road network for cases where there is a high vehicle probe speed delta in a short space.
2.2	What is the source(s) of detection (e.g. inductive detector loops / radar / a combination)? Also 112 call, dedicated emergency phone, eCall?			
2.3	What kind of hardware (e.g. road(side) systems) is used?			
2.4	What kind of software (e.g. video analytics) is used?			
2.5	How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? Is a common data standard used?	Detailed info is confidential - high level summary above	See 2.1. Data fusion is done between FCD & event data (notifications).	As above. Data standard is bespoke
3.1	To whom (and/or which automated system) are alerts reported?	Users of TomTom Traffic	Alerts are reported to 1/ our travellers, and 2/ to SIMN ("Stichting Incident Management Nederland"). SIMN is a collaborative venture bringing together emergency assistance centres active in the recovery of passenger vehicles. On behalf of the affiliated emergency assistance centres, SIMN is responsible for the contracting of recovery companies that operate on trunk roads.	To any INRIX customers who use the Dangerous Slowdowns product
3.2	How are alerts reported (e.g. visual or audible)? If you receive eCall messages are they voice and/or data?	Depends on end-solution and driver settings, TomTom traffic can report alerts in both visual and audible format	1/ Alerts to travellers: both visual & audible; 2/ Alerts to SIMN: datafeed.	As the data provider, we produce data for customers to make alerting choices based on their own end-user use cases
3.3	What kind of information is being shared with receivers (e.g. operational staff or automated response systems)?			
3.4	In which format is information being shared with receivers (e.g. operational staff or automated response systems)?			
3.5	Which information about stopped vehicle alerts are logged by the receivers (e.g. operational staff or automated response systems) and in what kind of system?			
4.1	How are stopped vehicle alerts verified (e.g. what is the process, what is the architecture & is data fusion used)?	When we see that a GPS probe has stopped we usually try to verify by matching with another source i.e. a traffic feed coming from a road authority or our moderation team that can view on-street camera	Verification is done by our community: we ask them to confirm/deny the presence of stopped vehicles.	The alerts are not verified on an individual cases
5.1	What are in your opinion the most important benefits of each method? (e.g. less collision risks (safer), cheap, always functioning, reliability)	GPS method is cost-efficient and accurate	Our incident detection system improves driver awareness and driver safety. A high coverage is guaranteed because of our significant community size.	Probe based stoppage detection's most important benefits are : uses existing data, functions in all conditions, no reliance on infrastructure
5.2	What are in your opinion the biggest shortcomings of each method? (e.g. expensive, not functioning in specific weather conditions)	GPS method requires density - i.e. it works best on motorways/highways and less on rural roads	In low traffic areas, it may take longer for stopped vehicles to be detected.	Probe based stoppage detection's most important shortcomings are : dependency on probe penetration rates, latency
5.3	Have you researched the impact of stopped vehicle detection methods on the risk of collision events? If yes, could you please share the results/report(s)?			
5.4	Could you (roughly) estimate both operational and implementing costs of each method?			
5.5	If two or more methods are used: Which method do you consider most valuable and why (e.g. on which aspect)?	N/A		N/A
6.1	What kind of other/new stopped vehicle detection technologies/methods is your organisation interested in? Are you aware of eCall?	N/A	E-call or similar types of detection generated by stoped vehicles themselves.	Vehicle signal data (hard braking, etc.), neural networks to enhance probe stoppage detection
6.2	Is your organisation involved in the development of new detection technologies/methods? - Which technologies/methods? - How would you explain the method functionally (e.g. what is the architecture & is data fusion used)? - How would you describe the current state-of-the-art of this technology/method? - (When) do you expect to implement this technology/method?	Use of in-vehicle sensor data to detect accidents/broken down vehicles. TomTom is a part of the Data for Road Safety Initiative	We are looking at methods where incident detection can be done based on FCD only (no notifications needed).	As 6.1 - no more concrete plans than this on the roadmap currenty

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