RAIDER

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Summary Report with Final Results and Recommendations

Deliverable 5.1

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Project Coordinator TNO

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Executive summary

RAIDER (Realising Advanced Incident Detection on European Roads) is a research project funded within the framework of ERA NET ROAD by the National Road Administrations of Belgium, Switzerland, Germany, Netherlands, Norway and United Kingdom. The project investigates how to improve incident detection systems by incorporating new technologies for roadside systems and utilizing in-vehicle systems and nomadic devices. Improvements in incident detection are expressed in terms of detection quality and the estimated costs and benefits of the detection systems. The project, which began in November 2011 and runs to July 2013 is being carried out by a consortium comprising TNO from the Netherlands, AIT from Austria, TRL from the UK and FEHRL based in Belgium.

Incident detection is an essential capability for Road Authorities to manage their road networks and adequately respond to incidents. Issues with the quality of detection, such as a high false alarm rate, delays in detection, or inaccurate location of incidents, directly impact their operations. Significant investments may be required to improve the detection quality with additional roadside detection systems. At the same time, new developments in road side systems, nomadic devices and in-vehicle systems, and in third party services, may provide solutions that improve both incident detection quality and reduce the costs for National Road Authorities.

RAIDER is a research project aiming to improve the performance of incident detection systems in a cost-effective manner by incorporating new technologies for roadside systems and utilizing in-vehicle systems and nomadic devices. A methodology is developed to qualitatively assess the performance and costs of technologies and to integrate these in system configurations for incident detection systems.

This summary report presents the project results in the form of examples how a road authority can apply the methodology and fact sheets to assess and select innovative technologies, how to integrate these in new detection systems and how to assess the performance and costs.

Details on the methodology, technologies and other relevant Use Cases can be found in earlier deliverables on the User Needs and Requirements [1], and the generic specifications in [2]. The focus for incident detection is on the detection of accidents, broken down vehicles and extraordinary congestion, on motorways and secondary roads. The most relevant new technologies considered are eCall, cooperative systems, and nomadic devices, and in addition new road side detection technologies are considered for tracking vehicles and for travel time estimation. Detection performance is characterized in terms of detection rate, detection accuracy, detection delay, and false alarm rate. Detection performance is specified in a generic way, e.g. in terms of penetration rate or detector spacing and coverage. Set up, maintenance and operation costs are considered for setting up a new system, or upgrading or retrofitting existing systems. A Technology Library with fact sheets for the technologies is provided for reference in Annex 1 from [2].

The main conclusions and recommendations that can be motivated with the methodology are:

- As eCall will be mandatory, it is expected to provide reliable and accurate detections of almost all major accidents on all roads after 2020 at a low cost for the NRA. It can be recommended to integrate eCall in incident detection systems of NRAs. Nevertheless it cannot provide detections of other incidents and other systems will be needed, even for detection of minor accidents.
- Cooperative systems will provide reliable and accurate warnings for accidents, vehicle breakdowns and congestion that can directly be applied for incident detection by the NRA on all road types. Once the penetration rate is sufficiently high, it will

provide the best detection performance and the most cost-effective system concept. However, the penetration rate is expected to be too low to meet the required detection rates by 2020.

- Nomadic devices provide a cost-effective solution for all three types of incidents. The detection performance may not satisfy the minimal requirements in all Use Cases. The reliability of accident and breakdown detection is significantly less than for eCall or in-vehicle systems. The detection delay may be too large due to the communication and service provision solutions. The competition in the number of applications and service providers may also result in low penetration rates of vehicles providing the detection information.
- Bluetooth detectors provide the most cost effective solution to congestion detection if the detection delay and accuracy due to the detector spacing are acceptable.
- Video tracking and scanning radar systems are the only detection technologies considered in this project that can provide the required performance for accident and breakdown detection by 2020. These road side solutions should be considered as an intermediate solution till they can be replaced by in-vehicle or nomadic devices.

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Definitions

Term	Definitions
Incident	Any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand, such as traffic accidents, broken down vehicles, spilled cargo and debris, extraordinary congestion
Accident	The collision of one motor vehicle with another road user, a stationary object, or person
Vehicle breakdown	The operational failure of a motor vehicle such that the vehicle is slowed down considerably or becomes stationary
Debris	Rubble, wreckage, litter and discarded garbage/refuse/trash, scattered remains of something destroyed
Vehicle fire	Vehicles on fire on or next to the road. This is regarded as a special case of vehicle breakdown
Recurrent congestion	Predictable congestion caused by sheer weight of traffic, for example during rush hours
Extraordinary congestion	Unpredictable congestion caused by extraordinary events like abnormal traffic flows, traffic accidents, broken down vehicles, vehicle fires, wrong-way-driving, road works, or weather events.
Limited visibility	Visibility restrictions caused by (for example) smoke, fog, bad weather
Wrong-way driving	A motor vehicle driving against the direction of traffic
Motorway with hard shoulder	Any route with grade separated interchanges with a continuous non-running lane for refuge
Motorway without hard shoulder	Any other route with grade separated interchanges without a continuous non-running lane for refuge. May be a tunnel, bridge, elevated section, section of network with active hard shoulder running.
Secondary or Arterial Road	Any route with at-grade intersections, may be urban or rural, a dual or single carriage way with or without a central median separating traffic of opposing directions
Detection Rate	Ratio or percentage of the number of detected incidents to the total number of actual incidents during a given time period
Detection Time	Time delay between occurrence and detection of an incident.
False Alarm Rate	Ratio or percentage of false positive detections per unit of road length and unit of time, as a measure of operator work load (see [1], section 4.2, for FAR definitions); i.e. [number of false alarms / km / day]
Location Accuracy	The distance between the real and the detected incident location
False Alarm Rate	Ratio or percentage of false positive detections per unit of road length and unit of time, as a measure of operator work load; i.e. [number of false alarms / km / day].
Penetration rate of Equipped Vehicles	The ratio of vehicles that have the equipment installed and activated. In this report, the PEV is defined as the ratio of vehicles that have the equipment installed *and* activated. Vehicles that do not have the equipment or applications activated or have lost communication, are regarded as unequipped vehicles from the perspective of road side incident detection.

Abbreviations

Abbreviation	Meaning
AID	Automatic Incident Detection
ANPR / ALPR	Automatic Number/License Plate Recognition
CAM	Cooperative Awareness Message
DR	Detection Rate
DENM	Distributed Environmental Notification Message
DT / TTD	Detection Time, Time To Detect, or detection delay
E-Call	Pan-European in-vehicle emergency call system
EETS	European Electronic Toll Service
IR	Incident Rate
ETS	Electronic Toll Services
FAR	False Alarm Rate
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HGV	Heavy Goods Vehicles
ILD	Inductive Loop Detector
MIDAS	Motorway Incident Detection and Automated Signalling
MDIR	Manual Driver Intervention Rate
NRA	National Road Authority
ND	Nomadic Device
OBU	On-Board Unit
PC	Passenger Car
PEV	Penetration rate of Equipped Vehicles
PSAP	Public-Safety Answering Point
RIS	Road side ITS Station, i.e. a cooperative road side unit
TJAW	Traffic Jam Ahead Warning
UTC	Urban Traffic Control
V2I / I2V	Vehicle to infrastructure communication of cooperative ITS stations
V2V	Vehicle to vehicle communication of cooperative ITS stations
VIDS / VIPS	Video Incident Detection System / Video Image Processing System
VIN	Vehicle Identification Data or Vehicle Identification Sequence
VIS	Vehicle ITS Station; i.e. the OBU of a cooperative vehicle
WMI	World Manufacturer Index

1 Introduction

1.1 ERA-NET ROAD II programme

"ERA-NET ROAD II – Coordination and Implementation of Road Research in Europe" is a Coordination Action funded by the 7th Framework Programme of the EC. The partners in ERA-NET ROAD II (ENR2) are United Kingdom, Finland, Netherlands, Sweden, Germany, Norway, Switzerland, Austria, Poland, Slovenia and Denmark (www.road-era.net). Within the framework of ENR2 a joint research programme "Mobility – Getting the most out of Intelligent Infrastructure" is initiated. The funding National Road Administrations (NRA) in this joint research project are Belgium, Switzerland, Germany, Netherlands, Norway and United Kingdom. The main objective of this programme is to improve the management of the European road network. "High quality traffic management/information data and incident detection" is one of the four objectives within this strategic research opportunity (SRO) addressed in this project.

1.2 Incident Management and the quality of traffic data

Across Europe, incidents account for an estimated 10% to 25% of all congestion and are the largest single cause of journey unreliability [3]. "Incident" is a broad term for which different definitions are used: here we use as a working definition (by analogy from [4]) "any non-recurring event that causes a reduction of roadway capacity or an abnormal increase in demand, such as traffic accidents, broken down vehicles, or extraordinary congestion".

Incidents critically limit the operational efficiency of the road network and increase safety risk for road users. Incidents cause congestion due to the temporary and sudden lane closures, and consequently cause travel time delays. Another serious problem is the risk of secondary crashes due to the congestions. As an example of the direct effects on congestion, it was estimated in the Netherlands that 13% of vehicle hours lost were directly related to incidents in 2009 [5]. While 80% of these incidents were small and could be solved by road users, 20% lasted longer and heavily influenced throughput.

The objective of incident management is to reduce the effects of incidents, both in terms of throughput and safety. Incident management is a process of the following activities: detection and verification of the incident, providing traveller information and traffic control, alarming emergency and rescue services, scene management, road clearance and recovery [6]. Efficient incident management requires close cooperation of many different organisations including the road operators, road authorities, emergency response teams and vehicle recovery teams.

This project focusses on the first step in incident management; incident detection. Incident detection is the process of detecting the presence and location of an incident by a road operator. For the detection of incidents, various information sources can be used, like calls from motorists by mobile telephone or call boxes, and calls from surveillance or emergency teams. This project, however, only considers systems for automated incident detection.

The roles and responsibilities of road operators and authorities in incident management evolve while new incident management strategies are being developed, e.g. [3], [6]. In this context, requirements and needs for incident detection and the quality of incident data also evolve. Incident detection is an essential capability for road operators and authorities to manage their road networks and adequately respond to incidents. Issues with the quality of detection, such as a high false alarm rate, delays in detection or inaccurate location of incidents, directly impact the efficiency and effectiveness of incident management. High quality of data enables faster resolution of incidents and proactive measures to avoid or minimize traffic disturbance. One of the findings from [3] is that "The most powerful tool in minimising the impact of incidents – and the one that is in the NRA's direct control – is the provision of fast, direct, high-quality information in a standard format that is acceptable across Europe".

1.3 Improving Incident Detection

Existing systems for incident detection are primarily road side based systems to detect congestion using for example inductive loops, video cameras or radar systems. These systems require high setup and maintenance costs and are only installed on vital sections of the network. The larger part of the motorway network and almost all secondary roads in Europe are not equipped with incident detection systems. Existing systems frequently experience operational issues with the quality of detections, such as too high false alarm rate, large delays in detection, or inaccurate location of incidents. These issues directly impact the effectiveness of the systems and result in increased costs of operations for verification of incident alarms.

Significant investments may be required to improve the detection quality with additional roadside detection systems, and to extend the network with incident detection. New developments in road side systems, nomadic devices, in-vehicle systems and third party services may provide solutions that improve incident detection quality and reduce the costs for NRA. Relevant question is "When and how can these technologies be applied or integrated into existing detection systems to improve the detection performance in a cost effective manner?"

The answer depends very much on the existing situation and the desired situation of a NRA. The requirements and priorities for the desired situation can be diverse. The NRA may wish to improve the performance for specific types of incidents, or to reduce costs while maintaining a certain level of detection performance. Different technologies may become relevant for different types of incidents, types of roads, traffic volumes. Different technologies provide different options to upgrade, retrofit or replace an existing detection system.

The detection performance of an incident detection system is determined by many factors, such as the operating traffic conditions (e.g. traffic volume, road capacity, heterogeneity of vehicle fleet), situational conditions (e.g. road geometry, ramps, curves, buildings or trees obscuring the line of sight), environmental conditions (e.g. weather, light and visibility) and incident conditions (e.g. number and class of vehicles, location on the road and position relative to sensors). Most factors are variable, and hence the detection rate, time, and accuracy, and the false alarm rate will vary as well with the conditions.

The detection performance can be optimised to best match the user needs and requirements for a range of conditions by optimising the configuration of the incident detection system. The system configuration specifies the type, location and mounting of sensors, and the type and configuration of incident detection algorithms. Increasing the density of road side detectors for example, will increase the detection accuracy and detection rate but will also increase setup costs. Increasing the detection rate for accident detection on critical locations for example will require a more sophisticated detection algorithm which will increase the processing and detection time as well. Decreasing the false alarm rate for detection of vehicle breakdowns for example can also be realised by more sophisticated detection algorithms and consequently increase detection times. The infinite number of scenarios for improvement require specific and tailor made solutions within the performance range of a detection technology.

Innovative technologies like cooperative systems, nomadic devices and new road side detection systems provide significant shifts in the ranges of values for performance criteria and in the associated costs for road authorities compared to existing detection technologies.

Improving incident detection systems with new technologies is a conceptual design problem, in which the concept of the system configuration is selected and adapted. Typical for conceptual design is to perform the first iteration loops as a qualitative design process. A qualitative design selects the detection technologies and the types of data fusion and incident detection algorithms. The performance of the qualitative design is also evaluated qualitatively. Detection performance can be qualified as ranges of parameter values for performance criteria that are characteristic for a technology and system configuration.

The system configuration is gradually refined and quantified in following iterations. The system configuration can be quantified for example by detector spacing and mounting, or penetration rate of equipped vehicles, and the update frequency of detections. Performance evaluation is also refined and quantified to evaluate the effects of the parameter changes of the system configuration.

Once the concept of the system configuration is frozen, products are selected and optimized and interfaces to existing systems are designed in detail.

1.4 Project Objectives

RAIDER is a research project aiming to improve the performance of incident detection systems in a cost-effective manner by incorporating new technologies for roadside systems and utilizing in-vehicle systems and nomadic devices.

This is a conceptual design problem. The main objective is to develop generic specifications for incorporating new technologies in incident detection systems. A generic specification is a specification of an incident detection system in a generic way that is applicable to many NRAs in Europe, rather than a specific solution for a specific system of a specific NRA. A generic specification defines the configuration of a detection system, including its main components and the main features of these components, such as the technologies, data fusion and incident detection algorithms, and the main configuration parameters such as the penetration rate of equipped vehicles or the spacing and coverage of road side detectors.

A generic specification expresses the performance and costs of a technology or incident detection system in a generic and qualitative way, i.e. in terms of the system configuration parameters. Section 2 presents a summary of the generic specifications of technologies and incident detection systems.

The generic specifications enable a road authority to select new technologies, system concepts and configurations for setting up a new system, or for upgrading or retrofitting existing systems. The generic specifications also enable the qualitative assessment of the improvements in performance and the associated effects on costs. Application of the generic specifications from section 2 is demonstrated in section 3.

1.5 Project Scope

The scope of the RAIDER project is restricted along several dimensions to keep focus in the project. RAIDER considers incident detection systems on a conceptual level to make the results applicable to many National Road Authorities (NRA) instead of addressing a specific situation. At the conceptual level, technologies can be characterised by their main features for the system configuration and typical value ranges of performance criteria and costs. At the conceptual level, technologies can be assessed and compared qualitatively. Concretisation to a specific situation and product is left to the NRA.

An existing situation of an NRA is characterised in a Use Case. A Use Case defines a current situation in terms of the road network, traffic volume and existing detection systems. Table 13 shows the Use Cases that are most relevant for European NRAs and have been used as examples. A NRA can define one or more scenarios to improve the existing situation of a use case to a desired situation, as exemplified in section 3.

RAIDER has a focus on near-future technology improvements with a target time horizon for implementation between 2015 and 2020. The most relevant new technologies considered are eCall, cooperative systems, nomadic devices, and road side technologies for tracking vehicles (i.e. video and radar tracking systems) and for travel time estimation (ANPR, tolling systems and Bluetooth scanners).

The types of incidents are limited to those in Table 1. The technologies and incident detection solutions are assessed on the performance and cost criteria defined in Table 2 and Table 3.

Table 1: Incident types

Accidents	The collision of one motor vehicle with another road user, a stationary object, or person
Vehicle breakdown	The operational failure of a motor vehicle such that the vehicle is slowed down considerably or becomes stationary
Extraordinary congestion	Unpredictable congestion caused by extraordinary events like abnormal traffic flows, traffic accidents, broken down vehicles, vehicle fires, wrong-way-driving, road works, or weather events.

Table 2: performance criteria

Detection Rate (DR)	Ratio or percentage of the number of detected incidents to the total number of actual incidents during a given time period.	
Detection Time (DT)	Time delay between occurrence and detection of an incident.	
Detection Accuracy (DA)	Detection Accuracy is measured in different criteria, depending on the incident class:	
	Location accuracy (LA)	The distance between the real and the detected incident location.
	Number of vehicles	The capability to identify the number of vehicles involved in an accident.
	Vehicle class (VC)	The capability to distinguish between light vehicles such as passenger vehicles and light commercial vehicles, and heavy goods vehicles.
False Alarm Rate (FAR)	Ratio or percentage of false positive detections per unit of road length and unit of time, as a measure of operator work load; i.e. [number of false alarms / km / day].	

Table 3: cost criteria

Setup costs	Costs associated with the initial setup of the proposed new incident detection system, or the additional costs for upgrading or retrofitting an existing system, including all hardware costs (e.g. sensors, detector stations or vehicles, communications networks from the roadside to central stations, and detection and operator support systems at central locations), associated software, and the equipment and manpower for installation, mounting and calibration of the system.
Maintenance costs	Costs associated with the on-going maintenance during the lifetime of the incident detection system, including any necessary regular cleaning, calibration, and regular replacements
Operational costs	Costs associated with the day to day operation of the working system, including for example, manpower costs for validating incidents or data processing, and data provisioning services, e.g. from nomadic devices.

1.6 Project Structure and Deliverables

The generic specifications have been developed in two project phases and reported separately.

Phase 1 – User Needs and Requirements: Deliverable D2.1 [1]

- Experts from the National Road Authorities have been consulted as stakeholders to define the scope of the project; i.e. to select the top priority types of incidents and most pressing issues as reference cases for research.
- Stakeholders have also been consulted to assess their operational experiences and issues with existing systems, and to define user needs and requirements for incident detection systems (now and in the future) as a reference for evaluating new technologies.
- Quality criteria are derived from user needs and requirements, operational experiences, and issues with the functionality and performance of incident detection systems.

Phase 2 – Deliverable D4.1: Generic Specifications for Incident Detection Systems [2]

- Defines and presents the Use Cases, innovative detection technologies and criteria for performance and costs assessments in more detail.
- Annex with a Technology Library with fact sheets for the innovative technologies.
- Methodology for developing the generic specifications and for assessing detection technologies and incident detection systems. A summary and examples are given in section 2.
- Five most relevant Use Cases to exemplify the methodology for selecting and specifying improved incident detection systems. A summary is given in section 3.
- Guidance for estimation of costs and benefits to demonstrate the business case for new technologies.

2 Generic Specifications

The main objective is to develop generic specifications for incorporating new technologies in incident detection systems. A generic specification defines the configuration of a detection system, including its main components and the main features of these components, such as the technologies, data fusion and incident detection algorithms, and the main configuration parameters such as the penetration rate of equipped vehicles or the spacing and coverage of road side detectors.

A generic specification also contains estimates of the performance and costs of a detection system. This requires two models that will be described in the next subsections:

- The performance of a technology and complete incident system is modelled in terms of system configuration parameters.
- The costs of a technology and complete incident system are modelled in terms of system configuration parameters.

2.1 Qualification of detection performance and costs

Detection performance and costs can be qualified as low, medium, high and very high by defining intervals of the corresponding performance and cost value ranges. Table 4 shows the qualifications from [2] that are based on guestimates from literature and the authors. These guestimates should be interpreted as an example for the evaluations and assessment. An NRA should adapt these to their specific reference standard.

Table 4: Qualitative grades of detection performance and costs

Detection Rate (DR)	Low <= 50%	Medium > 50%	High > 80%	Very High > 99%
Detection Time (DT)	Very High >= 5 min	High < 5 min	Medium < 1 min	Low < 10 sec
Location Accuracy (LA)	Low >= 100 m	Medium < 100 m	High < 10 m	Very High < 1 m [1)]
False Alarm Rate (FAR) [False Alarms/day/km]	Very High >= 25	High < 25	Medium < 2.5	Low < 0.25
Suitability[2)]	Low (Does not satisfy all high priority requirements)	Medium (Satisfies all high priority minimum requirements)	High (Satisfies all *minimum* performance requirements)	Very High (Satisfies all performance requirements)
Costs	Very High €€€€	High €€€	Medium €€	Low €

[1)] Lane level accuracy

[2)] The suitability qualifies the overall performance relative to the requirements of a Use Case in section 3.

2.2 Generic specification of detection performance

The incident detection performance can be estimated from the data quality and algorithm performance in the data flow through the components of the detection system. Figure 1 sketches the data flow and component dependencies in the system.

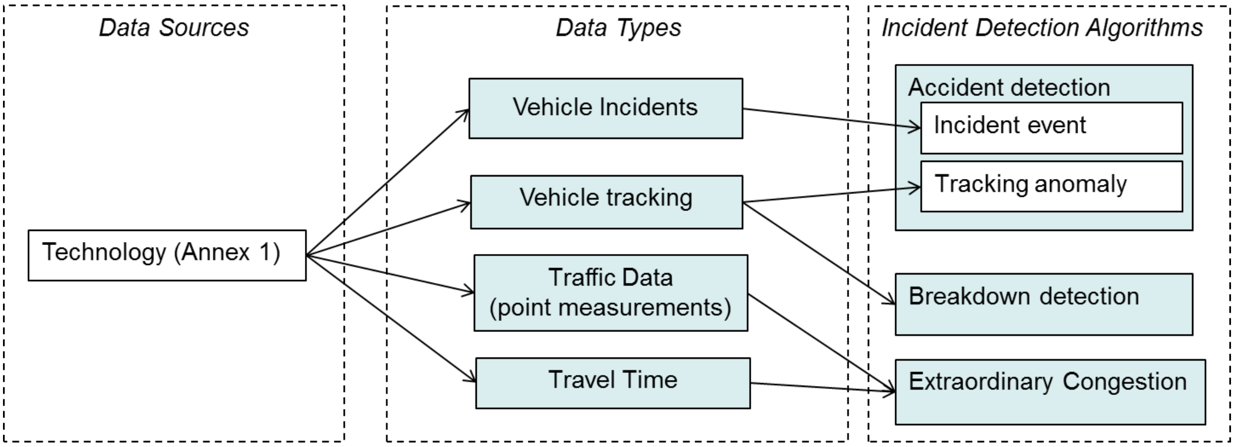

Figure 1: Detection performance model relationships (Figure 5 from [2])

Incidents can be detected by different types of algorithms, and an incident detection algorithm requires input from data sources of a specific data type, such as vehicle incidents, vehicle tracks or travel times. Accident detection for example, can be based on vehicle incidents detected directly by cooperative systems or nomadic devices. Accidents can also be detected from anomalies in vehicle tracks from cooperative systems, nomadic devices or road side tracking detectors.

Innovative technologies considered in RAIDER are data sources that provide data about incidents as input to incident detection algorithms. Data sources can provide data of one or more data types and of specific data quality. Cooperative systems for example can provide warnings for detected incidents and vehicle tracks. Data fusion algorithms can also be regarded as a data source that provides data of some type. An example is the fusion of vehicle tracks from road side tracking systems and cooperative systems. Existing detection systems commonly use a single source of data from a single type of road side detector and do not fuse this with other data sources. More complex configurations will use multiple data sources, including data from vehicle-based systems or nomadic devices either directly or through data providers.

The detection performance of an incident detection algorithm is determined by the capabilities and configuration of the algorithm and by the quality of the input data. The detection rate for accident detection for example, directly depends on the penetration rate of vehicles equipped with cooperative systems or nomadic devices. The detection time in this example depends on the communication medium, update frequency, and delay in data provision via a data provider. The false alarm rate can be estimated from the reliability of accident detections by the sensors of the devices.

The importance of Figure 1 is that the data quality and detection performance criteria can be related to terms of configuration parameters of specific technologies. Annex 1 from [2] contains a Technology Library with fact sheets for the innovative technologies considered in RAIDER. A fact sheet defines the main system configuration parameters, and models to express the detection performance criteria in terms of the configuration parameters. The fact sheets also provide guestimates for typical system configuration parameters and qualitative assessments of the performance and costs.

The following subsection gives an example from [2]. The example shows how alternative system configurations affect performance and costs, and how the suitability of the technology can be assessed over time by a configuration parameter (penetration rate of equipped vehicles (PEV)).

2.2.1 Example of Generic Specifications for Cooperative Systems

A cooperative ITS is an Intelligent Transportation System in which vehicles, road infrastructure and back offices cooperate to improve active road safety and traffic efficiency. The architecture, communication and applications are being standardised by ETSI, CEN and ISO. A first Basic Set of Applications [7] is being defined that include applications relevant to each incident class considered, such as a post-crash warning, collision warning, stationary vehicle warning, and traffic jam ahead warning. Although the systems, applications and standards are still in development, it is likely that cooperative systems will be available by 2020 and provide direct input for the detection of accidents, broken down vehicles and congestion.

There are two configurations to communicate the on-board detections to road operators:

1. The road authority has its own network of road side units (RIS) that can receive the messages from equipped vehicles via the ITS G5 communication network and send the information directly to the traffic control centre for operator support within a second. To receive accident or breakdown warnings from the vehicles, or to track vehicles, full ITS G5 communication coverage is required. With a typical communication range of 500m, a density of road side units is needed every 1 km:

$$DENS_{RIS} = 1.0 \text{ RIS per km of road}$$

2. A service provider collects the vehicle information via a cellular network and processes the data in a back office.
   - If the road authority provides the service, then the information can be provided directly to the road operator. The end-to-end communication delay can be as low as 10 seconds.
   - If the road authority has to acquire the data from the third party service provider, then the end-to-end delay may be in the order of 5 minutes

The penetration rate of vehicles (PEV) determines the performance of cooperative systems. In [8] a PEV was estimated for incident related cooperative applications between 5-10% by 2020 when introduction would be initiated by 2012. By 2030 most vehicles are expected to be equipped with ITS Stations, possibly integrated with eCall. A first guestimate for a penetration rate is:

$$PEV_{V2I} = 5\% \text{ by } 2020$$

$$PEV_{V2I} = 90\% \text{ by } 2030$$

The data quality from cooperative vehicles to provide vehicle incident detections is estimated in Table 5 in terms of configuration parameters and technology performance from literature and field tests. These applications detect accidents and breakdowns automatically from on-board sensors and systems. The reliability of the detections will be very high and result in very high detection rates and very low false alarm rates. The detection rate directly depends on the penetration rate of vehicles sending warning messages when they are involved in an accident or when they break down. The detection time depends on the communication medium. The location accuracy depends on the positioning accuracy of the vehicle systems and is estimated to provide lane level accuracy by 2020. The false alarm rate is expected to be negligible and proportional to the incident rate (IR) estimated from incident statistics. The performance criteria for the detection of extraordinary congestion are estimated in a similar way.

Road side incident detection algorithms can directly use the vehicle warnings. Detection performance is determined primarily by the communication coverage and density of road side units. This dependency is straightforward and also included in Table 5.

Table 5: Guestimates for in-vehicle accident and breakdown detection performance (Table 39 from [2])

Performance criterion for accident or breakdown detection		*Estimate*
$DENS_{RIS}$	Density of RIS	1 RIS/km
DR_A, DR_B	Detection Rate	*≈ PEV_{V2I}*
DT_A, DT_B	Detection Time with G5 V2I communication to a RIS (configuration option 1)	*< 1 sec*
DT_A, DT_B	Detection Time with cellular network communication to a service provider (configuration option 2)	*10 sec*
FAR_A	False Alarm Rate for accidents	*<< 1 % * IR_A * DR_A*
FAR_B	False Alarm Rate for breakdowns	*<< 1 % * IR_B * DR_B*
LA_A, LA_B	Location accuracy of on-board positioning	*< +/- 1.0 m*
VC	Vehicle class	*Yes*
DG	Dangerous goods	*Yes*

The detection performance can now be estimated for the selected configuration parameters (configuration option 1 or 2, PEV_{V2I} and $DENS_{RIS}$) and qualified in Table 6 and Table 7.

Table 6: Performance of Cooperative Systems for system configuration 1 (RIS, G5) (Table 41, [2])

<table>
<tr><th rowspan="2"></th><th rowspan="2">Accidents</th><th rowspan="2">Breakdowns</th><th colspan="2">Congestion</th></tr>
<tr><th>TJAW</th><th>tracking</th></tr>
<tr><td rowspan="2">System Configuration</td><td colspan="4">PEV_{V2I} = 5% by 2020 (90% by 2030)</td></tr>
<tr><td colspan="4">Configuration option 1:
$DENS_{RIS}$ = 1.0 RIS / km
ITS G5 (802.11p) short range communication</td></tr>
<tr><td rowspan="2">Detection Rate</td><td colspan="2">Low due to low PEV_{V2I}</td><td colspan="2">High (2020)</td></tr>
<tr><td colspan="2">(High by 2030)</td><td colspan="2">Very High (2030)</td></tr>
<tr><td rowspan="2">Detection Time</td><td colspan="2" rowspan="2">Low
< 1 sec</td><td>High (2020)</td><td>Medium</td></tr>
<tr><td>Medium (2030)</td><td>Low (< 10 sec)</td></tr>
<tr><td>Location Accuracy</td><td colspan="2">High (+/- 1.0 m)</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Vehicle class & Dangerous goods</td><td colspan="4">Yes</td></tr>
<tr><td rowspan="2">False Alarm Rate</td><td colspan="2" rowspan="2">Low</td><td>Medium (2020)</td><td rowspan="2">Medium</td></tr>
<tr><td>Low (2030)</td></tr>
<tr><td rowspan="2">Suitability</td><td colspan="2">Low (2020)</td><td>Medium (2020)</td><td>High (2020)</td></tr>
<tr><td colspan="2">Very High (2030)</td><td>Very High (2030)</td><td>Very High (2030)</td></tr>
</table>

Table 7: Performance of Cooperative Systems for system configuration 2 (3-4G) (Table 43, [2])

	Accidents	Breakdowns	Congestion - Tracking
System Configuration	PEV_{V2I} = 5% by 2020 (90% by 2030)		
	Configuration option 2: 3, 3.5, or 4G cellular network communications		
Detection Rate	Low due to low PEV_{V2I} (2020)		High (2020)
	(High by 2030)		Very High (2030)
Detection Time	Medium (> 10 sec)		Medium
Location Accuracy	High (+/- 1.0 m)		Medium
Vehicle class & Dangerous goods	Yes		
False Alarm Rate	Low		Medium
Suitability	Low (2020)		High (2020)
	Very High (2030)		Very High (2030)

The estimated penetration rates by 2020 and 2030 have a profound effect on the suitability of the technology, especially for accident and breakdown detection. The communication options clearly affect the detection time. The communication delay in option 2 is such that the Traffic Jam Ahead Warning (TJAW) messages do not provide addition information for congestion detection in addition to vehicle tracking.

The costs can be estimated directly from the system configuration parameters (e.g. Table 8). In the first configuration option, the road authority has to install new road side stations with a unit cost of 3000 – 4000 €. This hardware can either be mounted on a pole or gantry on the side, above the road. The RSU needs to be connected directly or via Wi-Fi to the fixed IP network of the road authority. If a fixed communication network and detection systems (e.g. inductive loops) already exists, then retrofitting only requires the installation of the road side stations.

No maintenance is to be expected other than normal upgrades of the hardware and software of RSUs. No operational efforts or costs are required to verify the incidents received from cooperative systems, because the V2I messages contain most relevant data about incidents.

Table 8: Costs for Cooperative Systems for system configuration 1 (RIS, G5) (Table 42 from [2])

	New System	Retrofit to existing infrastructure	Use/upgrade of existing system
Set Up	€€	€	N/A
Maintenance	€€ (regular maintenance of RIS HW or SW)		
Operations	None		

2.3 Performance assessments of technologies

The process for defining generic specifications and the assessment for incident detection is performed for several innovative technologies and summarised in Table 9 - Table 12. Table 9 shows the performance for accident detection by 2020. The performance for the detection of vehicle breakdowns is similar (except for eCall) and not included here. The detection rate of eCall and cooperative systems is low due to the estimated low penetration rates by 2020. Performance significantly improves with the penetration rate (Table 10). Another disadvantage for eCall is that it only provides data on major accidents thereby reducing the detection rate for all accidents considerably.

Table 9: Performance assessment of technologies for accident detection by 2020 (Table 16, [2])

Technology	*DR*	*DT*	*FAR*	*LA*	*Vehicle Class & Dangerous Goods*	*Suitability*
eCall	Low	Medium	Low	High	Both	Low
Cooperative Systems configuration 1 (ITS G5 + RIS)	Low	Low	Low	Very High	Both	Low
Cooperative Systems configuration 2 (3G)	Low	Medium	Low	Very High	Both	Low
Nomadic Devices	Medium	High	High	High	No	Medium
Scanning Radar	High	Low	High	Very High	No	High
Video Tracking	High	Low	Medium	Very High	Both*	High

* Vehicle class, Dangerous goods by manual inspection of video

Table 10: Performance assessment of technologies for accident detection by 2030 (Table 17, [2])

Technology	*DR*	*DT*	*FAR*	*LA*	*Vehicle Class & Dangerous Goods*	*Suitability*
eCall	Medium	Medium	Low	High	Both	Medium
Cooperative Systems configuration 1 (ITS G5 + RIS)	High	Low	Low	Very High	Both	Very High

The performance for various approaches to congestion detection are summarised in Table 11 and Table 12. The detection rate of road side tracking systems (video, radar) is very high because the detector spacing is chosen to provide full coverage of the road. Similar detection rates can be achieved with tracking equipped vehicles when the penetration rate is sufficiently high.

Table 11: Performance assessment of technologies for Automatic Incident Detection, moving jam detection, congestion and stationary jam detection by 2020 (Table 25, [2])

Technology	*DR*	*FAR*	*DT*	*LA*	*Suitability*
Road side AID (existing systems)	Medium	Medium	High	Low	Low
Vehicle tracking with Cooperative Systems	High	Medium	High	Medium	Medium
Vehicle tracking with Nomadic Devices	High	Medium	High	Medium	Medium
Scanning Radar	Very High	Medium	Medium	Medium	Very High
Video Tracking	Very High	Medium	Medium	Medium	Very High
Data fusion of traffic data and vehicle tracking	High	Medium	Medium	Medium	High
Cooperative Systems – V2V TJAW	High	Medium	High	Medium	Medium

Table 12: Performance assessment of technologies for Automatic Incident Detection, moving jam detection, congestion and stationary jam detection by 2030 (Table 26, [2])

Technology	*DR*	*FAR*	*DT*	*LA*	*Suitability*
Vehicle tracking with Cooperative Systems	Very High	Medium	Medium	Medium	Very High
Cooperative Systems – V2V TJAW	Very High	Low	Medium	Medium	Very High

3 Use Cases

This section shows how the generic specifications enable the selection and assessment of alternative technologies to improve the detection performance for a specific Use Case in a cost effective way. This process consists of the following steps:

1. Extend the Use Case of an existing situation with requirements and priorities for the desired situation.
2. Alternative technologies are selected that best match the requirements. System configurations are sketched to integrate a technology, or a combination of technologies, into the existing system. The generic specifications allow adapting system configuration parameters to meet the requirements.
3. A quick qualitative assessment of the cost and benefits is made for alternative system configurations.

The qualitative assessment is based on generic specifications of technologies from section 2. The outcome is a short list of technologies that are most relevant candidates for a specific Use Case, and serve as a starting point for a more detailed assessment by an NRA.

Many Use Cases can be defined. Five of the most relevant and common Use Cases for European NRAs (Table 13) have been assessed in section 6 from [2].

Table 13: Most relevant Use Cases

Use Case	*Road Network*	*Traffic Volume*	*Existing Systems*
1	Motorway without hard shoulder	High	Inductive loops @ 500m
2	Motorway with hard shoulder	High	Electronic Tolling system
3	Motorway with hard shoulder	Low	-
4	Secondary road	High	-
5	Secondary road	Low	-

Several sets of requirements can be formulated for every Use Case, for example to improve the detection performance for one type of incident, or for a combination of incidents, or to reduce costs. The results will obviously be biased by the requirement set. The conclusions and recommendations on the feasibility and cost-effectiveness of new technologies should be interpreted as examples of the methodology, and are therefore not included as conclusions and recommendations on the technologies in this final report. Instead, the next subsection summarises the assessment for Use Case 1 to exemplify the process.

3.1 Example: Use Case 1

As an example here, the Use Case 1 is defined by a motorway without a hard shoulder, or with the hard shoulder used as an extra lane, with high volume traffic and with existing inductive loops at 500m spacing and a CCTV monitoring system. The requirements are set as an example only, and should be adapted by the NRA.

3.1.1 Requirements

The absence of a hard shoulder or refuge area significantly increases the impact on safety, congestion and incident response. Any accident or breakdown will block a running lane and result in immediate congestion and a high risk of secondary incidents.

The priority for performance requirements are:

- (Very) high detection rate (> 90 % and at least > 80%)
- Low detection time (< 10 sec and at least < 1 min) for accidents and breakdowns.

A medium false alarm rate and additional workload for traffic operators is acceptable.

High location accuracy is required to distinguish the lane in which the accident occurs. The operator also needs to know the classes of the vehicle(s) of the accident, especially whether a heavy good vehicle or dangerous goods are involved.

The means for immediate verification of incidents is required. Video cameras are required along the road segment for immediate verification of incidents unless the operator has other means of verification.

Requirements for congestion detection have a lower priority than for accidents and breakdowns. If any additional technology would still be needed, then the costs will be the primary criterion for selection.

Table 14: Options for new technologies (Table 30, [2])

Option	Technology	Suitability				Costs		
		Accidents	Break downs	AID	Conges-tion	Setup	Maint.	Oper.
1	Inductive Loop Detectors							
	Upgrade for tracking	Low	Low	Low	High	€	No extra costs	
	Fusion of ILD and RS tracking			High				
2	eCall					€	€	€
	2020 (PEV = 10%)	Low*)						
	2030	Medium*)						
3	Nomadic Devices					€	€	€€€/€
	events	Medium	Medium					
	RS vehicle tracking of nomadic devices			*Medium*				
	Traffic Data, FCD, Travel time data				Medium			
4	Cooperative systems							
	Configuration 1 (ITS G5)					€€	€€	0
	2020 (PEV = 5%)	Low	Low	Medium	High			
	2030	Very High	Very High	Very High	Very High			
	Configuration 2 (3G)	Low	Low	Medium	High	€	€	0
5	Video Tracking (upgrading CCTV system)	High	High	Very High	Very High	€€	No extra costs	
6	Scanning Radar	High	High	Very High	Very High	€€€	€	€€€/€

*) provides only events for major accidents

3.1.2 Options for incident detection systems

The assessment includes 6 options with good prospects (Table 14).

Accident and Breakdown detection

1. A cooperative system using ITS G5 short range communication has potentially the best overall performance for accidents, breakdown and congestion detection of all technologies considered (section 4.2). The detection rate does not meet requirements in 2020 due to the low expected penetration rate of equipped vehicles. The penetration rate is expected to be high enough by 2030 to provide a complete solution for all three incident classes.

   The NRA would have to install cooperative Road side ITS Station (RIS). A conservative estimate of the required density of 1 RIS every 800 – 1000m is used in this report. Alternative communication protocols would allow fewer RISs. The setup and maintenance costs for cooperative road side systems are amongst the cheapest road side systems considered, provide the best quality incident data, and the most cost-effective technology.

   Cooperative vehicles can also communicate via 3G, 3.5G or 4G to back offices of service providers or traffic centres. It is considered unlikely that the CAM messages used for vehicle tracking and AID will be communicated via cellular networks. It is not standardised yet that event messages for accident, breakdown and congestion will be communicated via 3 – 4 G. Potentially, these messages could also be sent by cooperative vehicles to service providers and provided to road operators for incident detection. In this case, the major difference with G5 communication media is the increased detection time.

The emerging technologies for eCall, cooperative systems and nomadic devices can provide a relatively inexpensive solution for incident detection, but can only meet the required detection performance after 2020 (e.g. 2030). To provide a complete solution by 2020, the NRA has to install additional road side detection systems. Two options can be suggested in combination with the existing CCTV cameras.

2. The existing CCTV camera system can be upgraded to a video tracking system. This is a cost effective solution to reduce setup costs and would not increase the existing maintenance and operations costs. The image processing software has to be replaced. If the spacing between the CCTV cameras is to larger (i.e. > $DENS_{RST}$) then additional cameras will have to be installed, which will increase the setup costs.

   In this case, additional solutions may be required during adverse weather conditions if the data from eCall, nomadic devices or cooperative systems is insufficient.

3. If the degraded functionality of video tracking under adverse weather conditions cannot be compensated with technologies selected from options 1-4, then the scanning radar provides a good alternative. Scanning radar provides a high detection rate comparable to video tracking under all weather conditions. The FAR of scanning radar is higher than video tracking, but that may be acceptable. In high density traffic, the spacing of scanning radars should be reduced to reduce occlusion. The setup costs would be higher than the upgrade of the video systems. Scanning radar cannot be used for incident verification, but the existing CCTV system provides just that.

Congestion detection

The existing loop detection system in combination with alternatives like the nomadic devices or cooperative systems provide the required detection performance. No additional detection technologies are needed for AID, jam or congestion detection.

3.1.3 Assessment of system configurations

Upgrading the loop detectors for vehicle tracking seems an obvious first choice. However, this system does not meet the detection rate required in high volume traffic situations and an alternative technology is required. The existing inductive loop detections can be combined and after 2020 gradually replaced by other detection technologies.

The following alternative system configurations can be proposed by combining options that provide cost effective solutions. All options are combined with the existing inductive loop detectors, CCTV system and eCall.

A. Nomadic devices provide a relatively inexpensive solution to improve the detection performance for accidents, breakdowns and AID. The requirements for the detection of accidents and breakdowns are not fully met though; i.e. the detection rate, detection time and false alarm rate.

   Data fusion of vehicle tracking data from nomadic devices can improve the detection performance of automatic incident detection significantly. This would require that the nomadic devices or cooperative vehicles are tracked and that this track data is available to the NRA for fusion with loop data. The costs for the NRA for using nomadic device data are relatively low.

   Nomadic devices, and fusing the track data with existing loop data, would provide the least expensive solution if medium detection performance is acceptable. The detection performance of data from nomadic devices is not expected to improve significantly after 2020 and do not provide a scenario to gradually replace the inductive loops.

B. A replacement strategy can be initiated by introducing cooperative systems in addition to the system configuration of 1. By 2020, the cooperative system will already be operational, and the detection rate will gradually increase with the penetration rate of cooperative vehicles. The inductive loops can gradually be abandoned when the penetration rate of cooperative vehicles reaches 45% (section 5.3 from [2]) and can replace AID.

   The system configuration requires a higher setup cost for the NRA than option 1. The operational costs will be much smaller though, due to the much lower false alarm rate. Detection performance will improve significantly to option 1; i.e. the detection rate will become higher, the detection time for accidents and breakdowns will be smaller, the incident location can be set to lane level accuracy and relevant vehicle information (vehicle class, dangerous goods) is obtained automatically.

C. The previous configurations will not provide the required detection performance by 2020. The only remaining option to realize the detection performance for accidents and breakdowns by 2020 is to install road side detection systems for vehicle tracking.
   a. The least expensive configuration is to upgrade the existing CCTV systems for video tracking. This configuration cannot provide the performance under adverse weather conditions when the detection rate of video systems degrades.
   b. Alternatively, scanning radar systems can be installed along the motorway section. The CCTV cameras remain in use for incident verification.

   This configuration makes the inductive loops redundant.

4 Recommendations on innovative technologies

4.1 eCall

eCall will work on the entire road network and is a good detection technology in any use case for major accidents, even by 2020 when the penetration rate is still low. eCall will be mandatory in all new vehicles and operational by 2020. The penetration rate is estimated to be PEV_{eCall} = 10% by 2020 and is likely to increase further without additional costs for NRAs. eCall will provide high quality detections of emergencies and major accidents at a relatively small cost for the NRA. The detection quality will be similar to other in-vehicle data from cooperative systems or from more expensive road side systems. Following assessments can be made:

- The detection rate of major accidents is proportional to the penetration rate of equipped vehicles, and is likely to become very high after 2020.
- The false alarm rate for major accidents will be low, as the detections are generated by the proper in-vehicle systems and filtered by a PSAP.
- The NRA may have to invest to integrate eCall information from the PSAP into the traffic management and control environment. This is an opportunity to make sure that the time delay for data exchange is minimal and that all information relevant to incident management is included. This will have a significant impact on the detection time (DT).
- eCall is only intended for emergencies and can only provide automatic detections of major accidents. Alternative technology will be required for minor accidents.

4.2 Cooperative Systems

Cooperative systems have potentially the best overall performance for accidents, breakdown and congestion detection of all technologies considered. The basic set of cooperative applications includes accident, breakdown and congestion detection. These events are detected by in-vehicle systems and provide a reliable and high quality data source for incident detection for the NRA, with a very high detection rate for equipped vehicles, low detection times and false alarm rates, and accurate location and vehicle information.

Cooperative systems are not mandatory like eCall and are likely to have a lower penetration rate by 2020, which is estimated to be PEV_{V2I} = 5%. This low penetration rate implies that the detection rate for the NRA cannot meet the requirements by 2020 and other (existing) detection technologies may still be required.

It is likely that the penetration rate will increase after 2020 to similar levels as eCall because new vehicles and aftermarket systems are likely to increase. When the penetration rate is high, cooperative systems can meet the performance requirements for all three incident classes, and no other detection systems would be needed for the three incident classes considered.

The event-based information for the incidents is most likely communicated via ITS G5 WiFi (IEEE 802.11p) between vehicles. The NRA would have to install new road side units with Road side ITS Stations (RIS) along the motorway sections. There are several implementation strategies possible:

- A conservative estimate of the required density of 1 RIS every 800 – 1000m is used in RAIDER [2]. This density would fully cover the motorway section to communicate to every Vehicle ITS Station directly. This is the most expensive solution taken in RAIDER.

- Alternative communication protocols are being developed and standardised for multi-hopping of event messages and collecting probe vehicle messages. This enables vehicles to store and forward event messages over distances longer than the G5 communication range, and to deliver the event messages when passing a remote RIS. The number of RISs could potentially be reduced significantly within the required detection time of 10 sec or 1 min.

In any case, the setup and maintenance costs for cooperative road side systems are amongst the cheapest road side systems considered. Nevertheless, this system configuration is only relevant when the detection of accidents and breakdowns is required. If only congestion should be detected, other technologies are more cost-effective.

If a road segment is not equipped with road side units, then cooperative vehicles may still communicate events on accidents and breakdowns via cellular networks (3, 3.5 or 4G) to back offices of service providers or Road authorities. It is not standardised if and how this communication medium should be used for events though. If 3-4G communication will be used, then the NRA could still receive the incident event messages with some additional increase in the detection time for incident detection.

4.3 Nomadic Devices

Nomadic devices can provide event data for accidents and breakdowns, and various types of data for congestion detection. The nomadic devices send the data to a back office of a third party service provider or an NRA. The system configuration is essentially a centralized approach via the cellular network communication and the back office. This is essentially different from the cooperative systems technology:

- The centralized data flow via the cellular network and a back office increases the detection time, which is particularly critical for the detection of accidents and breakdowns.
- The centralized data flow is vulnerable to the communication performance of the cellular network, and communication downtime is not uncommon. The reliability of the system is significantly less than that of an ITS G5 communication network.
- The setup and maintenance costs for the NRA will be relatively low, because the NRA does not have to install road side units along the road network.

There are a few disadvantages expected with detection performance:

- Although the penetration rate of the devices is expected to be very high by 2020, the effective penetration rate from which the NRA will receive incident data may be much lower. This is due to the wide variety in applications and service providers that a user of a nomadic device can choose from. This effective penetration rate is estimated at 25% for accident and breakdown event data, and at 5% for traffic, travel time and floating car data.
  - For congestion detection, the low PEV may not be an issue.
  - The detection rate (DR) for accident and breakdown detection is proportional to the PEV and is insufficient.

  The only solution to increase the PEV is to concentrate the data to only a few application or service providers, for example through an electronic market or data warehouse. This option is not taken into account here though. Hence, the suitability of the technology is rated as medium to all incident classes.
- Nomadic devices are not directly connected to in-vehicle systems[1] that detect accidents or breakdowns reliably. Instead, accidents and breakdowns should either be detected

[1] This is technically possible and considered as a cooperative system in this project.

from sensors on the nomadic device, or manually reported of the user. Both solutions will result in higher false alarm rates than the detections from eCall or cooperative vehicle systems.

- The detection time for receiving accident or breakdown detections is high due to the standard communication frequencies and data processing via the service providers. Technical solutions should be used to reduce the detection time to maximum 1 minute to be used for accident and breakdown detection by the NRA.
- Service providers can also provide traffic data, FCD and travel time data. When the effective penetration rates remain low (e.g. 5%), the congestion will be detected, but with increased detection time and decreased location accuracy. A service provider may improve the location accuracy when the penetration rate of devices increases well above 5%.

This makes the nomadic devices particularly suitable in Use Cases with a higher priority on cost minimisation and congestion, and lower priority on accidents and breakdowns.

4.4 Road side tracking systems

Video tracking and scanning radar systems are innovative technologies to improve road side based incident detection. It is estimated that eCall, cooperative systems and nomadic devices cannot provide the required detection performance for accidents and broken down vehicles by 2020 due to the estimated low penetration rates of equipped vehicles. It can be expected that the penetration rate will increase and meet the detection requirements after 2020, e.g. by 2030. Meanwhile, video tracking and scanning radar systems are the only detection technologies considered that can provide the required performance. The setup costs for these road side systems can be significantly higher though.

There is no objective motivation for a preference between video tracking and scanning radar systems. To provide similar detection performance, the setup costs of a new video tracking system is higher than of a new radar scanning system. Under adverse weather conditions, the scanning radar system will also perform better. However, a scanning radar system does not provide the capability for incident verification like video cameras. If additional CCTV systems need to be installed anyway, video tracking is the more cost-effective concept. This is especially the case if an existing video monitoring system can be upgraded.

5 Conclusions

A methodology is developed to improve the performance of incident detection systems on motorways and secondary roads in a cost effective manner. Incident detection is improved by using new technologies for roadside detection, and utilizing cooperative in-vehicle systems and nomadic devices. The new technologies are either used to setup new detection systems, or to retrofit or upgrade existing detection systems.

The methodology is based on the concept of generic specifications. A generic specification defines the configuration of a detection system, including its main components and the main features of these components, such as the technologies used, data fusion and incident detection algorithms, and the main configuration parameters such as the penetration rate of equipped vehicles or the spacing and coverage of road side detectors. The performance and costs are parameterised as functions of the main configuration parameters of the generic specification. The generic specifications provide a framework for qualitative assessment of the improvements in detection performance and the effects on the costs.

The generic specifications enable a road authority to select new technologies, system concepts and configurations for setting up a new system, or for upgrading or retrofitting existing systems. The generic specifications also enable the qualitative assessment of the improvements in performance and the associated effects on costs.

The User Needs and Requirements for incident detection systems are determined in consultation with stakeholders from National Road Authorities (NRA) in Europe and reported in [1]. Based on stakeholder input, the project has focused on three types of incidents (accidents, vehicle breakdowns and extraordinary congestion). Five Use Cases are selected that describing the typical existing situations of NRAs in Europe, and scenarios for the required improvement of incident detection capabilities on motorways and secondary roads are presented. In [2] the methodology is presented and applied for these Use Cases. The methodology provides the motivation to recommend new technologies for the Use Cases in terms of the qualitative improvements in detection performance and associated costs.

6 References

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