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

CEDR Transnational Road Research Programme
Call 2019

Safe Smart Highways

Preventing collisions with stopped vehicles in a live lane

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

Funded by the national road authorities of Austria, Belgium (Wallonia), Finland, Germany, Hungary, Ireland, the Netherlands, Sweden, and the United Kingdom (England), collaborating via CEDR.

SHADAR partners

- **Mott MacDonald**, United Kingdom
- **MAP traffic management**, Netherlands
- **Navtech Radar**, United Kingdom
- **Factum**, Austria
- **Chiltech**, United Kingdom

- **Supporters:** TomTom, GEWI, Vivacity Labs, BeMobile, Transport Scotland

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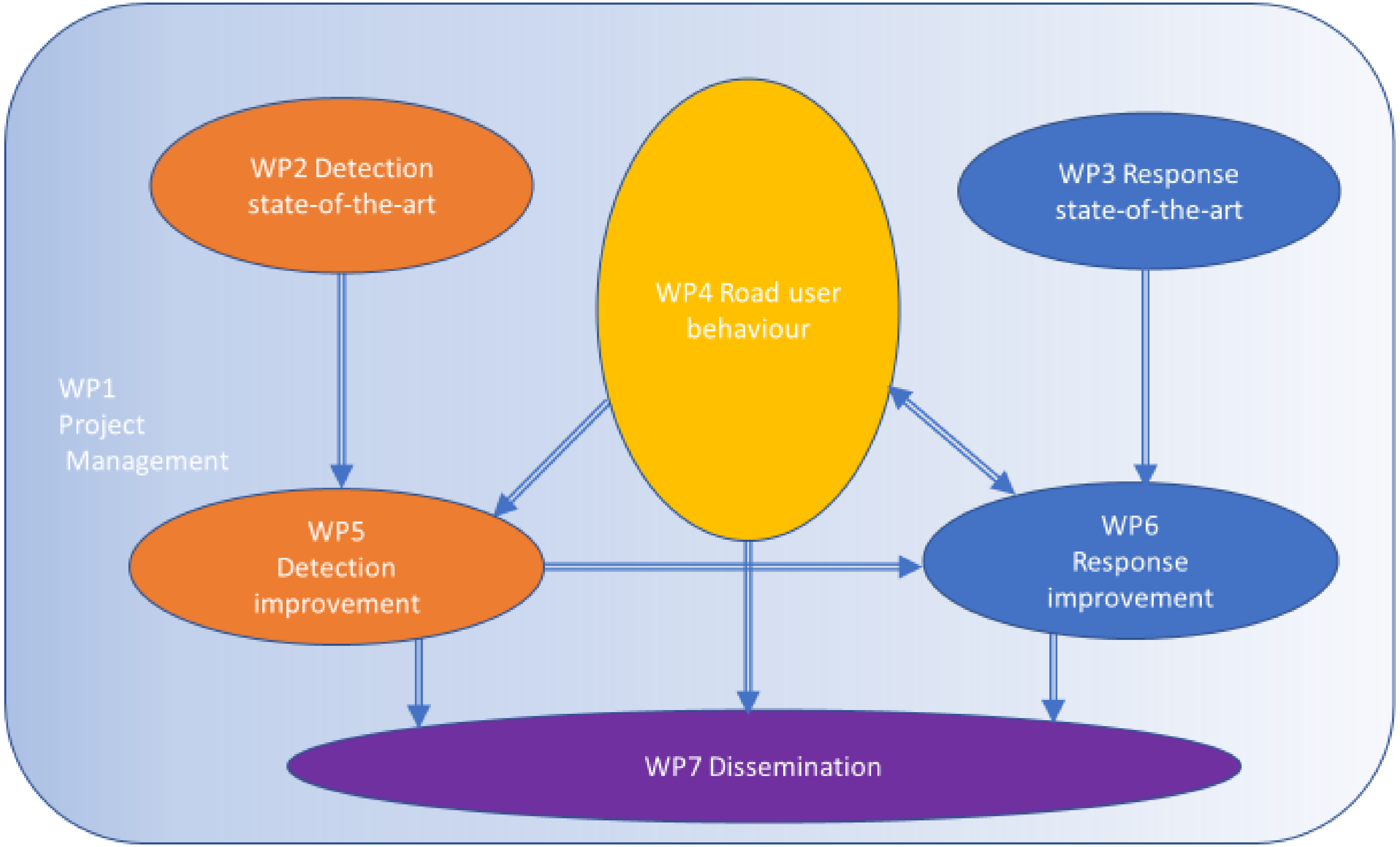
SHADAR research areas



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NAVTECH RADAR
Chiltech Limited
ITS – Telematics – Connected Car

Stopped vehicle hazards

Frequency and severity

- Recorded breakdowns on highways: thousands to tens of thousands per year per country.
- ~25% of those on a live lane (UK)
- + stops for many other reasons – collisions, obstructions, personal decisions

- Stopped vehicles the source of 1.6% of all fatal and serious accidents (Highways England, 2015).

Stopped vehicle detection (SVD)

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Stopped vehicle detection methods (survey of 8 countries)

Method	Usage
Phone call	Most countries (maybe all); ERTs or private calls
Social media	Waze used in several countries; 1 or 2 textual social media analysis
Traffic officers	Many countries have dedicated officers, others use police
CCTV	All countries have at least partial CCTV coverage, use for verification
AID cameras	Used mainly in tunnels, trials on open highways
Thermal cameras	Some usage in tunnels, minor local usage
Loops	Rare to be dedicated to SVD; common with low density, locally with high
Radar	Rotating radar dedicated to SVD in England, elsewhere local & general
LiDAR, Bluetooth, WiFi	No usage reported for SVD
Acoustic	Rarely used in tunnels
Floating vehicle data	Purchased from private sector, used operationally 2 countries, +R&D
C-ITS	Deploying operationally in Austria (+R&D in several countries)
eCall	Present in all; used in traffic operations in 3 countries

Stopped vehicle detection methods (survey of 8 countries)

- Multiple methods relying on human sight – widely used
- Multiple types of fixed sensors
  - – but *dedicated* SVD on open roads is uncommon
- Video analytics on existing traffic cameras seen as attractive – multi-purpose – but concern expressed over performance in unfavourable conditions
- Detection through connected vehicles less common – although several service providers offer relevant products
- Little quantitative evaluation published for any method, other than from limited trials.

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Stopped vehicle detection methods (survey of 3 SPs)

Responses reported by SPs

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

Detection Improvement

Further focus on newer detection sources

- Connected vehicle sources
  - via Data for Road Safety task force
  - via C-ITS
  - via private sector service provider APIs
- Social media
  - Twitter ⇩
  - Waze ⇧
- Aerial imagery
  - Satellites
  - UAVs

Waze / NDW study

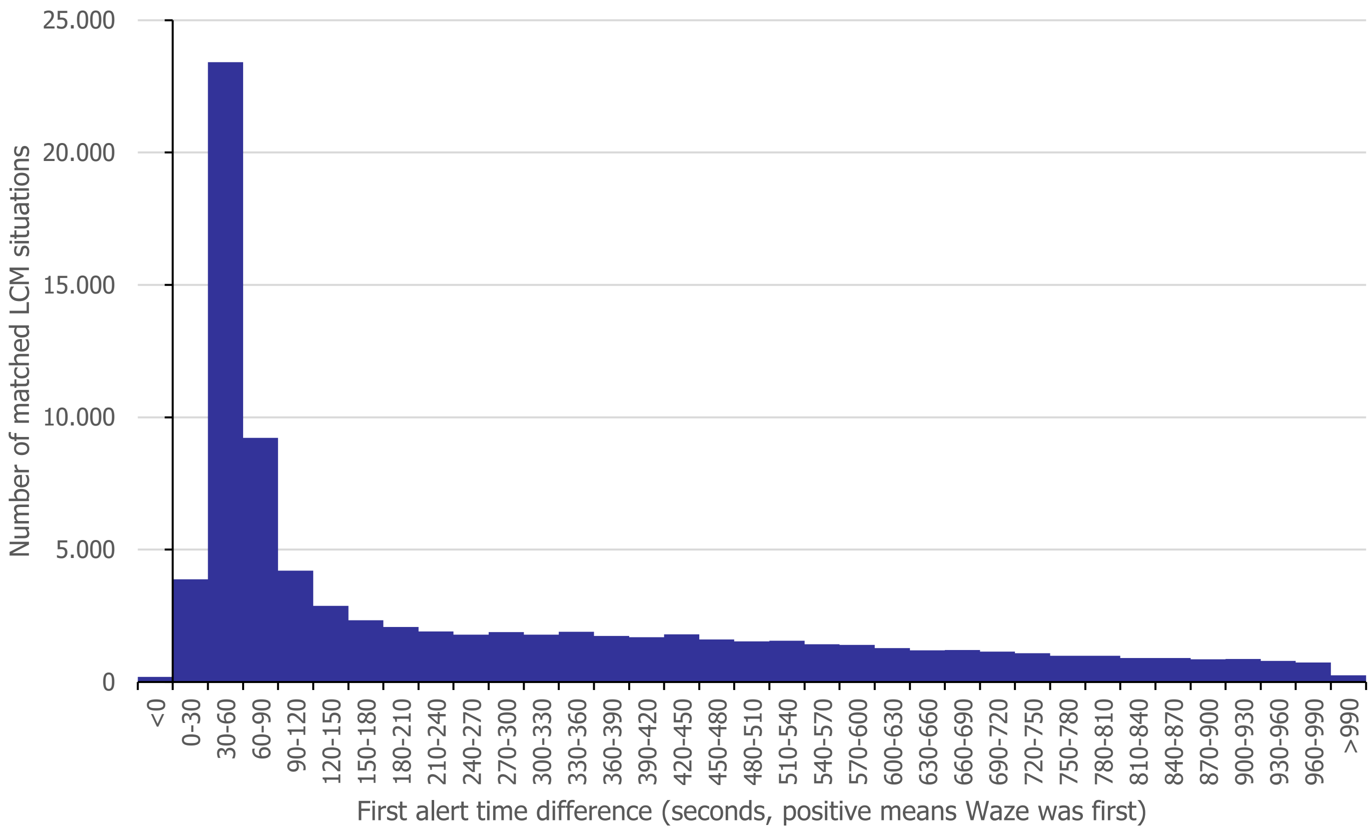
Data sample (2020) from NDW:

120,000 stopped vehicles

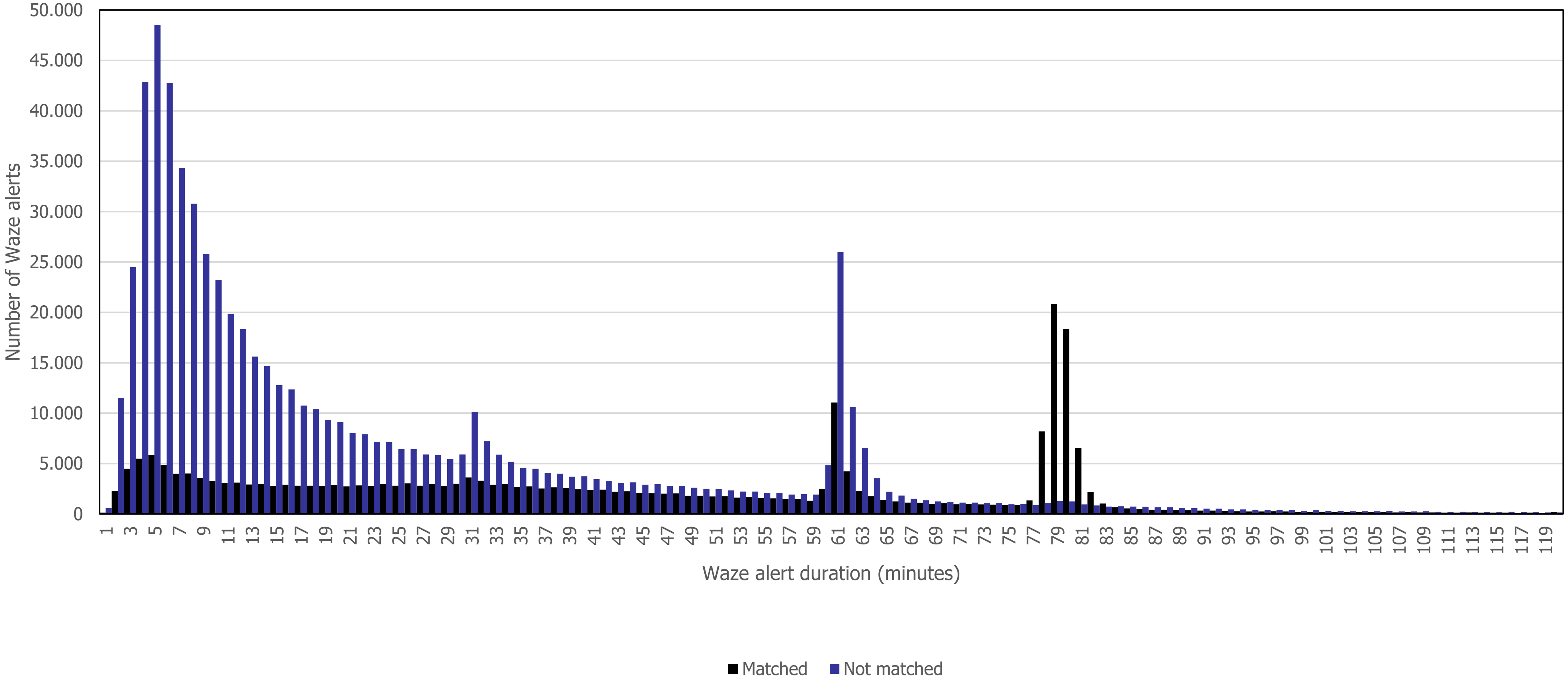
Data sample from Waze (2020, NL)

93% of NDW events matched to Waze alerts!

31% of Waze alerts matched to NDW events.

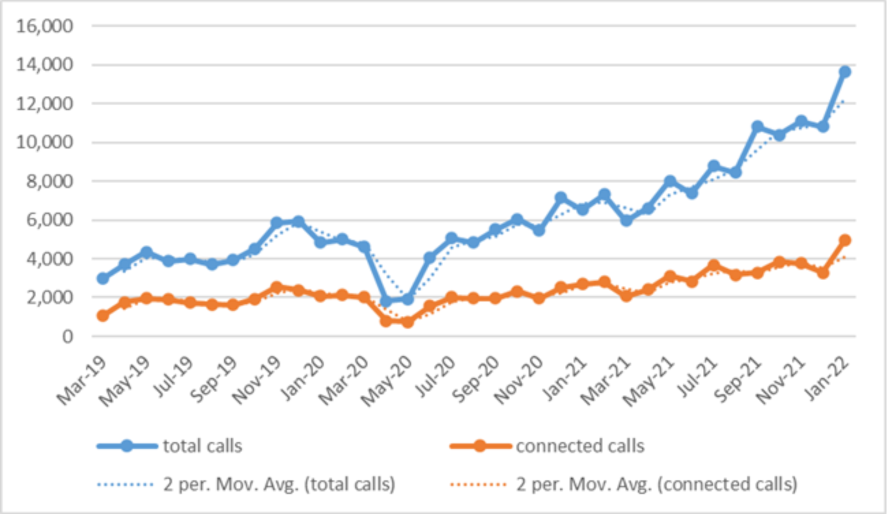


Waze / NDW study



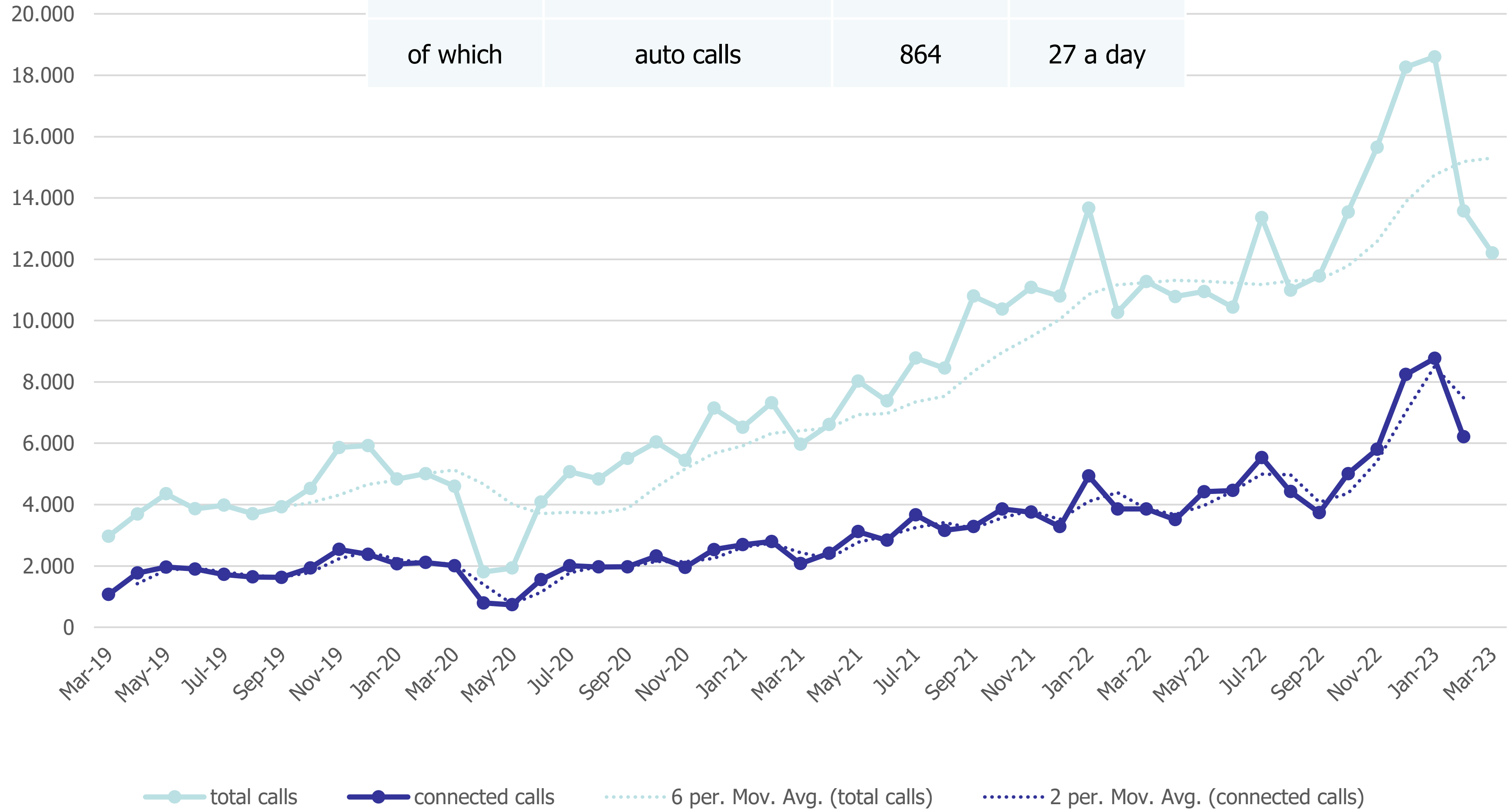
Detection through eCall

- Mandatory since 2018 (cars and light vans)
- eCall activations increasing (UK: >10,000 / month)
  - automatic activated -> strong confidence
  - manual activated -> less confidence
- Voice and **data** (enhanced through lookup):
  - Location
  - Vehicle classification
  - Fuel type (e.g. electric vehicles identified)
  - Number of occupants
- Can report events where there is no detection infrastructure
- Knowledge lacking in road users
- Systems can enhance data and reduce false alarms



eCall Volumes per month over 18 months (UK)

	calls to blue light	5,787	206 A DAY
of which	auto calls	864	27 a day



Radar

Rotating radar

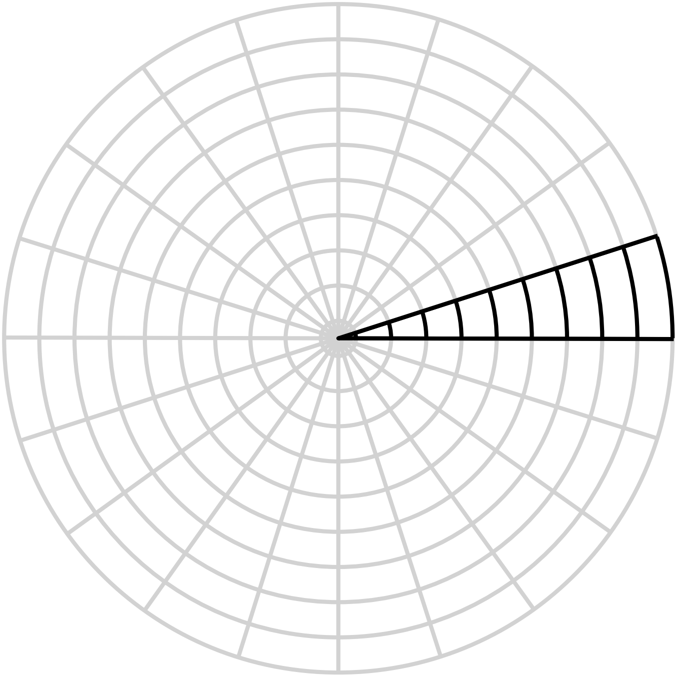
Technology specifications

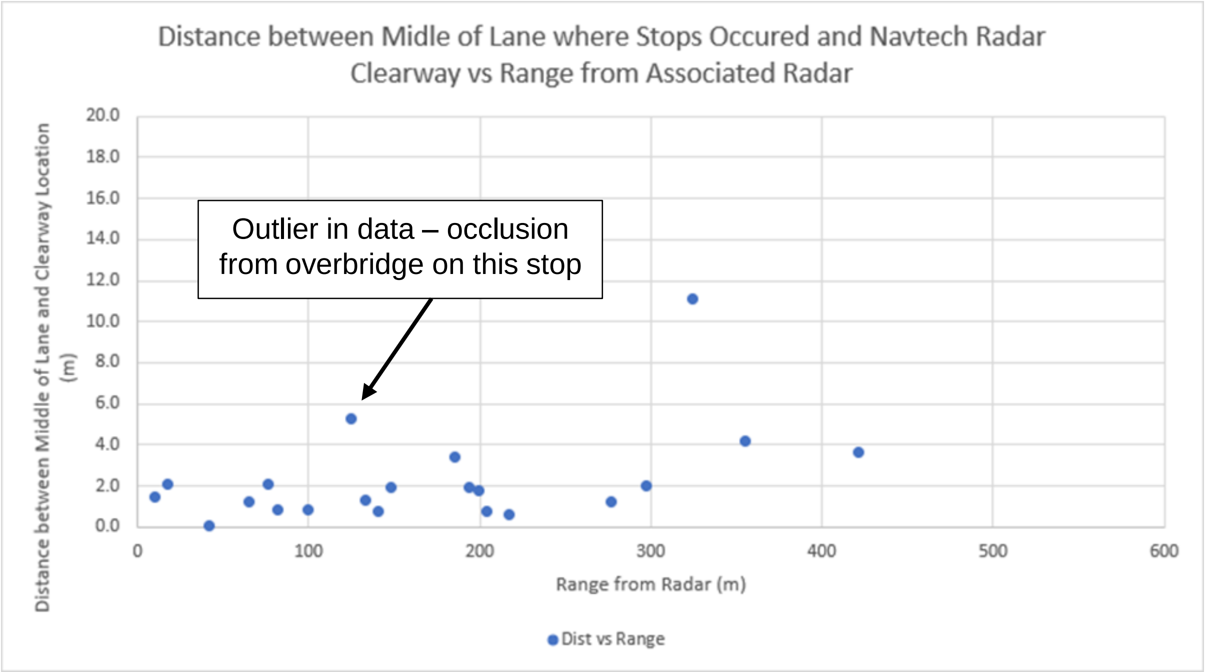
- Detection in fog, snow, rain, spray, smoke, all light levels - darkness to glare.
- Maximum operating range 500m

Radar deployment in England

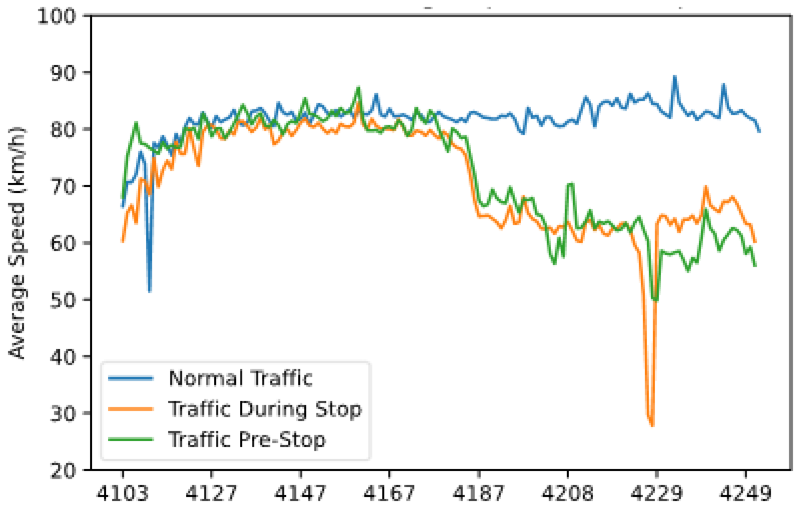
- Two operational pilots from 2016, 2018 covering ~40km
- Integrated alerts in traffic management system
- Initial trial found Detection Rate between 0.82 and 0.90 and a False Alarm Rate of 8.6%.
- Large scale operational deployment followed

RADAR improvement: Lane detection



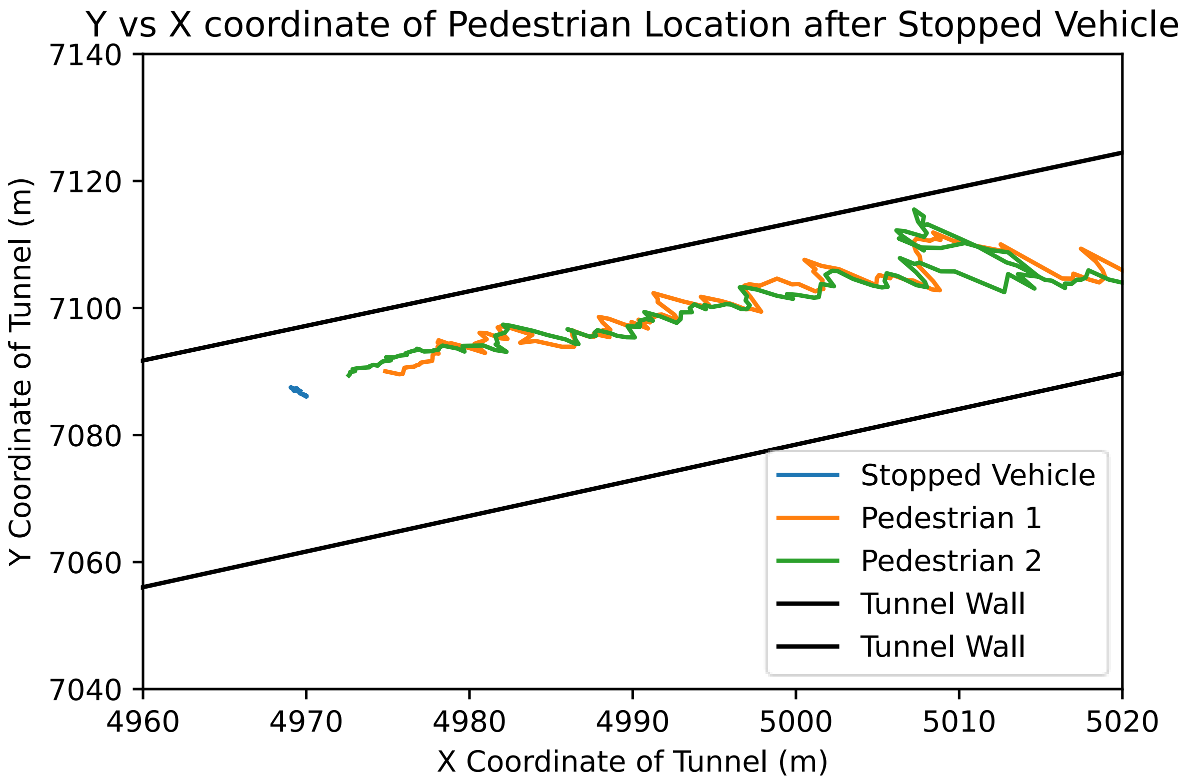


RADAR improvement: correlating tracked properties



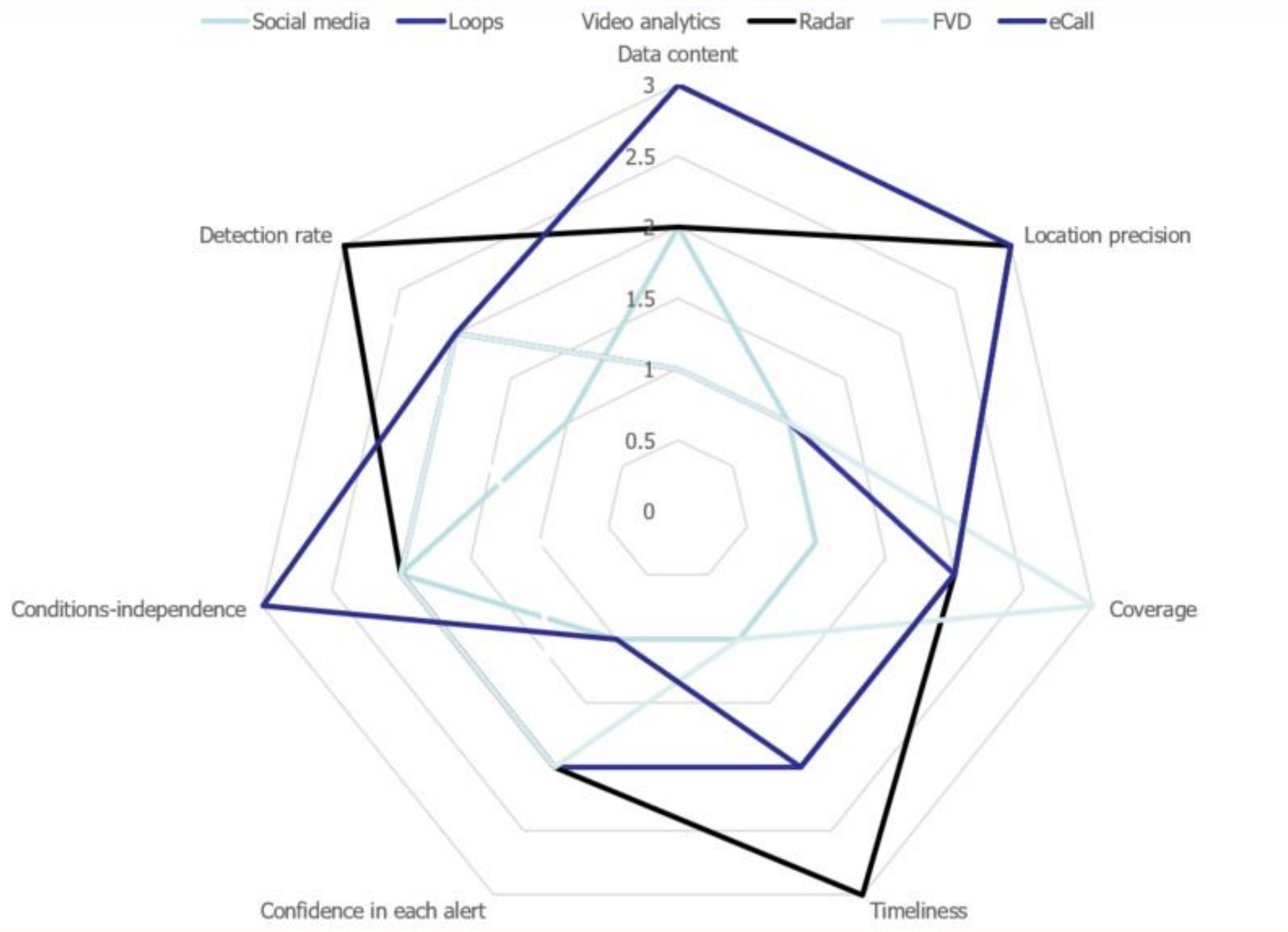
Slow vehicle (<25 km/h) alarm setting	Proportion of stops with preceding slow
>= 30m + >= 4 seconds	10%
>= 2 seconds	50%

RADAR improvement: Pedestrian detection



Stopped vehicle alert fusion

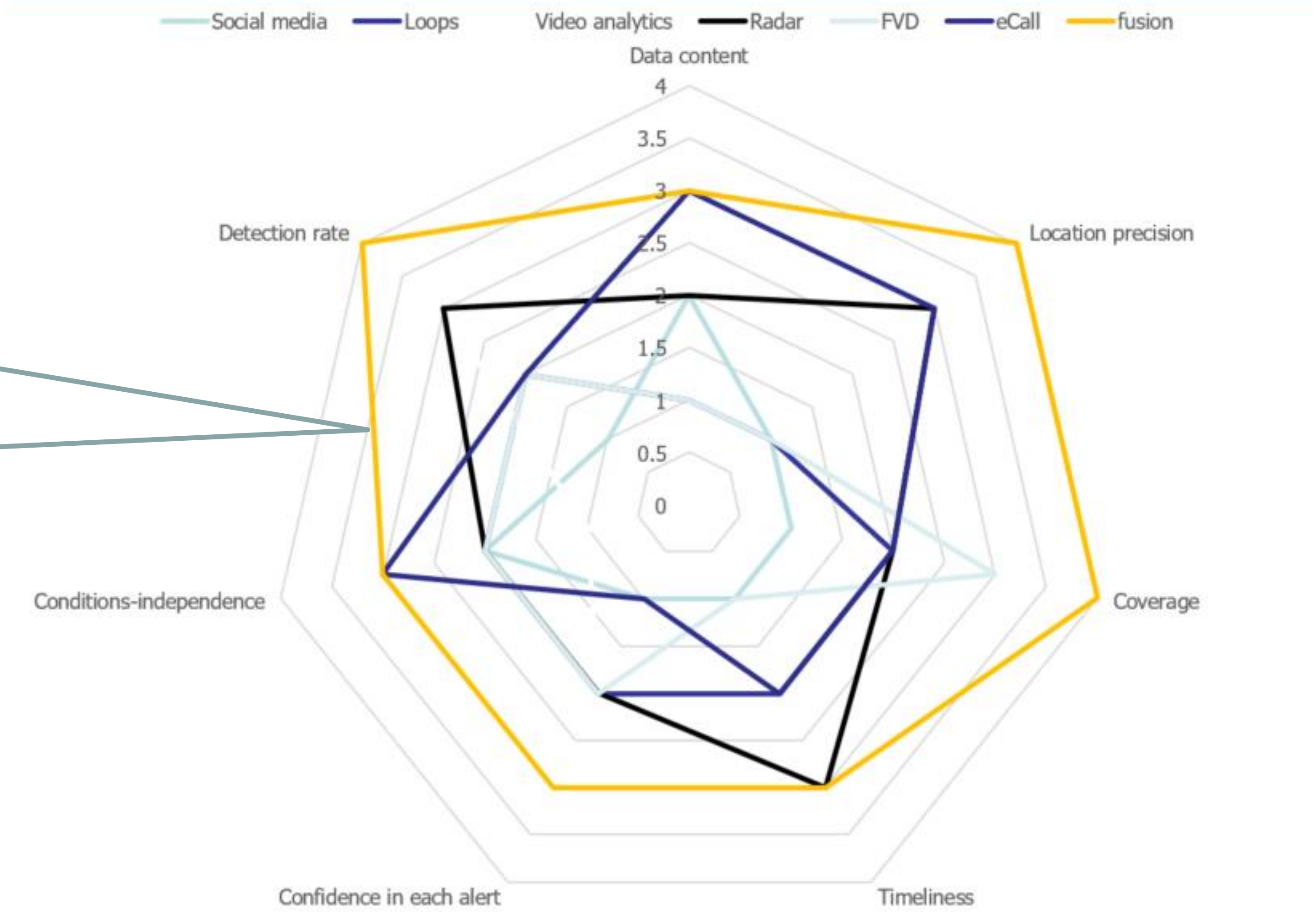
Simplified comparison against metrics



The numbers here are not scientific.
The point is that:
different detection methods
have different performance
on different metrics…

Fusion potential to improve on metrics

Data fusion from multiple sources has the potential to perform better than, or at least equal to, the best individual source on every metric.

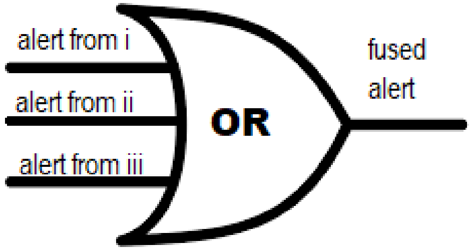


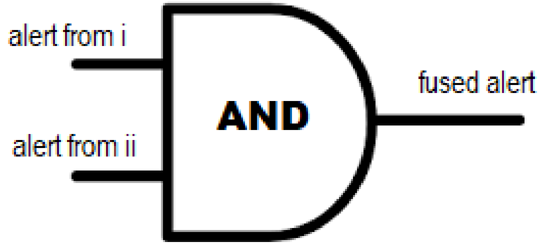
Statistical data fusion of stopped vehicle alerts

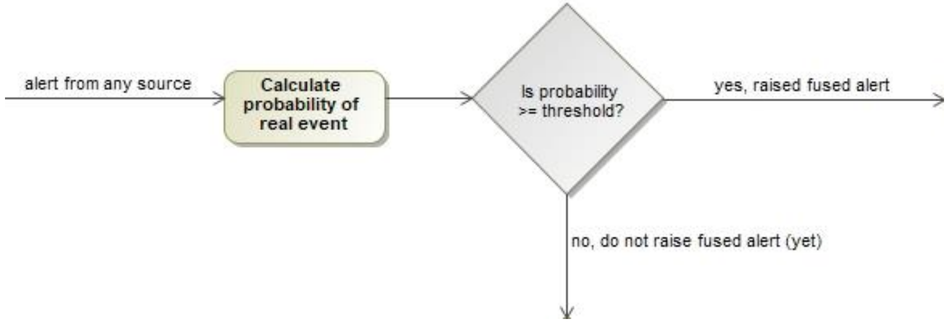
$$Detection\ Rate\ (DR) = \frac{True\ Positives}{True\ Positives + False\ Negatives}$$

$$Time\ to\ Detect(TTD) = interval\ between\ event\ occurrence\ and\ alert\ reporting$$

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







- We show how to calculate DR(***fused***), FAR(***fused***), TTD(***fused***)
  - to **understand performance achievable by fusing** candidate data sources.
  - to inform the choice of data sources to invest in – the most independent sources bring most benefit when fused.
- We show how confidence in a fused alert can be calculated from various factors (a priori or dynamic)
  - Use confidence to determine **how an alert is presented to an operator**

Fusion study on real data

A European highway, 3 months of co-located data from different detection methods.

- **Source A**: Data recording each true positive and false positive from source A, which had been verified by manual checking of camera footage.
- **Source B**: Data from traffic management system showing alerts raised by source B, with related operational actions.

	Source A	Source B
alerts in common locus	587	1930
human-verified	564	1355
false alarm/unverified	23	575
false alarm rate	4%	31%

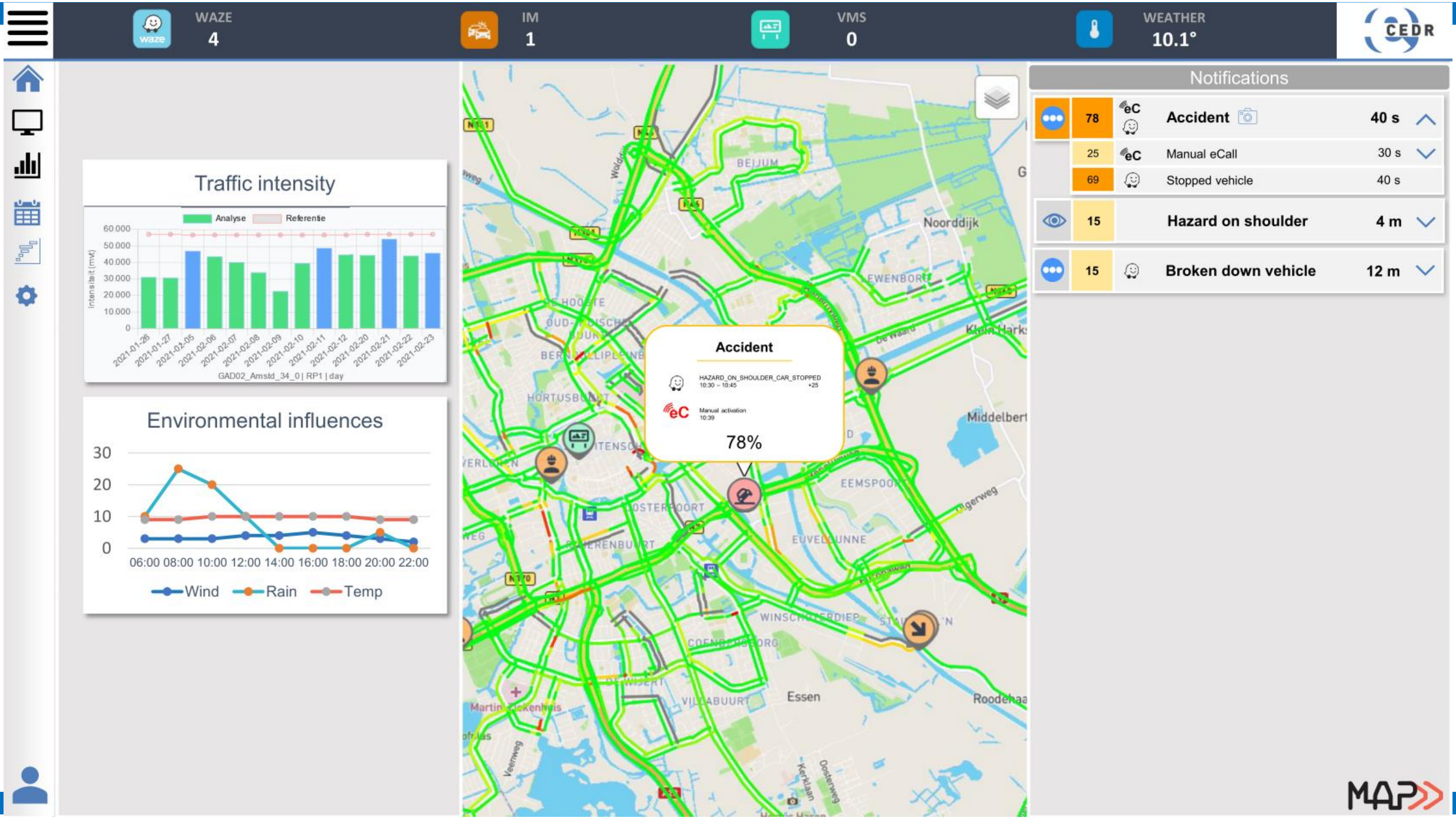
What fusion tells us, given assumptions

Inferring detection rate	Source A	Source B
Inferred detection rate	36%	82%
False alarm rate	4%	31%

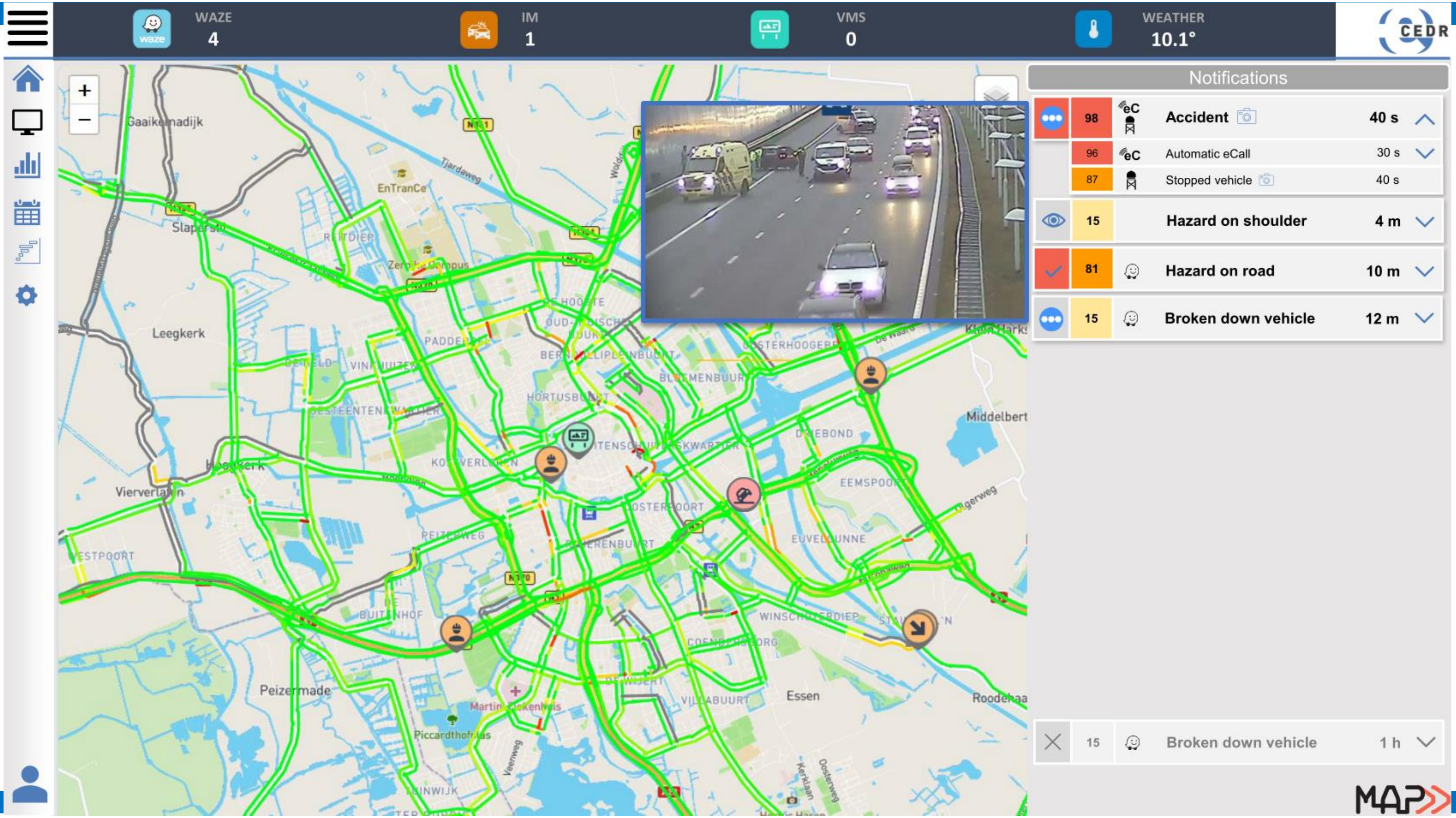
If fusion applied real-time	(max) DR	FAR
Source B alone	82%	31%
Sources fused (OR regime)	100%	27%
Sources fused (AND regime)	17%	1%

Confidence for alerts	Initially	Absence of other source confirmed	Both sources alert
Source A alerts first	96%	49%	99%
Source B alerts first	70%	56%	99%

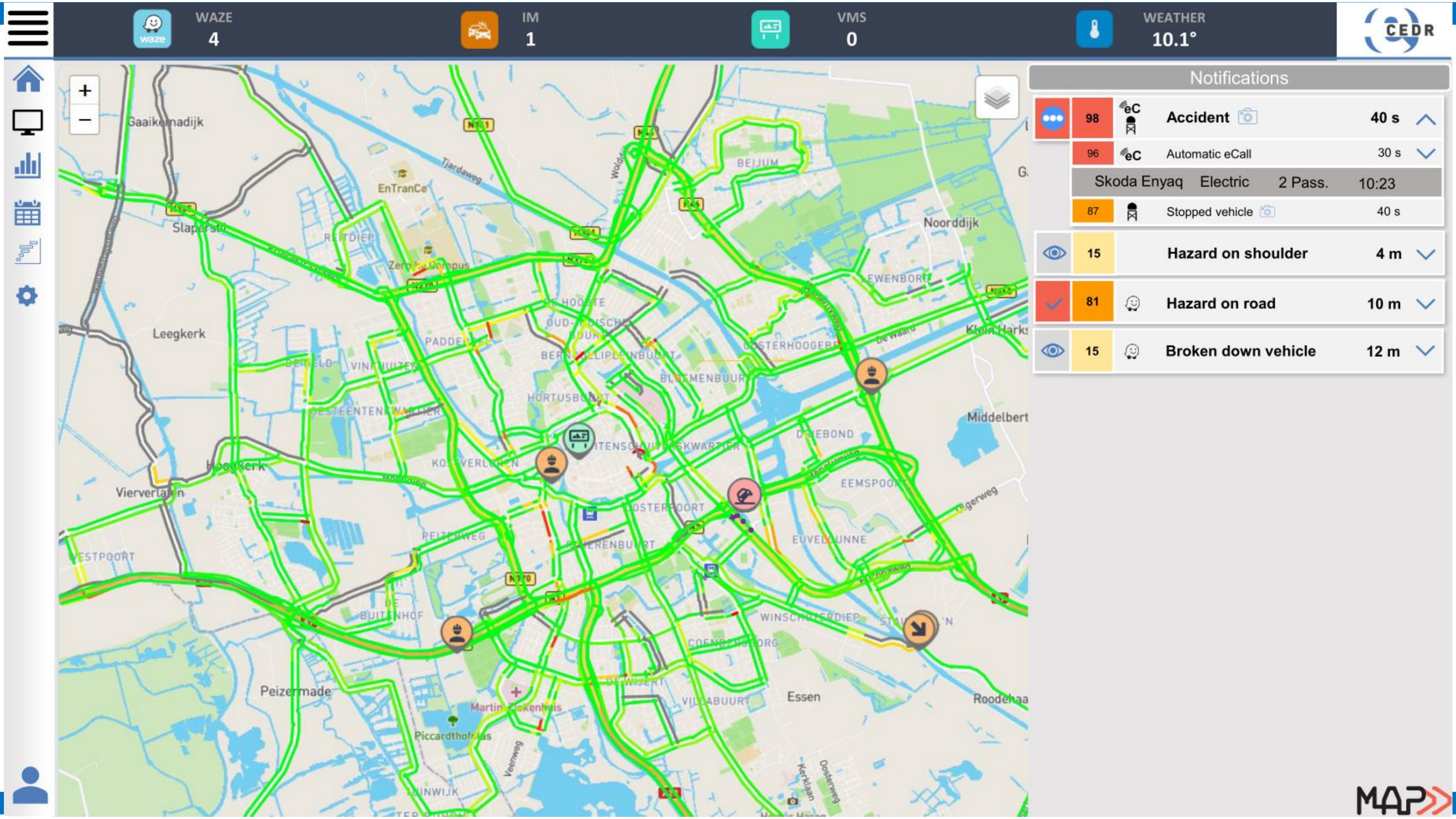
Reporting alerts - mockup



Reporting alerts - mockup



Reporting alerts - mockup

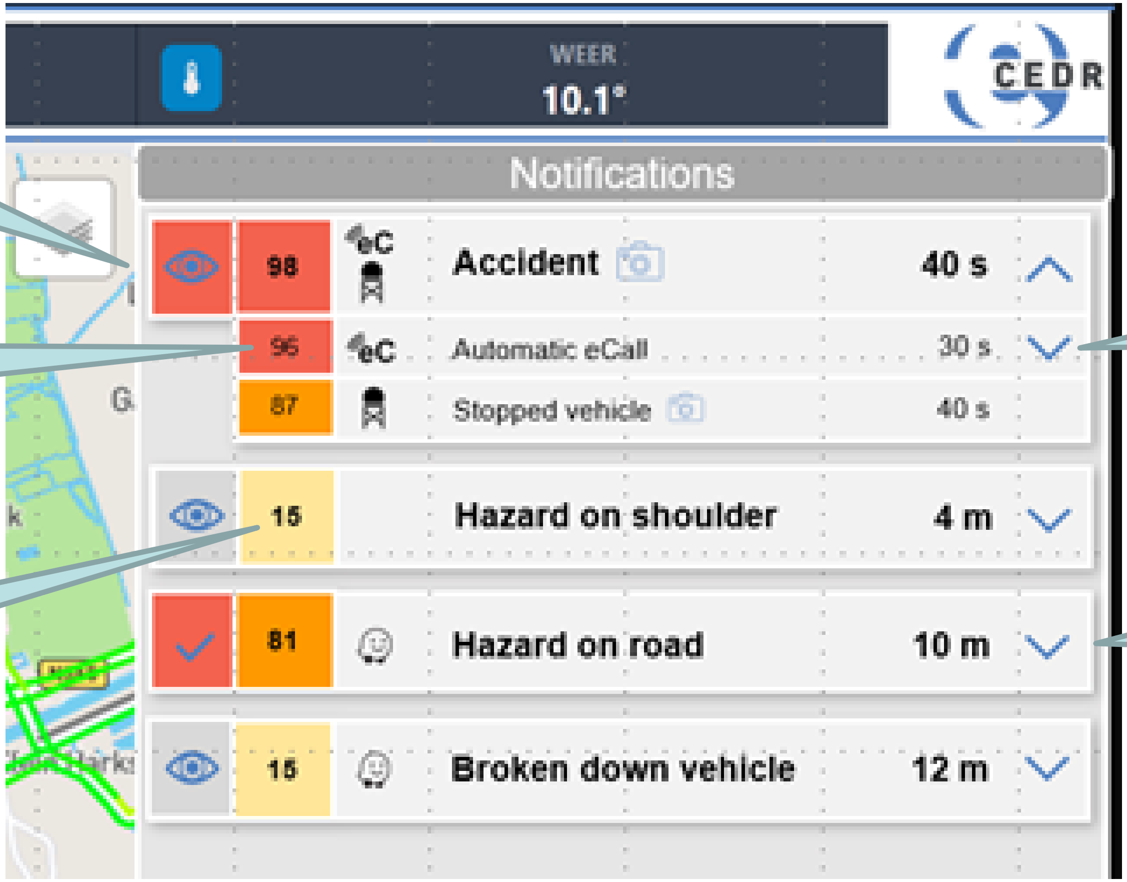


Fused alerts for traffic managers

Position indicating priority

Colour indicating confidence

Numeric confidence



Per-source details

Or collapsed summary

Technology performance reporting

These are not from real data, they are just to illustrate the kind of reporting possible

	Detection Rate (DR)	False Alarm Rate (FAR)	# unique true detections	# first to detect	mean time to detect (s)
Radar	85%	15%	87	530	15
Video	80%	15%	61	441	16
Waze	60%	10%	67	70	300
eCall	5%	40%	5	22	20
fused	95%	19%	-	-	15

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Technology performance reporting

These are not from real data, they are just to illustrate the kind of reporting possible

	Alerts confirmed true	Alerts with no stop confirmed	# unique confirmed alerts	# first to detect (confirmed event)
Radar	85%	15%	87	530
Video	85%	15%	61	441
Waze	90%	10%	67	70
eCall	60%	40%	5	22
fused	81%	19%	-	-

Technology performance management

Seeing different technology in same terms – useful, brings insight

- optimisation of existing technology
- informing new or continued investment decisions.
- informs confidence in the data sources.
- changes signal need for improvement in detection/verification

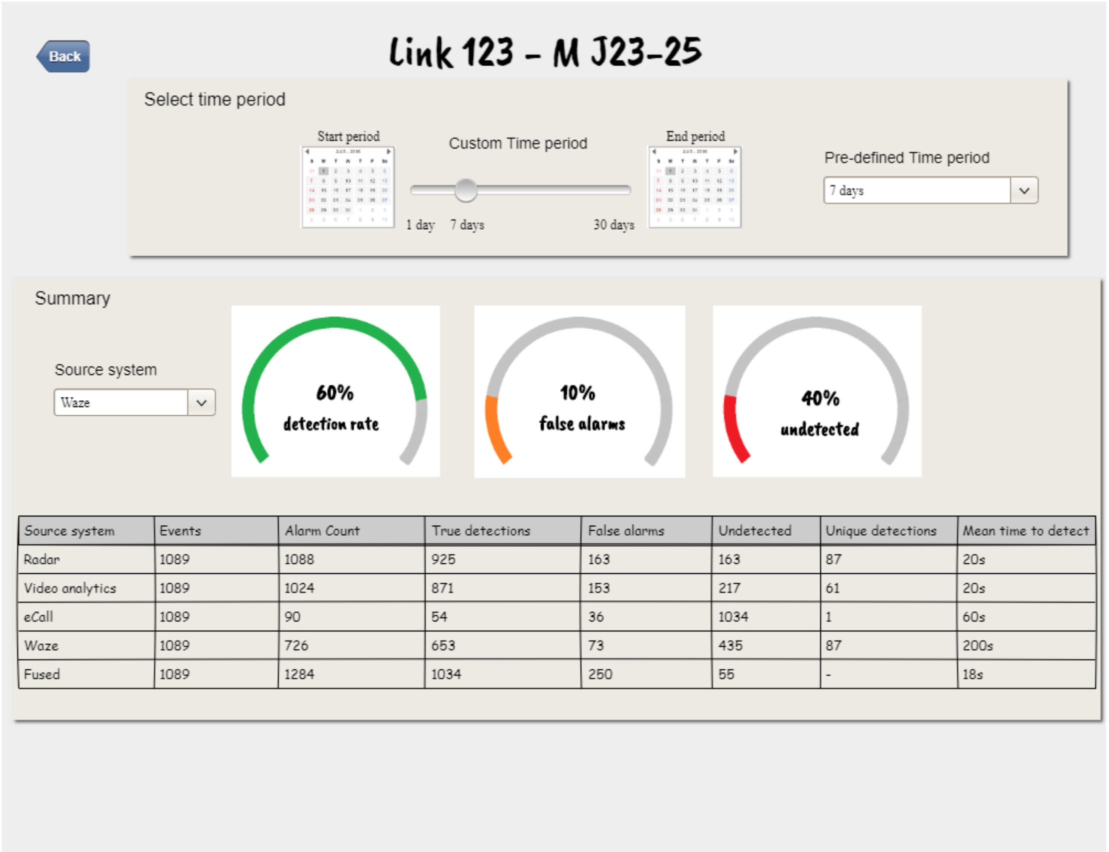
Ground truth important – especially when technology first introduced

- limit to what can be presented without ground truth data is important to comprehend.
- without ground-truth data, "first-to-detect“ and "unique detections“ still particularly useful.

View statistics for specific locations

- for resource planning, identifying new or growing hot spots, identifying gaps or problem locations requiring optimisation, calibration, or troubleshooting.

Scenario: Ground truth information available, with time to detect



Source system	Events	Alarm Count	True detections	False alarms	Undetected	Unique detections	Mean time to detect
Radar	1089	1088	925	163	163	87	20s
Video analytics	1089	1024	871	153	217	61	20s
eCall	1089	90	54	36	1034	1	60s
Waze	1089	726	653	73	435	87	200s
Fused	1089	1284	1034	250	55	-	18s

Road user behaviour

Road user behaviour

Objectives:

Focus on car drivers

- How they react in a situation with a stopped vehicle on motorways
- If they report an incident and whom they would contact
- How they want to be informed about stopped vehicles on motorways
- How they react to information given via various channels

Qualitative study - indicating the range of possible behaviour

Three main steps

1. Interviews with car drivers

2. VR-simualtion with stopped vehicle

3. VR-simualtion with stopped vehicle + additional information

Learned from the interviews

Information desired

- Time of incident
- Name of motorway - approximate location – which lane
- What is most important to consider
- How to behave (speed, which lane to choose etc.)
- Alternative routes

Information channels desired

- Traffic news
- Navigation app / SatNav
- Gantries
- In vehicle technology / screen on the dashboard

VR-simulation study - scenarios

Road	Event scenario	Weather condition	Traffic volume	Stopped vehicle hazard lights on	Driver standing next to stopped vehicle	Simulation Reference
Left Hand Drive: Rural dual carriageway with 4 running lanes in each direction	**Stopped Vehicle Event Scenario 1:** Vehicle stopped at Lane 1 near exit	Good	Light	Yes	Yes	L1A
		Light rain	Medium	Yes	No	L1B
	Stopped Vehicle Event Scenario 2: Vehicle stopped at Lane 2	Light rain	Light	Yes	Yes	L2A
		Good	Medium	No	No	L2B
Right Hand Drive: Rural dual carriageway with 3 running lanes + hard shoulder in each direction	**Stopped Vehicle Event Scenario 1:** Vehicle stopped at Lane 1 near exit	Good	Light	Yes	Yes	R1A
		Light rain	Medium	Yes	No	R1B
	Stopped Vehicle Event Scenario 2: Vehicle stopped at Lane 2	Light rain	Light	Yes	Yes	R2A
		Good	Medium	No	No	R2B

Procedure

- Pre-questionnaire
- General information (drive on motorway under different situations etc.)
- Test person (TP) was asked to comment on any situation while VR-simulation is running
- Simulation was stopped before the stopped vehicle and TP was asked about possible reactions
- Simulation was stopped after passing by the stopped vehicle and TP were ask about further reactions
- Post-questionnaire

First VR-Study - Summary

- A wide range of reactions and behaviours - some would have been dangerous
- No common knowledge about how to behave correctly.
- Gantries most preferred channel how the test persons would like to get information.
- Other channels such as IVT, smartphone (apps), navigation system and radio important information sources, too.
- A general warning (obstacle ahead, dangerous), which lane is affected and speed reduction considered as most important information
- No clear view on, if one should call for help or not. Police considered as the first contact point

2nd VR-simulator study –scenarios

Main difference → additional information was given

Impact protection vehicle (IPV)

Information on gantries

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2nd VR-simulator study –scenarios

Information via traffic news

Information on the dashboard

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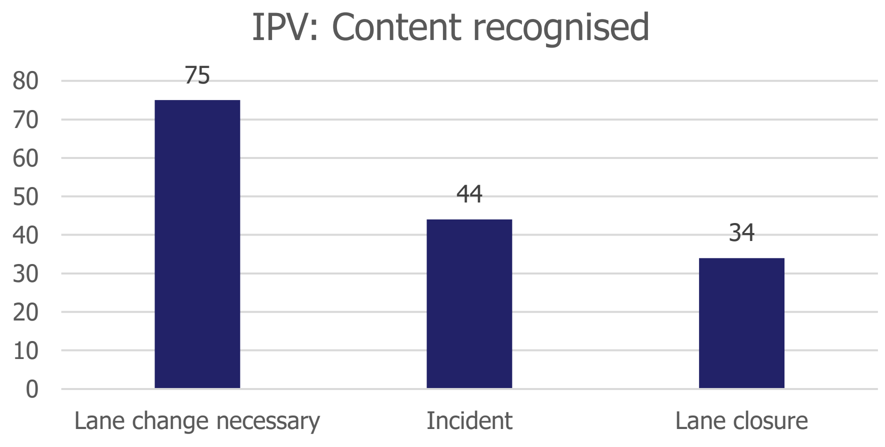
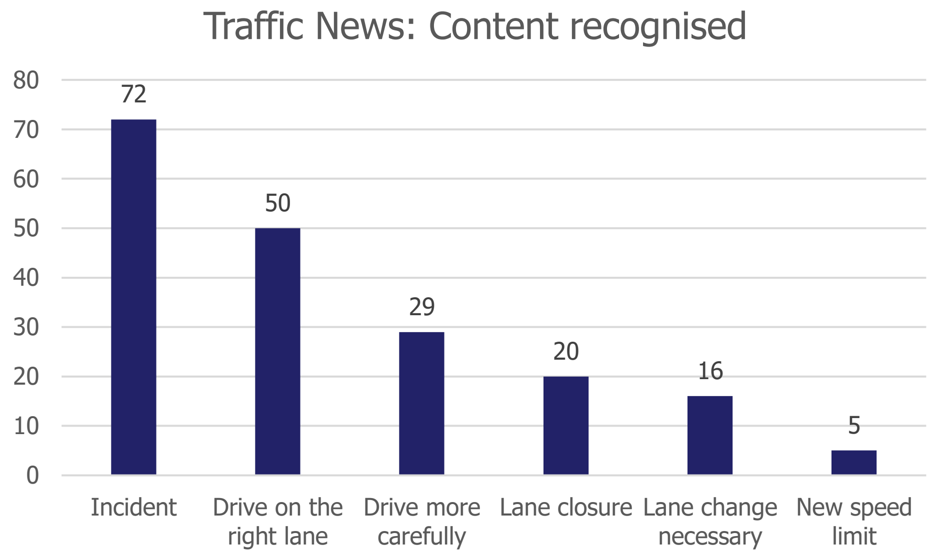
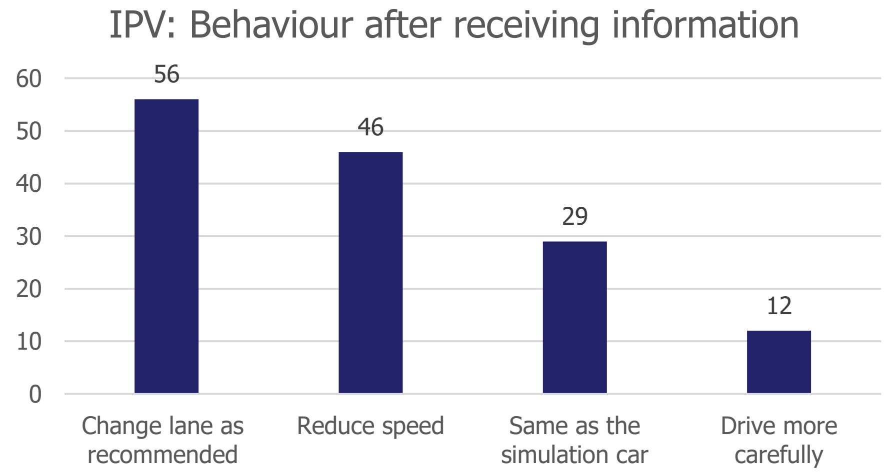
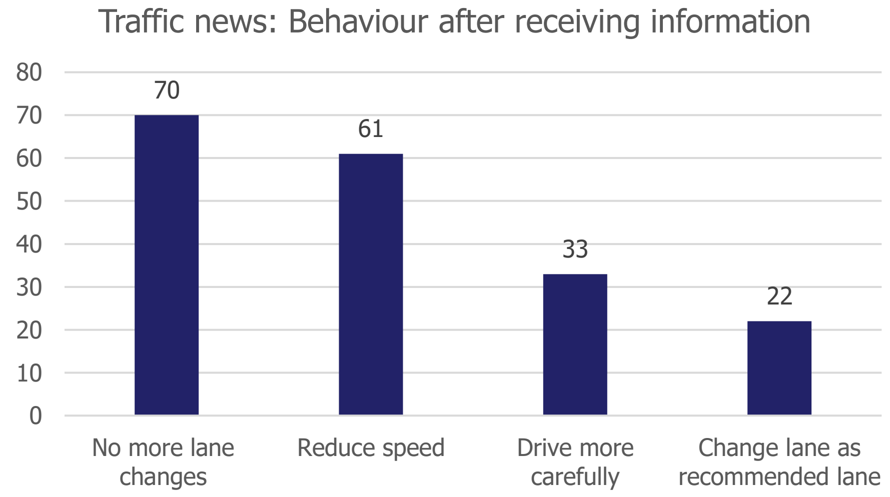
2nd VR-Study - Results

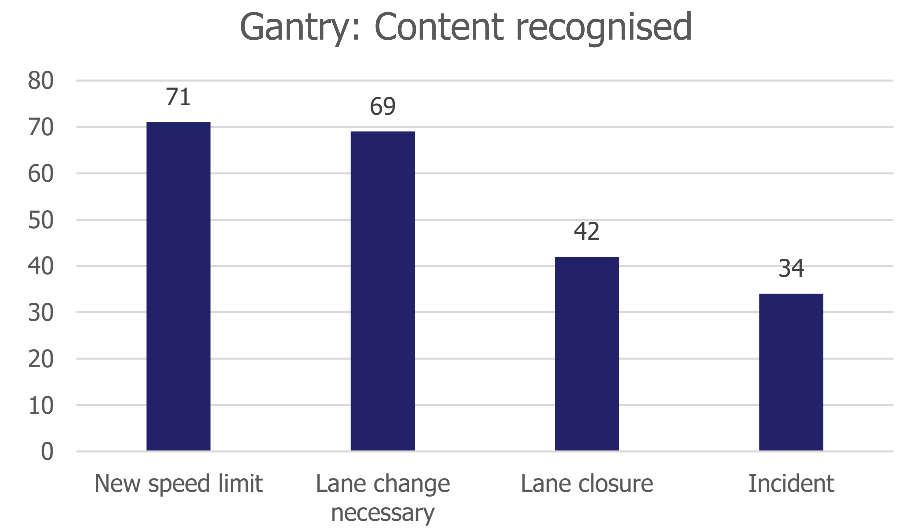


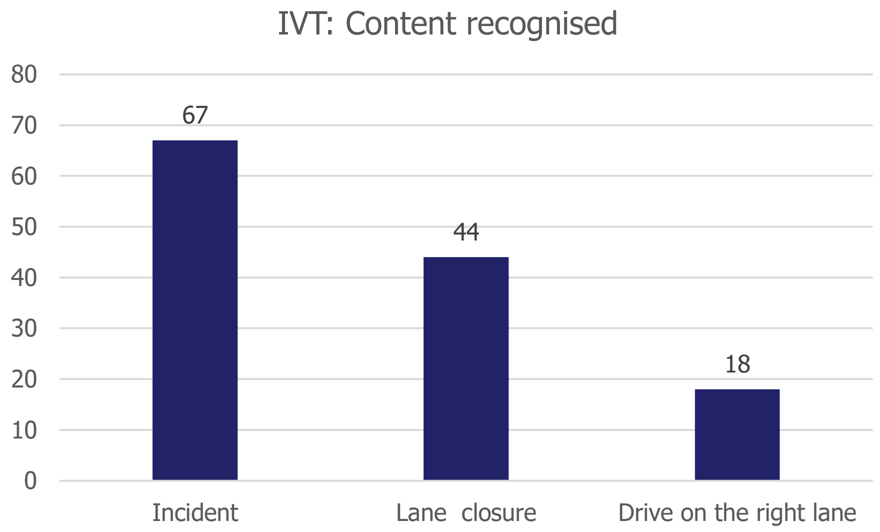


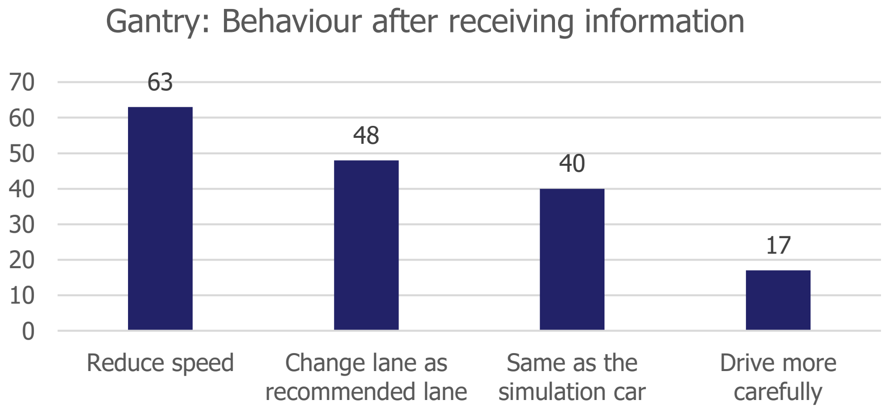


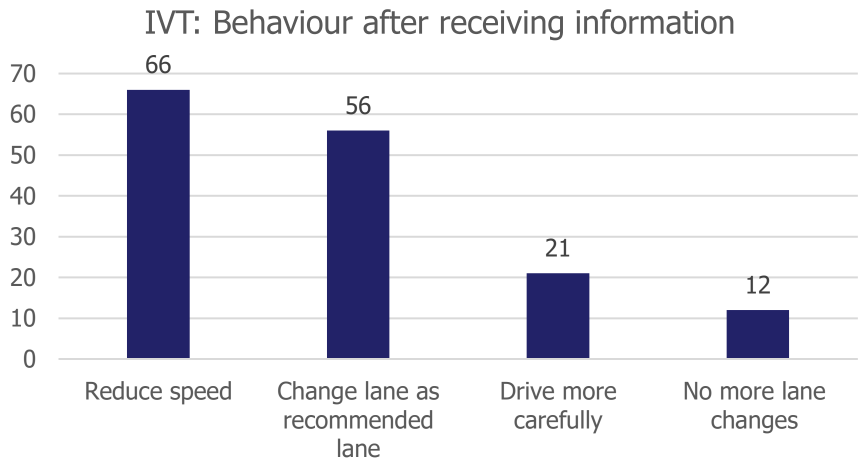


2nd VR-Study - Results







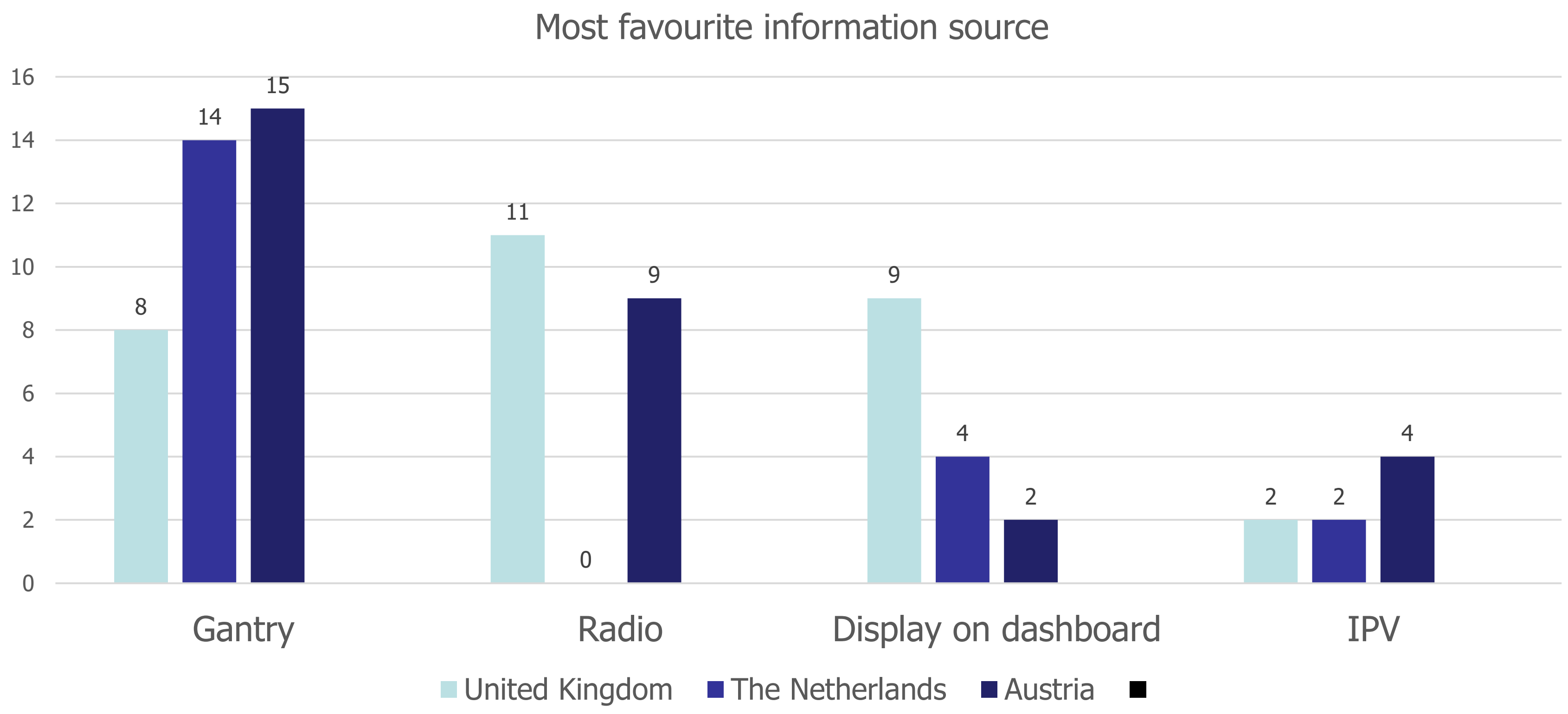


2nd VR-Study - Results

Information sufficient and early enough for different channels in %

	IPV	Gantry	Radio	IVT
Information was sufficient	60	58	72	58
Information was given early enough	40	90	80	30

2nd VR-Study - Results



2nd VR-Study - Summary

- Generally:
  - Main information was received by the test persons
  - Test person would mainly react according to it

- Problems:
  - IPV: warning too late, needs to be announced earlier
  - Gantry: hard to read (weather conditions), missed information
  - Radio: should be repeated, do not remember all information
  - Display on dashboard: visual information distracts

Conclusions I

- **Short and precise information**

  Where (approximate location, which lane is affected); what do I have to do → clear instructions. Too much text on the gantry or dashboard irritates and might distract the driver

- **Repetition of information**

  Repeated information makes it possible that it is perceived by many road users, that the content is understood, and that the information is considered important.

- **Multilingual information**

  Not only traffic news, but written information on gantry desired in other languages, too. Symbols used e.g. lane change arrows should have international validity.

Conclusions II

- **Multisensory information**
  Visual information can be complemented by auditory information and vice versa to appeal to as many senses as possible.
- **Multichannel information**
  Even though gantries were rated as the best source of information by many test persons, using multiple different information channels can get the attention of a wider range of road users.

Conclusions III

- **Make it a topic in the driver’s education**
  How to react to a stopped vehicle is obviously not part of driver's education. This topic should be included in the training and a "three-step plan" should be taught on what is best to do in such a case.
- **Make a traffic safety campaign**
  Most test subjects were surprised and shocked at the stopped vehicle, as they hardly ever experienced such a situation. Road safety campaigns on stopped vehicles brings such a situation to people's attention.
- **Publicise a Hotline**
  The test persons did not know whom to turn to in such a case. An easy-to-remember number, which is also propagated in the media, creates a point of contact for situations related to traffic events.

Stopped vehicle hazards - response

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Stopped vehicle responses

Interviews with responders

- Transport Scotland (Scotland)
- ASFINAG (Austria)
- Rijkswaterstaat (The Netherlands)
- National Highways (England)
- ConnectPlus (England)
- West Midlands Police (England)

Topics

- Control room processes to manage stopped vehicles in live lanes
- Technologies and resources
- Training and resilience
- Situational awareness
- Driver behaviour



Response: physical factors

- Range of control room technologies in use (detection, incident management, communication, informing road users)
- Each supports a more rapid response:
  - Warning VMS, speed limits, lane closed signals, dispatch traffic officer
- Need resilience because individual items of technology fail
- Dedicated detection technology has made control room newly aware of patterns e.g. transient stops
- Control rooms adapted physical layout for COVID19

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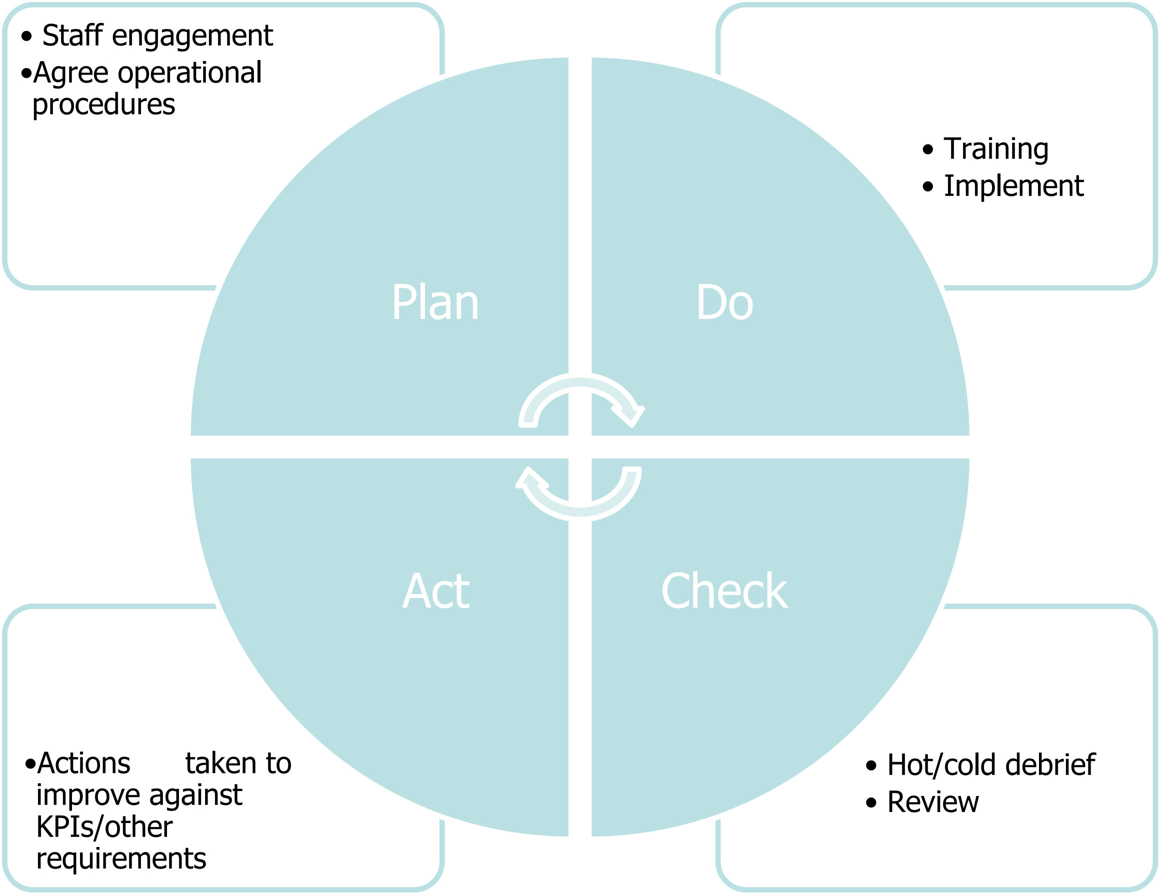
Response: cognitive factors

- Well-defined procedures limit each operator's ability to deviate from protocol to make individual decisions
- Some evidence that operator experience also a factor in choice of traffic management measure
- Success factor: Operational staff engagement with introduction of technology – ideally involvement with technology development - then sufficient training.

Response: organisational factors

- Control room crucial link between incident & stakeholders
- Skills development
- Detailed process definition with KPIs
- Literature: data overload? interviews disagreed: technology supports
- All 4 NRAs had PDCA cycle
- Provide driver education to improve driver behaviour



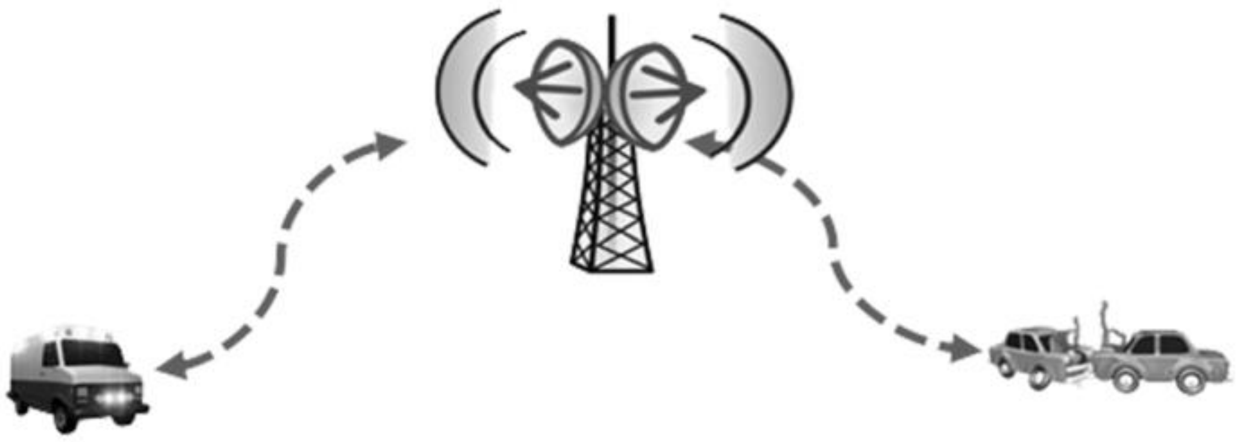
Operational response interviews

Common themes across 4 interviewed countries:

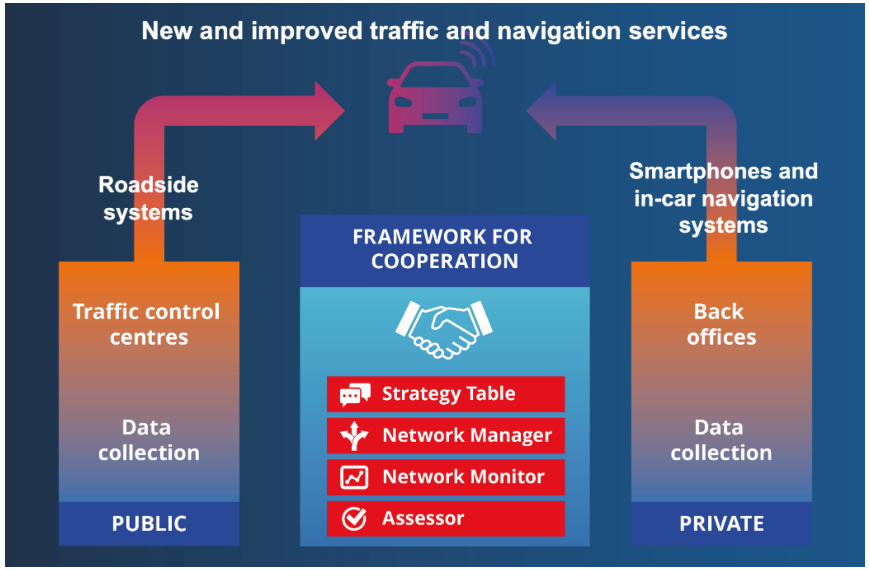
- welcome information from **more sources**
  - either for verification or for separate investigation
  - additional vehicle information (e.g. from eCall + lookup) would improve response
- welcome **explicit indications of confidence**
- a **confidence threshold** would be used (e.g. enabling response action, automation, specificity of messages)
- some worry that fusion may wrongly combine separate events, leading to premature clearance

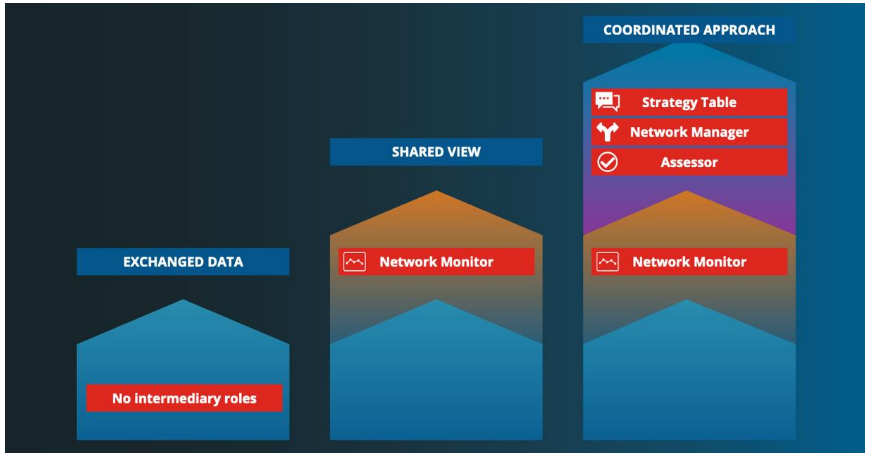
Connected vehicles and devices in NRA response

Potential post-eCall incident support communication (“ISIS”)



Connected vehicles and devices in NRA response





9 interviews with road authorities

- Current state-of-art = data exchange
- Going further: difference of views national vs local roads authority
- Most are interested in pursuing **joint strategy table** with service providers BUT some say only IF chance of uptake of actions by service providers, which is doubted.
- Range of opinions on **incentives & commercial rewards**: can work … some incentives could work … *will not* work.
- Intermediary **network manager and assessor**: Some find difficult to envisage, or envisage only for some aspects e.g. social media dissemination; roles should be clearly defined services, IT services even.
- Funding - some see a challenge, maybe even impossible

TM 2.0 Levels of Cooperation

System Optimal (capacity & public priorities) **Level 4**

PA orchestration of TM stakeholders **Level 3**

Route guidance in line with PA priorities **Level 2**

Geofencing and emergencies **Level 1**

Exchange of Information **Level 0**

PAs and SPs

-PAs
-SPs

-PAs (TMCs)
-SPs
-Road Infrastructure (ROs and traffic industry)

-Road infrastructure
-SPs
-TMCs

-TMCs
-Road Infrastructure
-Fleet Operators
-PT
-Micromobility operators
-Shared mobility operators
-Freight operators
-SPs

SHADAR research dissemination

SHADAR dissemination highlights

Papers

- Transport Research Arena (TRA) 2022 “Stopped vehicle hazards: detection and response”
- Article for ZVS (Zeitschrift für Verkehrssicherheit) German-language peer-reviewed scientific journal
- Paper for TOTS (Transactions on Transport Sciences) English-language peer-reviewed scientific journal
- ITS European Congress 2023 "Fusion of stopped vehicle alerts”
- ITS European Congress 2023 "Harvesting stopped vehicle alerts from eCall data"

Special session

- Delivered Special Interest Session on Stopped Vehicle ITS at ITS World Congress 2021

Presentations of SHADAR results to:

- ICTCT (International Co-operation on Theories and Concepts in Traffic safety) 2022
- Grouping of traffic managers from UK road authorities
- CEDR working group Road Safety
- Workshop with SAFEPATH, which has all SHADAR reports for use

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

For more details on the CEDR Safe Smart Highways programme:

Visit
https://www.cedr.eu/peb-call-2019-safe-smart-highways