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Recommendations for future test sites

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Executive summary

The SiTe Automation Practical LEarning (STAPLE) project was funded as part of the CEDR Call 2017 on Automation. The aim of the project is to provide a comprehensive review of technological and non-technological aspects of the most relevant connected and automated driving test sites across Europe and beyond, in order to understand the impact of these sites on the NRA's core business and functions.

Over 70 test sites in Europe and elsewhere were identified through personal contacts and knowledge of the project team, web searches and discussion with the CEDR CAD group and industry contacts. The output of this work was a catalogue of connected and automated driving test sites, identifying and categorising 37 test sites in Europe (Deliverable 2.1). The sites are also presented in a Google map page which gives the locations of the test tracks and approximate extent of road-based test sites.

A preselection of 16 test sites for further investigation was made by the project team and discussions with the CEDR CAD team at a workshop in Tallinn. These sites were prioritised based on factors including; provision of information to the team in the first phase, the type of track or roads involved (excluding low speed pods in campus environments for example) and sites or projects that would be operational beyond the lifetime of the project. Final agreement was made, and visits made to the following sites by members of the project team, CEDR project officers and representatives of NRAs:

- Horiba MIRA, Midlands, UK,
- Alp.Lab, Graz, Austria,
- TRANSPOLIS, Lyon, France.

Discussion were also held with the Midlands Future Mobility test road to learn about the plans for this 20-year project. The findings are presented in Deliverable 3.1.

Following this work, the project team took the learnings from the test sites initially categorising the test sites by road / track type, for example urban, interurban, simulations, detailing the practical implications for each and noting test sites in each category and occasions where NRAs were directly involved. The sites where priority areas for NRAs (safety, traffic efficiency, customer service, maintenance and construction and data / C-ITS) were discussed and implications for NRAs presented. In the absence of data provided directly provided by test sites, the impacts of CAVs, CVs and AVs for these priority areas were detailed in relation to potential impacts, benefits, or infrastructure requirements for NRAs in the future. This was supplemented by four cases with more in-depth analysis to provide a concrete overview of activities at specific sites or projects addressing aspects that align with the work of NRAs. These were:

- Highways England: Construction and maintenance vehicles, work zone safety,
- TRANSPOLIS test site: cyber security and data case study and self-driving vehicle cyber security testing capabilities,
- ENSEMBLE truck platooning project, and
- ZENZIC: CAVs cyber security testing capabilities

From the work undertaken, a series of findings were made, which are presented joint Deliverable 4.1 and 4.2. A summary of some of the key findings are as follows:

- Test sites can be reluctant to share data except where there is either direct government involvement (e.g. TRANSPOLIS) or direct agreements in place.
- CAVs have not developed at the pace initially expected at the outset of the project, however the test sites are undertaking tests for various use cases, some of which (e.g. autonomous white line pre-marking robot) are beginning to be deployed.

- Whilst CAVs may not have developed at the pace expected, CVs could help with many NRA priorities around congestion, efficiency and safety through a combination of cooperation with themselves and the infrastructure. As the penetration levels of CVs increases, it could enable the gradual removal of physical infrastructure through in car messages particularly related to incidents and speed limits. There is a requirement for 100% transference of roadside information to drivers, solutions to cover non-connected users (e.g. through aftermarket parts or other mechanisms such as mobile phones) will need to be found.
- A mixed traffic fleet will be in place for some years to come, so there will be a requirement for physical and digital infrastructure.

From the findings developed, a series of recommendations were made. The original plan was that these would be discussed with the CEDR CAD group at the TRA conference in Helsinki and/or a CEDR group meeting in Bern, however the outbreak of COVID19 prevented this from happening. Instead, three online workshops were held with representatives of the CEDR CAD group, project officers, research institutes and interested experts and a fourth workshop with the CEDR CAD group only. Following an overview of the work undertaken on the project, the MURAL whiteboard tool was used to present the recommendations, clarify or add new one, vote on those of highest interest, and finally to discuss and categorise the difficulty of implementation of the recommendations.

The following key recommendations were made:

- NRAs, the auto industry, and OEMs could benefit from talking with each other more.
- More work needs to be undertaken around privacy on data collected from public roads.
- Work needs to be undertaken on cross-country data sharing and standardisation of testing.
- NRAs should identify the main construction and maintenance operations with a view to robotising tasks and removing road workers from live carriageways.
- Interactions between ODDs should be investigated, and particularly for minimum risk manoeuvres: other than stopping. Useful lessons learned on ODD could be further investigated based the PEGASUS Project results
- Mixed traffic trials at various speeds should be undertaken.
- Provide guidance for CEDR to become involved in EC Research and Innovation projects.
- A roadmap for removal of traditional infrastructure should be prepared, noting the requirement for 100% transference requirement for key information.

The recommendations listed above were elaborated on in the report using a template indicating the votes received from the 4 workshops, ease/difficulty of implementation, benefits of implementation, route to implementation, timeline for implementation, barriers to implementation and practical learnings from test sites.

In the areas investigated, there are a variety of simulation, visualisation, test tracks and test beds that address NRA needs across Europe. One area that is possibly lacking is road trials that traverse international boundaries and work on this should be undertaken to ensure interoperability of systems across Europe. Depending on specific NRAs needs there is a variety of testing scenarios available. NRAs can become mutual partners and participate in consortia together with the OEMs and other relevant data and service providers to be able to obtain and exchange data and best practices. Since the test site performance and safety information resulted from specific tests and trials undertaken by each site is typically confidential it is proposed that NRAs join such initiatives or join ventures and become a mutual partner. More open communication from all parties could lead to the development of projects that address common areas of interest such as safety, traffic efficiency and customer service, and help accelerate the deployment of connected and autonomous vehicles.

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Abbreviations

| | |
|--------|--|
| ADAS | Advanced Driver Assistance Systems |
| AI | Artificial Intelligence |
| AV | Automated Vehicle |
| C-ITS | Cooperative Intelligent Transport Systems |
| CAD | Connected and Automated Driving |
| CAM | Connected and Automated Mobility |
| CCTV | Closed Circuit TV |
| CEDR | Conference of European Directors of Roads |
| CV | Connected Vehicle |
| FMOT | French Ministry of Transportation |
| GLOSA | Green Light Optimal Speed Advisory |
| HD | High Definition |
| HIL | Hardware In the Loop |
| I2V | Infrastructure to Vehicle |
| ICT | Information and Communications Technology |
| IT | Information Technology |
| ITS | Intelligent Transportation Systems |
| MAAS | Mobility As A Service |
| NRA | National Road Authorities |
| ODD | Operational Design Domain |
| OECD | Organisation for Economic Co-operation and Development |
| OEM | Original Equipment Manufacturer |
| PEB | Programme Executive Board |
| PVD | Probe Vehicle Data |
| RWW | Road Works Warning |
| SAE | Society of Automotive Engineers |
| SIL | Simulation In the Loop |
| STAPLE | SiTe Automation Practical Learning |
| TMC | Traffic Management Centre |
| V2I | Vehicle to Infrastructure |
| V2V | Vehicle to Vehicle |
| VSOC | Vehicle Security Operations Centres |
| VRU | Vulnerable Road Users |
| VTT | VTT Technical Research Centre of Finland |

1 Introduction

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads (CEDR). CEDR is the Road Directors' platform for cooperation and promotion of improvements to the road system and its infrastructure, as an integral part of a sustainable transport system in Europe. Its members represent their respective National Road Authorities (NRA) or equivalents and provide support and advice on decisions concerning the road transport system that are taken at national or international level.

The participating NRAs in the **CEDR Call 2017: Automation** are **Austria, Finland, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden** and **the United Kingdom**. As in previous collaborative research programmes, the participating members have established a Programme Executive Board (PEB) made up of experts in the topics to be covered. The research budget is jointly provided by the NRAs as listed above.

The aim of the Site Automation Practical LEarning (STAPLE) project is to provide a comprehensive review of technological and non-technological aspects of the most relevant connected and automated driving test sites across Europe and beyond, in order to understand the impact of these sites on the NRA's core business and functions. This project will provide NRAs with the necessary know-how on connected and automated driving tests sites and test beds, with the aim of supporting their core business activities, such as road safety, traffic efficiency, customer service, maintenance, and construction.

The STAPLE project consortium will support the NRAs through the following objectives:

1. Provide an overview of connected and automated test sites/beds in Europe and beyond.
2. Provide a catalogue of these sites and detail how they contribute to NRA priorities.
3. Undertake a detailed investigation into a selected number of test sites including visiting a selection of sites.
4. Assess the implications of the findings of the test sites for future NRA options.
5. Analyse and report on the practical learnings from test sites worldwide, including gaps where NRA needs are not addressed.
6. Provide a report and recommendations for future research and test sites focus.

Objectives 1, 2, and 3 were covered in Work Package (WP) 2 (Overview of connected and automated driving test sites) and WP3 (Test Sites Data Collection).

Objectives 4 and 5 were covered in WP4 (Analysis and impact assessment of test sites), while objective 6 is the focus of WP5 (Reporting and Recommendations) and is presented in this report.

The goal of the work preceding this recommendations report, i.e. Analysis and impact assessment of test sites, was to provide an analysis of data collected in previous work packages, and thereby provide a summary of the practical learnings and insights gained within the STAPLE project. The work includes a detailed analysis and impact assessment of key performance areas, providing an overview of practical learnings from the test sites. Furthermore, WP4 deals with assessments of the impacts of different test sites, as well as socio-economic impacts.

This report is structured so that the results of the main research tasks (i.e. practical learnings from test

sites, impact assessment of different test sites and socio-economic assessment of different test sites) are integrated in the separate chapters, although chapter 3 has a main focus on practical learnings from test sites, while chapter 4 has a main focus on impact assessment of different test sites and socio-economic assessment of different test sites. All tasks are introduced together with a common methodology unifying the work and followed by final chapter summarising the key findings and next steps of the project.

2 Work undertaken

The work to date covered the collection of details on motivation and benefit from connected and autonomous mobility and test sites in WP2, followed by prioritisation of test sites and test site visits in WP3. WP4 focussed on assessing the practical learnings from test sites and preliminary recommendations. In this, WP5 we will be undertaking final reporting and recommendations, as outlined in Figure 1.

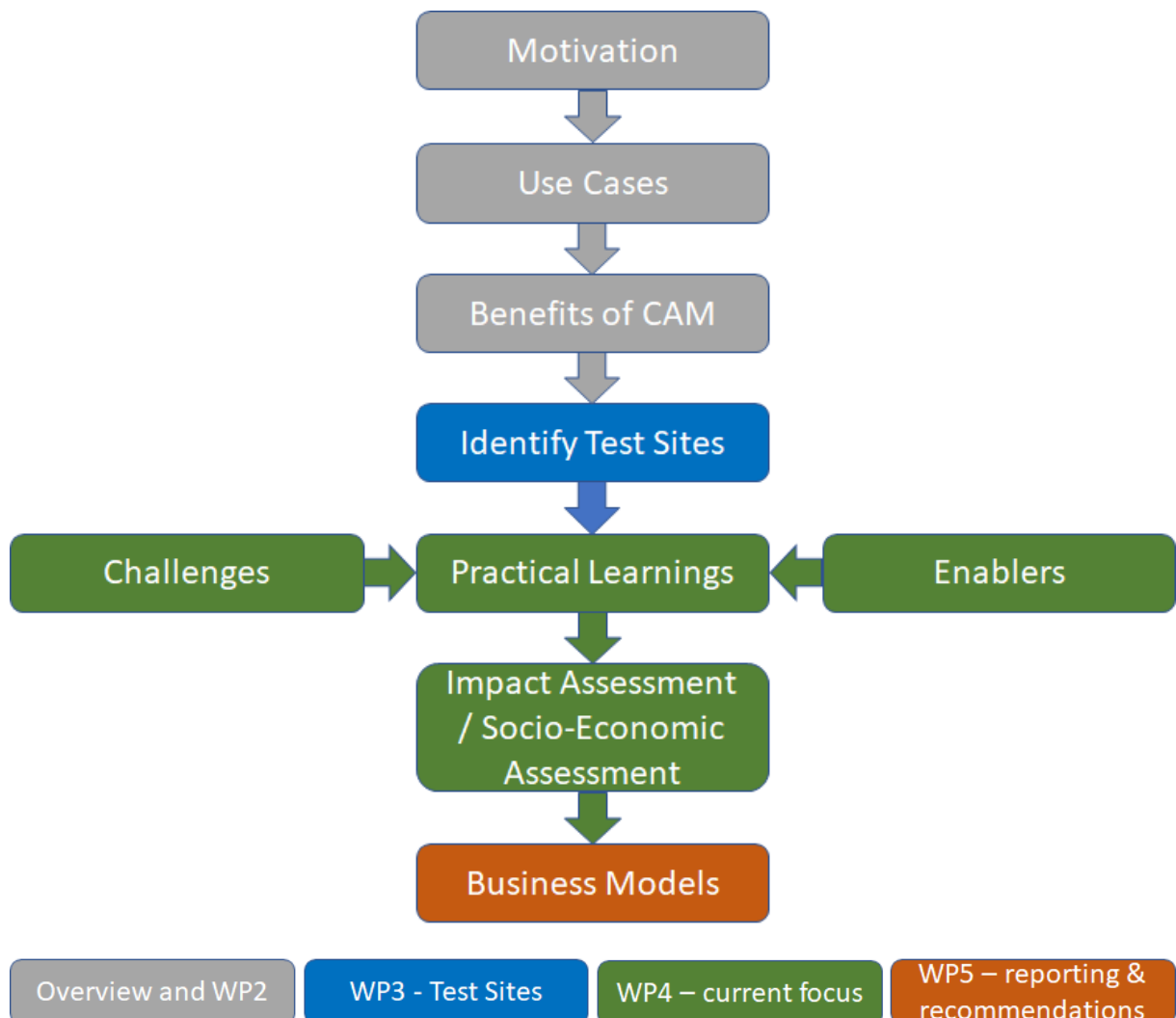


Figure 1 Overview of the STAPLE methodology

2.1 Test sites identification

In WP2, test tracks and test sites worldwide were identified and categorised against NRA priority areas of Safety, Traffic Efficiency, Customer Service and Construction and Maintenance as well as identifying use cases, largely aligned with those selected in the MANTRA (Making full use of Automation for National Transport and Road Authorities) project, also funded as part of the CEDR 2017 Automation call. Pre-selection of sites of interest was also made. An Excel workbook with the sites identified by continent, country and various use cases was prepared, as shown in Figure 2, which allows users to

select sites of interest.

| | A | B | C | D | E | F | G |
|----|-----------|-------------|-----------------------------------|--|--|------------------|--|
| | Continent | Country | Short name | Name of Test site/Test bed | Location | Public / Private | Partners |
| 1 | | | | | | | |
| 22 | Europe | UK | Colas Impact Protection Vehicle | Colas IPV | UK | Private | Colas |
| | Europe | Netherlands | Brainport Pilot site | Autopilot | Brainport, Netherlands | PPT | TNO (leader), DLR, HELM, Huawei, IBMIE, NEC, NEVS, NOP, TECHN, TT, TU Eindhoven, Valeo, Vicomtech, TASS International. |
| 23 | | | | | | | |
| 24 | Europe | Sweden | AistaZero | Active Safety Test Arena Zero | West Sweden | PPT | Joint (Owned by RISE and Chalmers, but with private industry partners) |
| 25 | Europe | Sweden | Test Site Stockholm | TSS | Kista (Stockholm region) | Private | Private |
| 26 | Europe | Sweden | Test Site Sweden - West | TSS-W | | | Other, run as a project |
| 27 | Europe | Sweden | Modern Mobility in Barkabystraden | MMMB | Barkaby, Järfälla municipal (Stockholm region) | PPT | PPT - joint |
| | Europe | Finland | AURORA | AURORA - intelligent road section (Pahtonen-Puthaanranta) | located on Main Road 22 in Finland | Public | Public, managed by The Finnish Transport Agency's |
| | | | | EB - Aurora, the Arctic intelligent transport test ecosystem | | | |

Figure 2 Screen shot of Excel catalogue

A Google map with the European test sites was also prepared, as shown in Figure 3 with test tracks shown in red and test roads, shown in blue. Clicking on individual sites brings up a tab with more information and the site website if available, with an example presented in Figure 4.

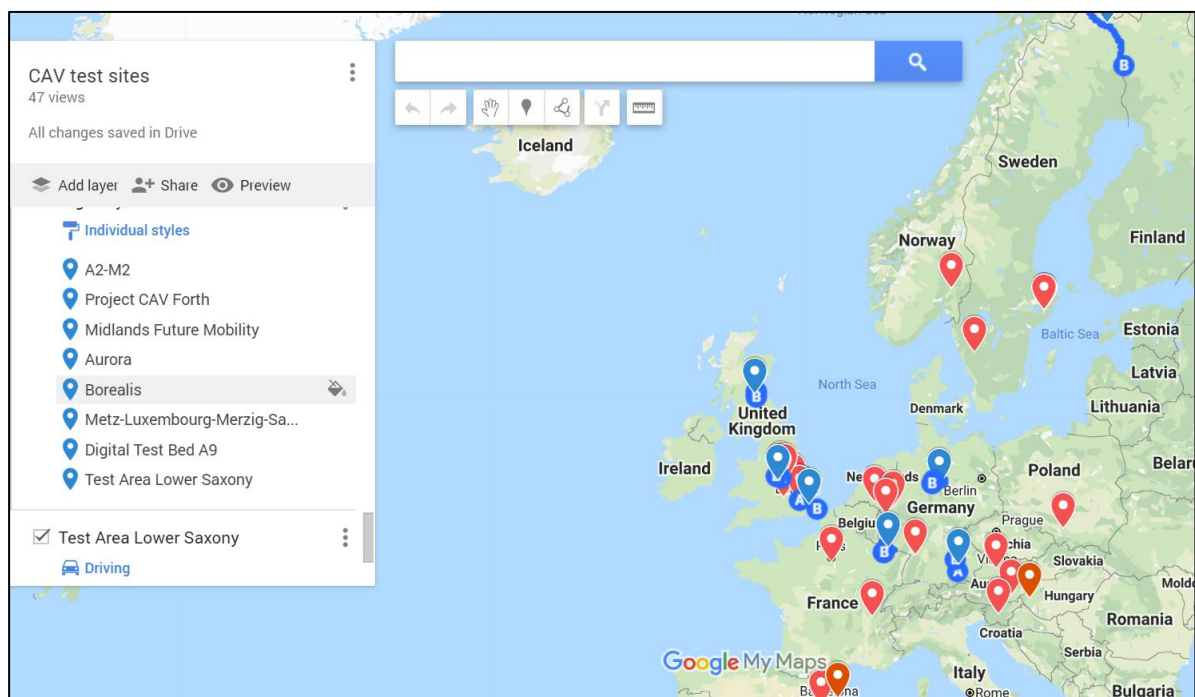


Figure 3 Overview of European Test Tracks / Sites identified

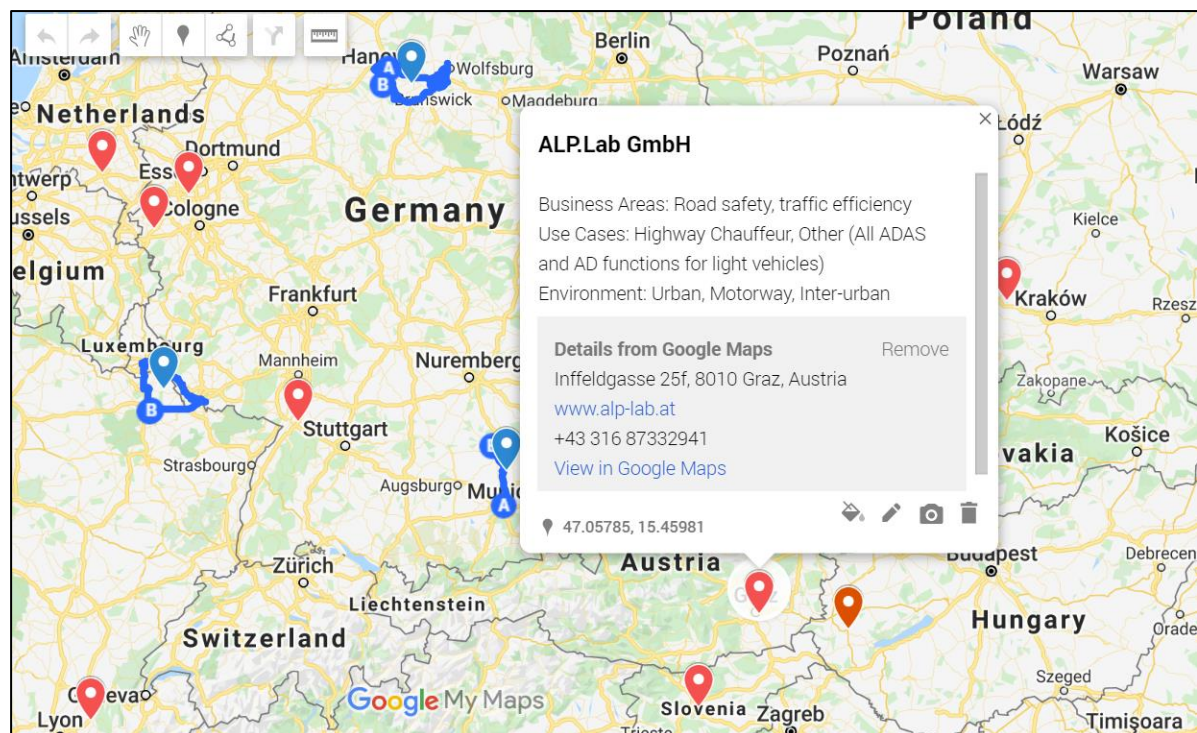


Figure 4 Closer view of map, showing information available.

The outputs of WP2 were presented in deliverable D2.1 Catalogue of connected and automated driving test sites, submitted in February 2019.

2.2 Test sites survey, investigation and visits

In WP3, a survey of test sites was undertaken to augment the preselection undertaken in WP2.

An electronic survey of 11 questions were sent to all test site operators identified by the STAPLE consortium (72 test sites). Selected findings from the survey included:

- Road safety: most use cases covered, various speeds, human in the loop, physical infrastructure testing (e.g. barriers) and cybersecurity
- Traffic Efficiency: moving traffic, congested traffic and traffic incidents, trip optimization for a shuttle based on the real time demand, impacts of different penetration rates, automated vehicle platoons, fuel saving and effects in mixed traffic situation.
- Customer Service: Customer perception of CAVs, issues around privacy and data protection, considering social inclusion, with trialling facial recognition as a payment model and analysing data to better understand how social inclusion is covered
- Construction and Maintenance: passive, active, and interactive and connected roadworks warnings, real time data collection by maintenance vehicles.

A preselection of sites of interest was undertaken based on criteria including; whether they would remain active beyond the end of the STAPLE project, whether they had shared information with the project team and whether the type of testing was relevant to NRAs (e.g. campus testing and urban applications were generally of less interest). The project team then visited two sites in the UK, one in France and one in Austria to gather further information. The first assessment and pre-selection of the test sites / beds performed in WP2, based on the criteria outlined above, yielded the following test

sites/beds (in no particular order):

1. Alp.Lab – Austrian Light Vehicle Proving Region for Automated Driving, Austria
2. Testregion DigiTrans, Austria
3. TFN – Testbed Lower Saxony, Germany
4. A2-M2 Connected Corridor, UK
5. Testbed Midlands Future Mobility, UK
6. Colas IPV – Testbed Colas Impact Protection Vehicle, UK
7. Horiba – MIRA TIC-IT, UK
8. AstaZero AB, Sweden
9. AURORA – E8 Aurora, the Arctic Intelligent Transport Test Ecosystem, Finland
10. BOREALIS – Test Ecosystem for cross-border testing with Finland, Norway
11. ZalaZONE Automotive Proving Ground, Hungary
12. TRANSPOLIS, France
13. CLL – Catalonia Living Lab, Spain
14. IDIADA Proving Ground, Spain
15. Brainport, Netherlands*
16. A9, Germany*

* Added to the list at a workshop held with the CEDR CAD group

A stakeholder workshop undertaken with the CEDR CAD group in Tallinn in March 2019, provided insights as to which ones were of interest, including the addition of 2 more sites. These views were considered by the consortium when considering which sites to visit, with the following sites visited by members of the STAPLE consortium together with the PEB members:

1. Testbed Midlands Future Mobility, UK
2. Horiba – MIRA TIC-IT, UK
3. Alp.Lab – Austrian Light Vehicle Proving Region for Automated Driving, Austria
4. TRANSPOLIS, France

In addition to the test site visits, more detailed information was obtained from interviews with the test site operators. Detailed outputs of WP3 are presented in D3.1 Summary of findings from interviews and site visits, submitted in September 2019.

2.3 Test site impact and socio-economic assessment

In WP4, we looked at how NRAs could benefit from the use of test sites, looked at opportunities and challenges, considered the impact assessment and undertook a review of social and economic impacts of increased connected and autonomous mobility.

Various impacts including socio-economic aspects, economic aspects, and core areas of NRAs such as safety and maintenance are outlined in this work based on four case studies. Furthermore, examples

of beneficial work that can be conducted on open and closed environment test tracks were presented. From the case studies, the potential of test sites and how they can support NRAs in their work with things such as evaluation and testing, standardisation and legislative work, maintenance of our roads and so forth became evident. Several examples of direct impacts of test sites on the responsibilities of NRAs include:

- Connected and automated driving will likely have both positive and negative impacts on the economy and society.
- Whilst fully autonomous vehicles may be further away than anticipated at the start of this project, CVs offer significant opportunities to increase traffic efficiency.
- Fully autonomous and machine assisted plant offer significant gains in productivity, accuracy, and quality. The advent of 5G may introduce the potential of remote operation of plant, further improving operative utilisation, whilst encouraging new entrants to the sector.
- Automated or semi-automated highway platoons will increase fuel efficiency and potentially increase driver utilisation.
- The skills, training, qualifications and continuing professional development offered now, will not be suitable for the future.
- New ways of working and training will be required. What is currently taught in a classroom environment, may quickly become outdated.
- We can speculate on what the impacts may be, but the rapid change of technological advance ensures that nothing is certain.

The detailed outputs of WP4 are presented in combined deliverable D4.1 and 4.2, Practical learnings from test sites and impact assessments, December 2019 v1 and March 2020 v2.

3 NRA requirements and test site focus

3.1 NRA Requirements

NRA's have various key objectives, in areas such as safety, capacity, efficiency and customer service. Extensive information is available on how CAVs could help deliver these objectives; key areas are outlined below:

- Safety
 - Improved safety through cooperative driving, smoother and consistent driving, and avoidance of driver distraction (for level 4/5 CAV).
 - Improvement of construction and maintenance safety through automation of certain tasks, reducing road worker exposure
- Capacity
 - Improved flow through more consistent driving and less braking (at SAE levels 2/3) and potentially from closer following and narrower lanes (levels 3/4).
- Efficiency
 - CAVs could potentially reduce the requirement for maintenance through smoother driving and reduction in braking. Significant efficiency improvements could be realised from connected and automated plant (CAP), particularly for construction activities.
- Customer service (identified by Highways England as road users (public), road workers and those living alongside the strategic road network)
 - Improvement to road users through smoother driving and less braking (at SAE levels 2/3) and potentially from autonomous driving on certain sections (levels 4/5), supported by physical and digital infrastructure. There should also be improvements in journey time reliability.
 - Road worker safety should be improved by removing them from the live highway, with certain tasks controlled remotely or autonomously by robots.
 - Smoother driving and reduction in stop/start traffic jams would improve air quality and potentially reduce noise for roadside communities. More efficient maintenance activities should reduce inconvenience as well.

3.2 Test site focus

In order for NRAs to understand the implications of the areas detailed above on their networks, rigorous testing of operation on tracks and subsequently, public roads must be undertaken to ensure safety and to understand what, if any, infrastructure response might be required.

Table 1 below, details the sites which address the areas listed above, along with an additional category of data, ITS, and digital environment, which can be viewed as an enabling instrument.

Table 1 NRA objectives met by shortlisted test sites

| Test Site | Road Safety | Capacity | Efficiency | Customer Service | Data, ITS, Digital |
|--|-------------|----------|------------|------------------|--------------------|
| Alp.Lab – Austrian Light Vehicle Proving Region for Automated Driving, Austria | ✓ | | | | |
| Test region DigiTrans, Austria | ✓ | | ✓ | | |
| Testbed Lower Saxony, Germany | ✓ | ✓ | ✓ | | |
| A2-M2 Connected Corridor, UK | | | ✓ | ✓ | |
| Midlands Future Mobility, UK | | | | ✓ | ✓ |
| Colas Impact Protection Vehicle, UK | ✓ | | | | |
| Horiba – MIRA TIC-IT, UK | ✓ | ✓ | ✓ | ✓ | ✓ |
| AstaZero AB, Sweden | ✓ | | | | ✓ |
| AURORA – E8. Arctic Intelligent Transport Test Ecosystem, Finland | ✓ | | | | ✓ |
| BOREALIS – Ecosystem for cross-border testing with Finland, Norway | ✓ | | ✓ | | |
| ZalaZONE Proving Ground, Hungary | ✓ | | ✓ | | |
| TRANSPOLIS, France | ✓ | ✓ | ✓ | ✓ | ✓ |
| Catalonia Living Lab, Spain | ✓ | ✓ | ✓ | ✓ | ✓ |
| IDIADA Proving Ground, Spain | ✓ | | ✓ | | |
| Brainport, Netherlands | ✓ | | ✓ | | ✓ |
| A9, Germany | | | | | ✓ |

As well as the general areas of operation, numerous test sites either directly investigate use cases as outlined by the MANTRA project, or have the physical or digital capacity to do so; there are shown in Table 2, below.

Table 2 Use cases addressed by shortlisted test sites

| Test Site | Highway autopilot including highway convoy (L4) | Highly automated freight vehicles on open roads (L4) | Commercial driverless vehicles as taxi services (L4) | Driverless maintenance and road works vehicles (L4) |
|--|---|--|--|---|
| Alp.Lab – Austrian Light Vehicle Proving Region for Automated Driving, Austria | ✓ | ✓ | | |
| Test region DigiTrans, Austria | | ✓ | ✓ | |
| Testbed Lower Saxony, Germany | ✓ | | | |
| A2-M2 Connected Corridor, UK | ✓ | | | |
| Midlands Future Mobility, UK | ✓ | ✓ | ✓ | ✓ |

| Test Site | Highway autopilot including highway convoy (L4) | Highly automated freight vehicles on open roads (L4) | Commercial driverless vehicles as taxi services (L4) | Driverless maintenance and road works vehicles (L4) |
|--|---|--|--|---|
| Colas Impact Protection Vehicle, UK | | | | ✓ |
| Horiba – MIRA TIC-IT, UK | ✓ | ✓ | ✓ | ✓ |
| AstaZero AB, Sweden | ✓ | | | |
| AURORA – E8. Arctic Intelligent Transport Test Ecosystem, Finland | ✓ | | | ✓ |
| BOREALIS – Ecosystem for cross-border testing with Finland, Norway | | | | |
| ZalaZONE Proving Ground, Hungary | ✓ | | | ✓ |
| TRANSPOLIS, France | ✓ | ✓ | ✓ | |
| Catalonia Living Lab, Spain | ✓ | ✓ | ✓ | ✓ |
| IDIADA Proving Ground, Spain | ✓ | | | |
| Brainport, Netherlands | | ✓ | ✓ | |
| A9, Germany | | | | |

4 Key conclusions from test sites investigation and assessment

During WPs 3 and 4, a greater investigation of test sites was undertaken to gain a greater understanding of how CAVs can impact on road administration operations, and test sites to reflect this. From the work undertaken, the findings were collected and grouped into the following categories:

4.1 Communications

- Test site operators are generally reluctant to give detailed information about their site operations, other than the services they offer. This is partly due to client confidentiality, but also related to privacy. Certain test sites (e.g. AlpLab) do have data sharing agreements with NRAs, based on long-standing working relationships and contractual arrangements.
- The automotive industry and OEMs are reluctant to share data but will work on industry groups. In the USA, safety data is shared more widely, as it is used as a marketing tool.

4.2 Testing

- Whilst there are a lot of simulation activities to assess the benefits / effects of CAVs in mixed traffic, there are few physical tests. Physical tests include individual vehicles driving autonomously or as platoon trials. Mixed traffic trials on sites / roads, could demonstrate clearer benefits of having CVs and at what penetration they would make a difference to areas such as congestion and efficiency.
- Testing or demonstration of most activities relevant to NRA objectives are covered at various test sites.
- Closed test tracks offer an excellent opportunity for undertaking high speed and/or dangerous tasks that could not be undertaken on public roads.
- Some of the on-road test sites can provide excellent capabilities for testing data and implications of connectivity in a real environment.

4.3 Applications

- The development of automated vehicles has not advanced to the extent envisaged at the start of the project and appear to be >15 years away (for level 5¹).
 - This means that traditional physical infrastructure needs to be in place for some time and that there will be mixed fleet for some years to come, albeit with increasing levels of connectivity.
 - Acceleration of connected vehicle capabilities would benefit from addition of digital infrastructure such as 5G, radio signs, I2V etc.
- Connected Vehicles are becoming more common and offer shorter term benefits, e.g. lane assist, traffic jam assist, adaptive speed control, GLOSA, parking assist and valet parking. All offer benefits to safety, efficiency and customer service and the deployment could accelerate higher SAE levels.

¹ Zenic in the UK considers that Level 4+ should be the area for focus with specific Operational Design Domains and that Level 5 (drive anywhere in any conditions) is not realistically achievable now for most drivers and most vehicles.

- Connected and autonomous plant offers significant benefits to safety, welfare, and efficiency in certain situations.
 - Machine assist can increase construction accuracy, avoid obstacles, and increase productivity.
 - Remote operation can remove workers from live carriageways or construction areas or hazardous locations. Truly remote location (i.e. controlling a machine from many miles away) could significantly increase productivity by having greater utilisation of plant with less waiting time by being able to move from plant to plant as required. It would also improve welfare facilities and potentially encourage entrants to the labour force.
 - Fully autonomous operation in certain locations would increase productivity by being able to operate continuously. It could also undertake monotonous, unskilled jobs, freeing plant operators to undertake complex tasks.

4.4 Data

- NRAs offering data for others to test new products / processes / applications (e.g. ConVEx, Midlands Future Mobility) can be an excellent way to help develop capabilities that will benefit the NRA. NRAs should ensure they value the data they provide.
- The auto industry is unwilling to share data (except through specific projects like ConVEx). More sharing of data between both parties could lead to significant advances.
- NRAs do not necessarily value the data they hold to the same extent.

4.5 Process

- For some projects, there is a step by step process potentially ranging from simulation, track trials, public road trials and finally deployment, e.g. Colas impact protection vehicle, recent UK cone laying trials. Other projects are not always undertaken in such a coordinated way.
- Innovative contractors (e.g. Colas, WJ) have invested in robotization and are willing to invest more but need a degree of certainty that NRAs will approve and adopt the technology and/or support their innovation efforts.
- There are likely to be non-transport robot developers / manufacturers / programmers who could address NRAs / NRA supply chain needs if they were engaged through innovation competitions or direct dialogue.

4.6 Summary

Despite the various findings, it should be recognised many actors involved in CAM have shared objectives, including:

- Reduction of KSIs, mainly because of the personal tragedy, but they also cost society money directly (insurance pay-outs, investigations) and indirectly (loss of potential taxes, disruption at the time of accidents),
- Improve traffic flow and efficiency to provide greater journey time reliability and smoother traffic, whilst also producing fewer emissions.
- Increase mobility options through shared mobility, repurposing road, or parking space for cycling / walking / new micro-mobility options,

- More efficient road maintenance, resulting in less disruption to road users and a reduction in costs incurred due to delays or diversions, higher customer satisfaction and improved road quality.

There are also shared risks from CAM. There is high potential for contradicting these outcomes by rebound effects. The ease of use and limited cost of CAV services could make them very popular, and demand for traditional transport modes will dramatically decrease, prompting severe cuts in public transport and the reduced use of non-motorized modes. How such increases in road travel will affect traffic congestion remains highly uncertain and is dependent on the degree in which automated vehicles will be capable of “coordinating” themselves for a better use of the roads. Therefore, road trips may slow down, and more time is spent in cars. This increases the opportunity cost of time of car travel.

NRAs need to be aware of these issues and consider the wider and unintentional consequences of the trials they support or promote. With coordination of trials and wide communication between NRAs, positive outcomes could be secured.

5 Recommendations

From the findings outlined in section **Error! Reference source not found.**, a series of recommendations were made and tested / validated in workshops as outlined below.

5.1 Workshop and validation of findings and recommendations

5.1.1 Workshop Attendees

Members of the CEDR CAD working group and other experts were invited to the workshops. The attendees to the workshops were from the following organisations.

Table 3 Organisations attending workshops

| Workshop 1 | Workshop 2 | Workshop 3 |
|--|------------------------------|----------------------------------|
| Traficon, Finland | Highways England, UK-England | Highways England, UK-England |
| Université Gustave Eiffel / TRANSPOLIS, France | Trafikverket, Sweden | Danish Road Directorate, Denmark |
| AlpLab, Austria | Asfinag, Austria | TRAFICOM, Finland |
| | BAST, Germany | CEDEX, Spain |
| | | ZAG, Slovenia |
| | | Rijkswaterstaat, Netherlands |

Following the three workshops detailed above, a fourth workshop was held with nine members of the CEDR CAD group to present the results. Four of the attendees had also attended one of the previous three workshops.

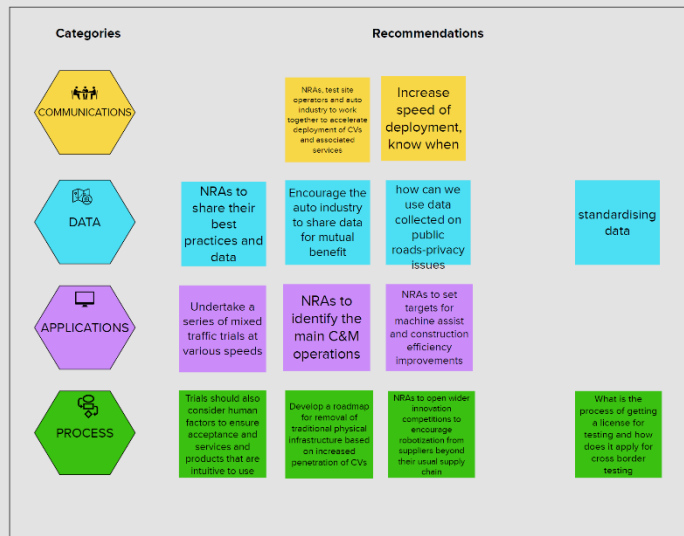
5.1.2 Workshop Format

It had been planned that a physical workshop would be undertaken at TRA and/or at a CEDR CAD group meeting, however, due to the COVID-19 outbreak, this was not possible. As such, 3 online workshops were held with industry representatives from NRAs, test sites and CAV experts.

Draft findings and recommendations were sent to the attendees in advance of the workshop. The workshop involved a quick summary presentation of the progress of the project, followed by an interactive session using the online 'MURAL' whiteboard tool. Following a brief tutorial on the tool, attendees were asked to look at the recommendations shown on the left of the screenshot presented in Figure 5, comment and challenge them and add any new ones. The recommendations were colour coded as follows: yellow-communications; blue-data; purple-applications and green-process. Additional recommendations were identified in the first two workshops were kept in place for subsequent workshops. One additional recommendation was also identified in the third workshop.

STAPLE Priorities diagram

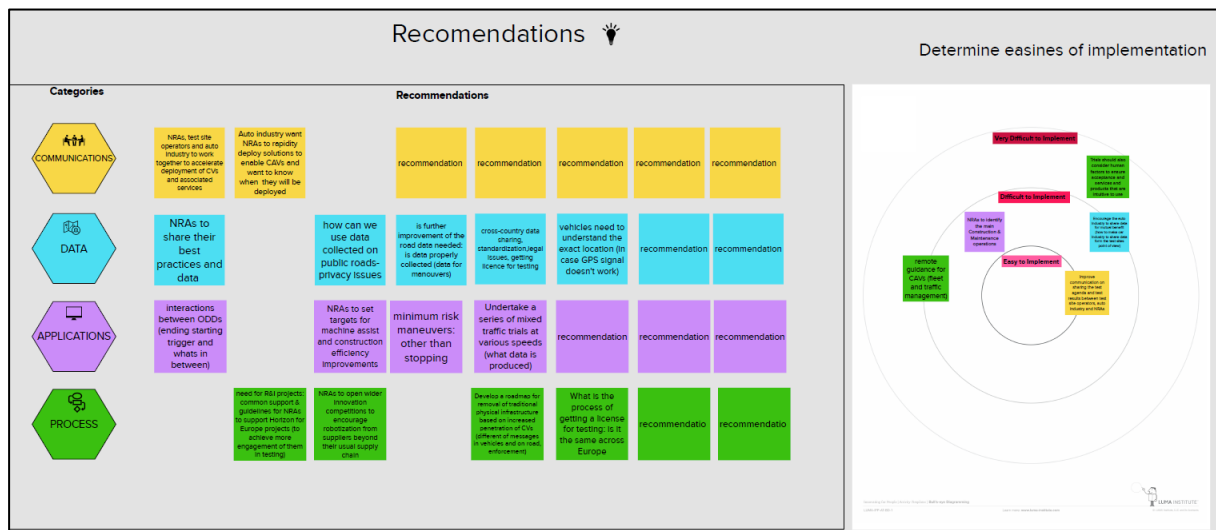
Recommendations



Determine easiness of implementation



Recommendations



Determine easiness of implementation



Figure 5 Screenshot of MURAL workshop no.3 findings

After this stage was complete, a voting session was open for the workshop participants, who were allocated 5 votes each, and asked to vote on the recommendations they felt were the most important, with a maximum of one vote for any single recommendation. A screenshot of voting results is presented in Figure 6. The recommendations with the highest votes were then discussed with regards to their ease of implementation, on the 'bullseye' diagram on the right side of Figure 5, to get an impression of both importance and urgency. As well as placing the recommendations on the bullseye (ranked easy, difficult or very difficult – or between points), there was a more general discussion concerning why certain recommendations were more or less easy to implement, which gave useful insights to the team.

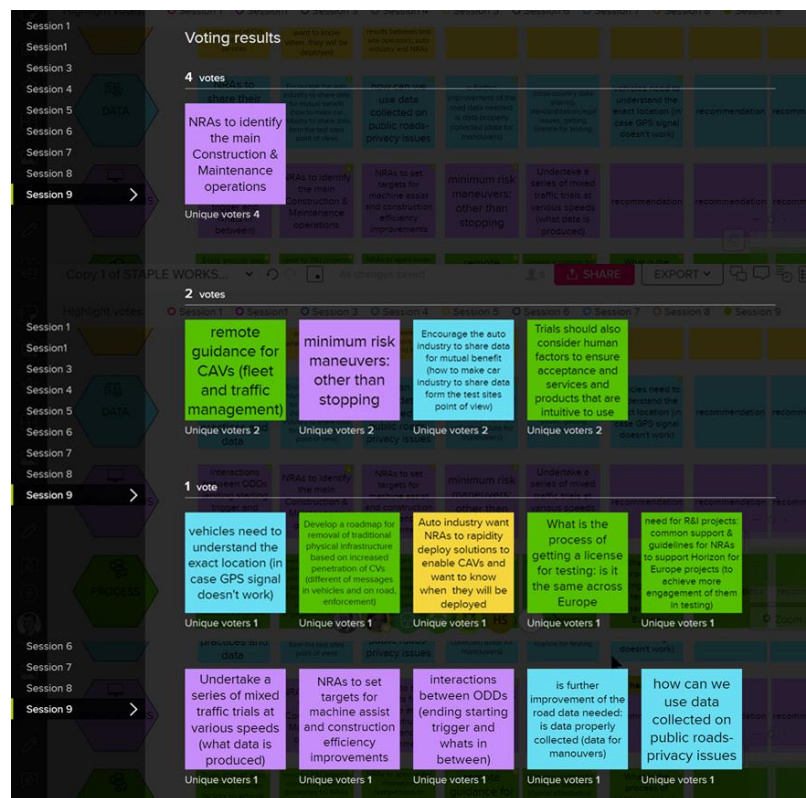


Figure 6 Screenshot of voting results

In the fourth workshop with members of the CEDR CAD group, the recommendations were presented and people were able to vote on them, but there was not the option to add additional recommendations, neither was time spent on assessing the level of difficulty for implementation. Rather, more time was spent in assessing the template for expanded recommendations (see section 5.4) and how test sites were addressing these, or not.

5.2 Final Recommendations

Following the workshops and internal discussion within the team, the following recommendations are presented in Table 4, below. As well as the recommendations, the short name is given where the recommendation has been plotted in graphs / charts in section 5.3; it is also noted whether the recommendation was one provided during work-package 4 (original), or added during one of the workshops.

Table 4 Recommendations

| Full Recommendation | Short version shown in graphs | Notes |
|--|--|----------|
| Communications | | |
| Improve communication between test site operators, auto industry and NRAs | Improve communication between stakeholders | Original |
| <ul style="list-style-type: none"> Consider setting up working groups (if they do not already exist) to learn from each other | | |

| | | |
|---|---|------------|
| and better understand their business priorities. | | |
| NRAs, test site operators and auto industry to work together to accelerate deployment of CVs and associated services, like GLOSA. | N/A – no votes and not presented in graphs | Original |
| Auto industry want NRAs to rapidly deploy solutions to enable CAVs and want to know when they will be deployed | N/A – no votes and not presented in graphs | Workshop 1 |
| Data | | |
| NRAs should share experience on how they have opened up their data (e.g. Midland Future Mobility) and what has worked / not worked, what they might do differently, business models etc, to encourage more trials across Europe. | NRAs to share best practice and data | Original |
| Encourage the auto industry to share data for mutual benefit. Investigate methods of protecting privacy, cyber-security concerns and commercial confidentiality. If CAVs take off in the future, and vehicle manufactures become mobility providers, they will need to do this. | Auto industry to share data | Original |
| How can we use data collected on public roads-privacy issues | Privacy issues for data collected on public roads | Workshop 1 |
| Cross-country data sharing, standardization, legal issues, getting licence for testing | X-country data sharing, standardization | Workshop 1 |
| Is further improvement of the road data needed: is data properly collected (data for manoeuvres) | Further improvement of road data | Workshop 1 |
| Vehicles need to know their exact position (in case GPS signal compromised) | N/As – no votes and not presented in graphs | Workshop 3 |
| Applications | | |
| Undertake a series of mixed traffic trials at various speeds to provide an evidence base of the benefits of various penetration levels of CAVs on efficiency and safety. | Mixed traffic trials at various speeds | Original |
| NRAs could identify the main C&M operations, e.g. snow-ploughing, resurfacing, white line marking, cone-laying etc and fund competitions to a) automate it, b) trial in on track, c) trial it on road and d) update the regulations to allow this | NRAs to identify the main C&M operations | Original |
| NRAs to set targets for machine assist and construction efficiency improvements / adoption of robots to encourage and stimulate supply chain investment and innovation. | N/A – no votes and not presented in graphs | |

| | | |
|--|---|------------|
| Minimum risk manoeuvres: other than stopping | Minimum risk manoeuvres: other than stopping | Workshop 1 |
| Interactions between ODDs (start and end trigger and what is in between) | Interactions between ODDs | Workshop 2 |
| Process | | |
| Trials should also consider human factors to ensure acceptance and services and products that are intuitive to use | Human factors in trials | Original |
| Develop a roadmap for removal of traditional physical infrastructure based on increased penetration of CVs and/or retrofitting existing vehicles / using smart phone capability to reduce physical signage etc | Roadmap for removal of traditional infrastructure | Original |
| NRAs to open wider innovation competitions to encourage robotization from suppliers beyond their usual supply chain, e.g. innovative SMEs, robotics companies. Outcome based competitions could encourage novel solutions. | N/As – no votes and not presented in graphs | Original |
| Remote guidance for CAVs (fleet and traffic management) | Remote guidance for CAVs | Workshop 1 |
| Need for R&I projects: common support & guidelines for NRAs to support Horizon for Europe projects (to achieve more engagement of them in testing) | Guidance for R&I projects | Workshop 1 |
| What is the process of getting a license for testing: is it the same across Europe | Process for getting licence | Workshop 1 |

5.3 Discussion of Results

The highest ranked interventions as voted for during the workshops and analysed for ease of implementation were as follows:

Table 5 Recommendations with highest votes

| Category | Subject | Votes |
|-----------------------|--|-------|
| Communications | Improve communication between stakeholders | 6 |
| Data | Auto industry to share data | 5 |
| | Privacy issues for data collected on public roads | 3 |
| | Further improvement of the road data | 3 |
| | X-country data sharing, standardization | 2 |
| Applications | NRAs to identify the main Construction & Maintenance operations | 4 |
| | Is further improvement of the road data needed: is data properly | 3 |

| | | |
|----------------|---|---|
| | collected (data for manoeuvres)? | |
| | Interactions between ODDs | 4 |
| | Minimum risk manoeuvres: other than stopping | 4 |
| | Mixed traffic trials at various speeds | 3 |
| Process | Guidance for R&I projects | 4 |
| | Roadmap for removal of traditional infrastructure | 3 |
| | Process for getting licence | 3 |
| | Remote guidance for CAVs | 2 |
| | Human factors in trials | 2 |

Ten recommendations were presented at the outset, with a further 10 suggested over the course of the three workshops. Of these, 14 (identified in Table 5 above) had both at least two votes across the three workshops and were assessed at least once for the level of difficulty (3 had no votes and 3 had 1 vote only and were not assessed by the workshop participants).

Some caution should be given to number of votes due to the relatively small sample size and the fact that some recommendations were made in workshops 2 and 3, meaning that those in the previous workshops did not have the chance to vote on them. Also, each group was made up of different participants with their own technical background, experience and job function, so whilst the recommendation of 'NRAs to identify the main construction and maintenance operations that could be robotized' received no votes in workshops 1 and 2, it was voted for 4 times in workshop 3, making it joint 3rd highest vote. Further, for those receiving no votes, it does not follow that they are not valid as at each workshop, the participants were asked if they disagreed with any of the recommendations, and none responded that they did.

Despite these caveats, to get an indication of both the popularity of the topics and their potential ease of implementation, the total votes received were plotted against an average of assessment of ease of implementation. For the implementation, a score of 1 was assigned to those considered easy, 2 for difficult to implement and 3 for very difficult to implement. Where the discussion placed a topic between two categories during the discussion, it was scored as 1.5 or 2.5.

Figure 7 presents a plot of the results in matrix format. The top right-hand quadrant shows those that received the highest votes and might be easiest to undertake. Notably, improving communication between NRAs, OEMs and technology companies (shortened to stakeholders on graph) received the most votes and was considered easy to undertake. Similarly, asking the auto industry to share data for mutual benefit was also popular in all 3 workshops, but was considered very difficult.

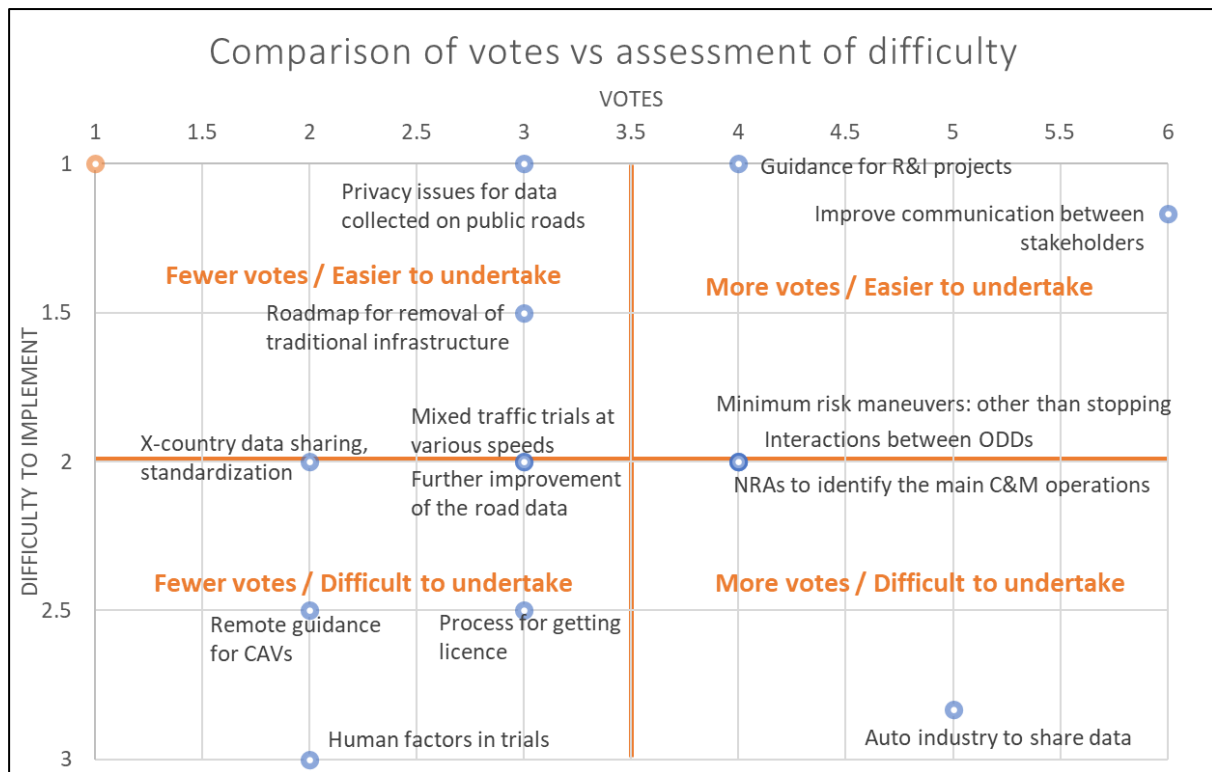


Figure 7 Comparison of votes vs assessment of difficulty of implementation

In Figure 8, a 'Spider' graphs presents both the number of votes and the difficulty of implementation. As the highest number of votes was 6, the averages of the level of difficulty to undertake have been doubled from 3 to 6 so they can be presented on the same scale. Note, however that whilst higher votes received (blue line) could be viewed as a positive, a higher rank for difficulty (orange line) means it is more difficult to implement.

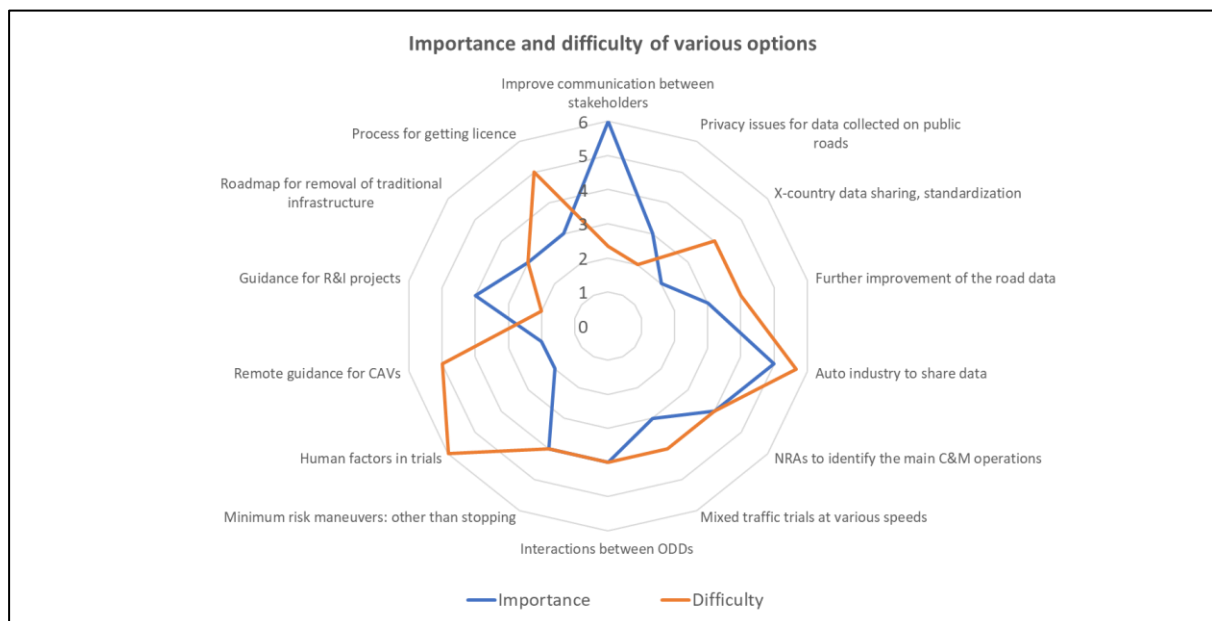


Figure 8 Spider graph of votes and assessment of level of difficulty of implementation

In the fourth workshop with the CEDR CAD group, further votes were cast on the recommendations, although some attendees had also voted in previous workshops. From the first round of voting, six recommendations with at least 4 votes were considered for expansion in a 'Roadmap for Implementation', presented in section 5.4. Following the additional workshop, a further three recommendations were included, shown in italics in Table 6 below; these were chosen in two cases, where 5 of the 9 people attending the workshop voted for it, and in one case due to discussions at the workshop. Further, it was agreed during discussions at the workshop, that the recommendations for 'Interactions between ODDs' and 'Minimum risk manoeuvres: other than stopping' should be combined, as whilst minimum risk manoeuvres are extremely important, they remain part of the overall ODDs.

Table 6 Selection of Recommendations included in Roadmap for Implementation

| Category | Subject | Workshops 1, 2 & 3 Votes | CAD Workshop Votes |
|-----------------------|---|--------------------------------|--------------------------|
| Communications | Improve communication between stakeholders | 6 | 5 |
| Data | Auto industry to share data | 5 | 3 |
| | <i>X-country data sharing, standardization</i> | 2 | 5 |
| Applications | NRAs to identify the main Construction & Maintenance operations | 4 | 0 |
| | Interactions between ODDs | 4 | 5 |
| | Minimum risk manoeuvres: other than stopping | 4 | 6 |
| | <i>Mixed traffic trials at various speeds</i> | 3 | 5 |
| Process | Guidance for R&I projects | 4 | 1 |
| | <i>Roadmap for removal of traditional infrastructure</i> | 3 | 2 |

5.4 Roadmap for Implementation

The highest ranked recommendations (as identified in Table 6) have been expanded to consider the benefits, how they could be implemented and what barriers there might be, that would need to be overcome. They are presented by category in the following sub-sections.

5.4.1 Communications

| Recommendation | | | |
|---|----|------------------------|------|
| Improve communication between test site operators, auto industry and NRAs | | | |
| Total Votes Received | 11 | Ease of implementation | Easy |
| Benefits of implementation | | | |
| Improved communication between stakeholders would help each party understand the others success criteria and areas of common interest, e.g. improved safety. It would also help to understand what data each party held and how it might be useful to the others. Finally, it would also likely help establish test trials where the NRAs' interests were considered. | | | |

Route to implementation

Consider setting up working groups to learn from each other and better understand their business priorities. CEDR could invite vehicle manufacturers, OEMs and test site operators to CAD meetings or arrange a conference / workshop to discuss potential for collaboration. Examples where working together has brought benefits to all parties could be highlighted at such an event.

Further, there needs to be a clear and defined strategy to this, with an end goal in sight, i.e. what would success look like, who would be involved in such a group, how often should it meet, should there be a formal structure, an MoU etc. A 'scattergun' approach with no clear guidelines or objectives will be unlikely to succeed.

Timeline for implementation

This can be undertaken as a short term, no regrets action. Given the current restrictions on travel, it is suggested that CEDR contact organisations with a view to meeting online at a small scale to scope ideas on how best to proceed. This will need ongoing commitment from CEDR and is proposed that one solution could be to appoint a 'Champion' to lead this activity.

Barriers to implementation

It needs to be recognised that there will be some areas that are commercially sensitive that companies will not share or discuss. Initially, at least, there may be some reluctance to get involved unless personal relationships already exist. Without this, the organisation or individual will need to understand 'what's in it for me', and CEDR should provide a compelling case why cooperation is in their interest.

Practical Learnings

Discussions by the project team with test site operators revealed a reluctance to share data or the results of projects, largely due to commercial confidentiality concerns or risking sensitive data entering the public domain.

There are examples (AlpLab, TRANSPOLIS) where NRAs have close involvement with the test site operators, including sharing of data. This is achieved by having specific agreements in place to share data.

The same is also true for projects such as ConVEx, where data will be aggregated from a diverse range of sources such as vehicles, infrastructure, and traffic control centres to be used by companies to achieve specific objectives. Midlands Future Mobility will see Highways England and Transport for West Midlands offer access to data from roadside units, CCTV, enabling organisations to test and validate CAM solutions in a connected physical environment. This too, will be on the basis on commercial agreements between the consortium and commercial operators.

It has been demonstrated that data can be shared in both directions between NRAs, test sites and OEMs, subject to contractual engagement. Improved communication between the parties could potentially open opportunities for increased sharing of data in the future for mutual benefit. Personal communication with a key member of the ConVEx² platform suggests it should be used as the model for future data sharing and suggested other facilities including Otonomo³, Caruso⁴ and

² <https://zenzic.io/testbed-uk/convex/>

³ <https://otonomo.io/>

⁴ <https://www.caruso-dataplace.com/>

Populus⁵, which whilst slightly different to ConVEx, offer an indication of where the market is heading.

5.4.2 Data

| Recommendation | | | |
|---|---|------------------------|----------------|
| Encourage the auto industry to share data for mutual benefit. | | | |
| Total Votes Received | 8 | Ease of implementation | Very difficult |
| Benefits of implementation | | | |
| <p>The auto industry has data that could be of significant benefit for NRAs in terms of understanding various traffic parameter, e.g. weather conditions through rain sensors on windscreens, skid resistance through ABS and congestion from accelerometer and GPS data. General suspension data might also be able to supplement detailed road pavement measurement and give early warning of deterioration of pavement condition.</p> | | | |
| Route to implementation | | | |
| <p>Whilst the auto industry data might be useful to NRAs, equally there could be data that NRAs hold that might be of use to the auto industry and OEMs. Currently, they may not know what data is held. The auto industry greatly values the data they hold and as such will require incentives to release it to NRAs; to date, this has generally been through NRAs or research bodies paying for the data. One option could be for NRAs to share their data in return for access to auto industry data; for this to be successful, NRAs need to understand the value of their data and why it might be useful to the auto industry. Data collected by roadside units could be useful for traffic and routeing options, for applications such as GLOSA, equally there are various options for collecting traffic data (flow, traffic jams) directly from vehicles, reducing the requirement for induction loops in the pavement, which could be achieved at low C-ITS penetration rates. This would be a cheaper option for road operators than purchasing floating probe vehicle data or floating mobile data from service providers based on GPS or cell phone tracking. The reason for this is that the road side units are owned by the road operators, so every car with an on-board unit (usually from an OEM, but potentially a mobile phone) will automatically send information such as speed and position thanks to the Probe Vehicle Data service. This data will be collected at no cost as there will need to be a connection (possibly a hybrid of ITS G5 for short range and cellular/5G for long range) between an AV to reach the high levels of reliability required to reach SAE levels 4 and 5.</p> <p>At medium penetration rates, C-ITS could have the potential to reduce the requirement for fixed cameras and operator patrolling, potentially enabling the collection of event information directly from the vehicles involved.</p> <p>At high penetration rates (at or close to 100%), there is the potential for a reduced requirement for Variable Message Signs and potentially fewer road signs as in-vehicle messages can be displayed, assuming that the legal requirement for 100% transference of road sign information to road users is met.</p> <p>The PIARC report⁶ on connected vehicles points out that road operators may seek to recover the</p> | | | |

⁵ <https://www.populus.ai/>

⁶ PIARC Report – Connected Vehicles - *Challenges and opportunities for Road Operators* – Task Force B1

costs for deploying C-ITS by generating revenue for the services provided. This could be from in-vehicle ITS, where the price to the consumer would include a revenue component for the road and traffic operator, covering at least the maintenance costs of the roadside ITS stations.

A research need will be to support and investigate methods of protecting privacy, cyber-security concerns and commercial confidentiality. If CAVs take off in the future, and vehicle manufactures can become mobility providers, this will be a critical issue for them.

Timeline to implementation

This will not be a short term, easy option. NRAs need to have something valuable to offer the auto industry and, as a first step, need to assess the data they collect and hold and understand what value this data might have for the auto industry. Parallel to this approach will be better communication with the auto industry as outlined in the recommendation above. Following this, a value offering should be made to the auto industry. This might best be undertaken at a European level for greater leverage although instances where individual NRAs have cooperated with industry could be a useful blueprint. CEDR might consider lobbying the EC to fund a Horizon Europe project around data sharing.

Barriers for implementation

As indicated in Figure 7, this recommendation had the second highest number of votes and the second highest level of difficulty for implementation as assessed in the workshops. There will be some data that industry simply will **not** release and other data that they will want to monetise. It was noted in one of the workshops that auto manufacturers in the USA are more open about sharing certain data, particularly safety data, which they use as a marketing tool. It may be that such an approach or perceived benefit could be encouraged in Europe. Again, this may be best achieved via the EC.

Practical Learnings

Limited data was available for this area, with test site owners reluctant to share the results of R&D projects and the auto industry unwilling to share data with NRAs. However, the test sites will be undertaking trials with auto manufacturers and OEMs that are highly relevant to NRAs, particularly in the following areas:

- V2V / V2I / I2V communications, relevant for in-vehicle signage, digital infrastructure requirements and potential removal of physical infrastructure (undertaken at AlpLap, Horiba MIRA, A2M2 and SMLL amongst others). The Autodrive project in the UK had several vehicle manufacturers (JLR, Tata and Ford) testing in-vehicle signage, looking to solve interoperability issues, whereas some of the existing systems are manufacturer specific.
- Special cases, such as stopped vehicle detection,
- Highway autopilot (undertaken at many test tracks and on-road)

One learning is that CEDR could collaborate to fund and participate in a R&D project in one of the above areas, but would need to ensure that the data was shared and that clear benefits for all parties concerned were outlined from the outset.

Recommendation

Cross-country data sharing, standardisation, legal issues and obtaining licence for testing

Total Votes Received

7

Ease of implementation

Difficult

Benefits of implementation

The benefits of this approach come mainly from the standardisation aspect of the recommendation. This would not only enable a single unified process for obtaining a licence for testing, but also set the framework upon which data could be shared. The wider and longer-term benefits would be to ensure that as there is a greater penetration rate of connected vehicles, and eventually level 4 and 5 CAVs, that they work seamlessly across European member states. This is particularly relevant for freight, which often travel long distances and through several member states, or for communities living in border areas.

Route to implementation

Whilst this was identified as being 'difficult' to achieve, the discussions with stakeholders at the workshop, suggested it would take a long time to get through the process, rather than there being any aspects that posed specific technical difficulties.

Such an implementation goes hand in hand with the deployment of CAVs and C-ITS infrastructure. The C-Roads platform⁷ already performs several trials on harmonised C-ITS deployment in Europe. This initiative can be extended to automation functionalities or a similar, European process must be started from scratch. The planned CCAM partnership in the upcoming Horizon Europe, the next research and innovation framework programme⁸ is a potential host of this process combining the most relevant stakeholders in Europe. Currently, their Strategic Research and Innovation Agenda is under development. It is key that NRAs have their say in this partnership. This could be either by becoming a member of the partnership or by a membership of a special interest group representing NRAs, representation in the governance of the partnership as well as active participation in the ongoing preparation and continuous consultation activities of the partnership.

The C-ROADS and CCAM platforms are relevant to many of the recommendations, including this one as a means of taking forward a cross sector approach to the deployment of CAVs and as such could be useful in the development of joint research projects.

Timeline to implementation

This is likely to be a lengthy process taking more than 5-7 years, as there will a period for drafting, then agreeing the standards through steps of iteration and public consultation. Upon agreement, there would again be a process of putting the standards and process into law. Also, the CCAM partnership is planned for the whole Horizon Europe period from 2021 till 2027.

Barriers for implementation

There are few, if any, technical barriers to this work. The main barriers will be procedural, organizational, and political barriers in getting the standards and processes agreed, put into law, and deployed.

Practical Learnings

All the physical test tracks are within individual member states, with little focus on this work. In the

⁷ <https://www.c-roads.eu/platform.html>

⁸ (https://ec.europa.eu/info/files/european-partnership-connected-and-automated-driving-ccam_en)

UK, the Horiba MIRA site is in the process of changing its city circuit from a layout that would allow right hand drive or left hand drive testing, to one that focusses on right hand drive (left side of road) driving only.

The Borealis and Aurora test sites in Norway and Finland join at the border of the countries, whilst even the truck platoon trials in 2016 had different requirements in each of the countries they drove through.

The most relevant test site for cross-border interoperability is the Germany-France-Luxembourg test area⁹, which considers these factors amongst a range of other focus areas, such as impact on infrastructure, safety, and traffic management. In addition to projects proposed by project partners (top down approach), there will be periodic calls for proposals (bottom up approach); CEDR could engage with this test bed and potentially look to develop trials that would help accelerate the test and standards requirements based on real world experience.

5.4.3 Applications

Recommendation

NRAs to identify the main construction and maintenance operations, to assess the potential for automation of certain activities.

Total Votes Received

4

Ease of implementation

Medium

Benefits of implementation

Automation of construction and maintenance operations would have significant benefit in several areas. Most notably, it could improve road worker safety by removing the requirement for highway operatives to be on, or near, the live highway. Instead, they could operate equipment remotely, either nearby, for example on the embankment or an overbridge, or with 5G coverage many kilometres away. For manual operation of plant in construction sites, robotics could reduce strain and improve worker health.

Another significant benefit should be through increased productivity, with robots or machine assisted plant offering more efficient working. Robotization of repetitive jobs would enable humans to concentrate on higher value operations.

Route to implementation

The initial task would be to identify the main construction and maintenance operations, e.g. snowploughing, resurfacing, white line marking, cone-laying etc, to determine both the technical potential for automation / remote operation or machine assistance, the benefits of undertaking it in terms of e.g. worker safety and the whether it could be undertaken in the short, medium or longer term. This should also consider any human factors where changes would be positively received or resisted.

NRAs should also speak with plant and equipment manufacturers and Tier 1 contractors to understand their plans and aspirations for the sector.

From this, a prioritisation or roadmap could be developed to allow NRAs to fund research, development and implementation activities and fund competitions to determine applications to a) automate, b) trial in on track, c) trial it on road and d) update the regulations to allow this. It may

⁹ https://www.bmvi.de/SharedDocs/DE/Anlage/DG/testfeld-deutschland-frankreich-luxemburg-konzept-fuer-das-grenzueberschreitende-digitale-testfeld.pdf?__blob=publicationFile

be useful to look at other industries such as nuclear decommissioning and mining sector to learn from their experiences and possibly open competitions to new entrants to the highways sector who may look at things differently, with no pre-conceived views.

There is also any ongoing H2020 call is dealing with this, namely MG-2-10-2020 – “Enhancing coordination between Member States' actions in the area of infrastructure research with a particular focus on biodiversity and ameliorating environmental impacts and full automated infrastructure upgrade and maintenance”. This call will have a Coordination and Support Action (CSA - typically 2-year and ~€1 million) focussing on biodiversity and a larger Research and Innovation Action (RIA – typically 3 years and €3 – 4 million) focussing on automation.

There is also an ongoing H2020 project, RIMA¹⁰ (Robotics for Inspection and Maintenance), which as an aim to “help small and medium-sized companies (SMEs) to develop novel solutions for different industry sectors”. Roads and bridges are one of the sectors with funding already made available for an SME to develop.

Timeline for implementation

There are already activities going on in this sector, including research being undertaken by Highways England and others in the UK and the development of robotics and machine assist by some of the large plant manufacturers. There are large mines where the trucks are fully autonomous.

Helping to further the development of these and bringing new solutions to market should be actively encouraged by NRAs as an immediate activity. Another task will be to work with unions and other organisations (see below) to consider the non-technical aspects.

Barriers to implementation

There are various technological challenges to implementation, with some activities being more difficult to automate than others. It was suggested in the workshops that maintenance activities could be more challenging to implement than construction ones, due to the additional complexity of live traffic.

A significant barrier could come from trade unions who view robots as replacing jobs, despite evidence to suggest that every technological revolution has created jobs overall. A phased approach could be taken to identify operations that would be welcomed by both unions and workers, such as mechanisms to remove workers from undertaking dangerous operations or to reduce repetitive strain through the use of, for example, powered exoskeletons. This should be coupled with a comprehensive training schedule to encourage new recruits and retrain current staff into digital ways of working.

Practical Learnings

There are examples of specific companies undertaking R&D activities in this area, such as the autonomous Impact Protection Vehicle developed by Colas, the pre-marking robot developed by WJ and recent trials undertaken by Highways England with two suppliers on laying and collecting cones from worksites. As indicated in Table 2, there are numerous test sites who undertake trials of construction and maintenance work, including Horiba MIRA, ZalaZONE and Aurora. Catalonia Living lab offers a variety of track and connected road trials, with trials of certain operations also possible at the Midlands Future Mobility area. Certain sites, such as Horiba-MIRA in the UK have specific off-road areas designed to test autonomous construction plant; this would also be potentially suitable

¹⁰ <https://rimanetwork.eu/>

for trialling some maintenance activities such as grass cutting and vegetation management.

Sites such as Horiba-MIRA, AlpLab and TRANSPOLIS have 4G and 5G connectivity and the ability to block signals and simulate tunnels or other dropped signals. This could be useful in trialling remote operation or fully autonomous operation of e.g. cone laying and collecting plant, to totally remove operatives from the carriageway. Some of the higher speed tracks could be used in subsequent trials of cone laying with live traffic at speed to simulate a motorway environment and ensure that road users would also be safe.

Some sites, such as Midlands Future Mobility and TRANSPOLIS offer simulator trials, to assess capabilities before going forward to physical testing. TRANSPOLIS has a digital twin and a unique 'phygital'¹¹ tool (combination of physical and digital) which is connected and reconfigurable, enabling configuration of mobility in all forms. Phygital is anything that crosses the divide between the digital and physical worlds to provide an immersive environment, often used in marketing activities.

One of the attendees at the CEDR CAD workshop expressed an interest in autonomous maintenance of streetlights; none of the test sites visited reported any facilities or trials in this area. In 2015, Leeds University received funding¹² to test robotics capabilities including 'perch and repair' drones that could replace streetlights, but no reports on trials have been found. Amazon have also filed a patent¹³ to use lampposts and other high locations for delivery drones to recharge, or shelter in case of storms.

Theoretically, numerous test sites with high levels of connectivity could undertake trials on such applications or such facilities could be added subject to funding.

An area of general interest is the use of probe vehicles collecting maintenance data with infrastructure connectivity (V2V / V2I). There are known to be numerous trials investigating such concepts including by the Danish Road Directorate using Raspberry Pis and mobile phones to collect road condition data. Some of the connectivity on road sites including Midlands Future Mobility could be used to test data transfer. The A2-M2 site running from London to Dover is trialling I2V connectivity for in display messages and concepts such as GLOSA.

There are areas where NRAs could potentially open innovation competitions, possibly extending beyond the existing supply chain,

¹¹ <https://peertopeermarketing.co/phygital/>

¹²

<https://eps.leeds.ac.uk/news/article/5228/leeds-wins-42m-funding-to-develop-robot-fixers-of-the-future>

¹³

https://www.engadget.com/2016-07-20-amazon-delivery-drone-perch-patent.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xllmNvbS8&guce_referrer_sig=AQAAAJuJ1e8TiLJ6cn6RjgihRxmNu6d-Sfibt7r6zz0IGJN7rih0yp_f9y8ROs3einAXq6POdiBckZabxtste7SMOLqVWLy_RMYl8_BWFCaggtXAsqhKuvcoMybH40ryJgxDjMr_iYfZ1OzpGYLZh0k7EdcXADKopMHDYspPukA6bkVc

Recommendation

Interactions between Operational Design Domains (start and end triggers and active operation), and minimum risk manoeuvres: other than stopping

Total Votes Received

19 (combined)

Ease of implementation

Medium

Benefits of implementation

The SAE¹⁴ definition of an operational design domain is ‘A description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/nighttime, etc.), prevailing traffic law and regulations, and other domain constraints.’ The ODD also includes the minimal risk maneuvers that allow the automated driving system to circulate.

ODDs are a key tool in ensuring the safe operation of CAVs from the point of handover of control, whilst operating in autonomous mode and finally in the driver retaking control of the vehicle. Within this, and important aspect is the development of minimum risk manoeuvres, other than stopping. Currently, the default operation in the event of an emergency is for the vehicle to come to a controlled stop. Whilst this might be an appropriate action in for a slow speed pod in an urban environment, at high speed in the outside lane of a motorway, this could be highly dangerous, as well as contrary to traffic laws in many countries.

Development of agreed ODDs and minimum risk manoeuvres would be another step forward in the development and deployment of CAVs. ODDs have been described in the CEDR 2017 Automation call MANTRA¹⁵ project as “ODD is a description of the specific operating conditions in which the automated driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/night-time, etc.), prevailing traffic law and regulations, and other domain constraints”. NRAs need to understand the physical and digital infrastructure requirements for CAVs to operate safely, and in accordance with ODDs on their network.

Route to implementation

The MANTRA project has outlined ODDs for a range of use cases, concluding that use cases for SAE level 4 and 5 will remain slow speed shuttles with a safety operator for some time, and that predictions for widespread adoption of automated driving has been too optimistic.

The MANTRA project has given a route map for some of the requirements for the use cases identified. They recommend that due to the cost of physical infrastructure, there should be a clear picture developed of likely concrete requirements to enable selected ODD requirements or infrastructure aspects.

It would seem appropriate to investigate further the use cases identified in the MANTRA project as a starting point and to develop a route map for their deployment and to understand in greater detail what the digital and physical requirements would be, and how digital twins could be used to assess impacts before investing. Whilst each member state will have its own requirements and legal basis for implementing solutions, a coordinated research effort could avoid repeating research, at least to reach a stage of high technological understanding of the issue and potentially some common

¹⁴ SAE J3016 June 2018

¹⁵ Deliverable D4.2 April 2020. Consequences of automation functions to infrastructure. https://www.mantra-research.eu/wp-content/uploads/2020/05/MANTRA_Deliverable_D42_Final.pdf

standards, before implementation at member state level. For example, one of the use cases identified in MANTRA was snow ploughing; as this is a common activity in Scandinavia, Baltic States and the Alps and Pyrenees, a coordinated response could be a cost-effective solution.

Timeline for implementation

The MATRA final deliverable proposes a timeframe for ODD for traffic management as follows:

2021-25 Research, agreements and MoUs with OEMs and ADS providers

2026-30 Studies, pilots, standardisation

2031-40 Deployment and use, continuous adaptation with ODD evolution

Depending on the specific use case, the timeframe and actions might differ, but it provides a general guide.

Barriers to implementation

There are several barriers or challenges to this. Firstly, the technological pace of change of, for example, sensors, cameras, and other vehicle technologies effectively continuously alters the ODDs in terms of the infrastructure requirements and response.

Additionally, as identified by the MANTRA project, there are some legal and regulatory issues regarding supervision, or even control of automated vehicles in situations where the ODD needs to be terminated due to unexpected situations. This will require regulations to allow NRAs to operate vehicles remotely with a secure radio frequency and NRAs need to be given the right to determine where on their network, remotely supervised vehicles can operate and for what functions.

Practical Learnings

This was not a scenario that was explicitly investigated during the projects and the developing the ODDs could require a range of testing and experimentation. For the use cases identified as part of the MANTRA project, there are many tracks and road sections where the technological use cases can be developed, even including winter operations.

In the case of a shuttle for instance, the route is usually predetermined and the most critical scenarios, which have the potential to create discontinuities/ruptures in the ODD, need to be identified. The role of the test site is important to create a set of tests related to the above-mentioned critical scenarios, which can be performed by simulation and real condition in the test site infrastructure.

The TRANSPOLIS test site has a digital twin, where scenarios can be played out in a digital environment before physical testing. Midlands Future Mobility have LiDAR and Coms scans of various sections of the road network enabling CAV testing in their 3D simulator before road trials. The Catalonia Living Lab has scanned over 6,000 KM of road data available for application in virtual simulation. The data consists of 3D images in combination with 3D point clouds obtained by LiDAR.

The Smart Mobility Living Lab in Greenwich and Queen Elizabeth Olympic park also has a digital twin along with live monitoring of the site and vehicles collecting test data. The PEGASUS Project provides another example aimed at “establishing generally accepted quality criteria, tools and methods, as well as scenarios and situations for the release of highly automated driving functions. The effort is focused on highway driving, and the PEGASUS research team has identified several elements of a scene that pertain to ODD, including traffic infrastructure (e.g., lanes, regulations, geometry), environmental conditions (e.g., surface grip from wetness, light, sun, fog, sensor obstacles), and traffic.

| Recommendation | | | |
|---|---|------------------------|-----------|
| Undertake a series of mixed traffic trials at various speeds (what data is produced) | | | |
| Votes Received | 8 | Ease of implementation | Difficult |
| Benefits of implementation | | | |
| The benefits of implementation would be as a means of generating data that would be useful to the NRAs, where this is currently lacking, or of poor quality. | | | |
| Route to implementation | | | |
| CEDR should assess what data would be useful which is currently lacking and determine how this could be achieved, e.g. simulation, track trials or road trials, or some combination. At this stage, further scoping of test site(s) or road(s) where this could be achieved needs to be | | | |
| Timeline for implementation | | | |
| Simulation trials could be undertaken in the short term. | | | |
| Track trials would need to be agreed in advance and properly scoped out, including the choice of where it would be done and how many vehicles would be involved. Road trials would involve further complexity, particularly at sites where use of RSU / CCTV or other digital infrastructure was required. | | | |
| Barriers to implementation | | | |
| Realistically, any track or road trial would require the involvement with one or more vehicle manufacturers or OEMs to record and generate the data. Potentially, a large fleet of vehicles could be required for this, either generating data from existing equipment and/or from external data recorders on the vehicles. This requires data agreements with the vehicle manufacturers or OEMs. | | | |
| Practical Learnings | | | |
| Depending on the data to be required, there are many sites or roads where this could be undertaken. There are numerous sites around Europe that offer simulation activities, whilst most large-scale test tracks could offer a controlled environment. As per | | | |
| Table 1, the following sites have data capabilities: Midlands Future Mobility, Horiba MIRA, AstraZero, AURORA, TRANSPOLIS, Catalonia Living Lab, Brainport and the A9 route in Germany. | | | |

5.4.4 Process

| Recommendation | | | |
|--|---|------------------------|------|
| Support and provide guidelines for NRAs to encourage their participation in Horizon Europe projects | | | |
| Total Votes Received | 5 | Ease of implementation | Easy |
| Benefits of implementation | | | |
| The need for Research and Innovation projects in this area is clear and some NRAs expressed an interest in getting more involved with Horizon Europe and other research projects to achieve more engagement of the EC for CAV testing. | | | |
| The benefits to NRAs would be clear procedures for engaging with, procuring, and cooperating in larger scale, pan-European Research and Innovation Projects | | | |

Route to implementation

Engage with NRAs to understand their research priorities and map against stated research objectives of the EC in the Horizon Europe framework. provide a research roadmap for CEDR. CEDR and individual NRAs to meet and discuss their research objectives and potential cooperation.

Timeline for implementation

This can be undertaken as a short-term operation, with a 6-month data gathering and research mapping project, followed by discussions.

Barriers to implementation

No specific barriers other than the fact that the EC have their own objectives for Research and Innovation which can be planned out several years in advance.

Practical Learnings

There are no specific practical learnings for this recommendation, however such an activity would support the technological and/or legislative issues identified in other recommendations.

Recommendation

Develop a roadmap for removal of traditional physical infrastructure based on increased penetration of connected vehicles

Votes Received

5

Ease of implementation

Medium

Benefits of implementation

The benefits of the removal of physical infrastructure is clear that smart motorway signage can cost £10 million (~€12 million) per km¹⁶. Much of this could be replaced in favour of digital infrastructure and in-vehicle signage. This would also lower lighting and maintenance requirements.

The workshop indicated that production of a roadmap would be easy, although implementation would be difficult, hence the 'medium' ranking.

Route to implementation

In the UK, Zenic has produced a detailed roadmap for automation which covers in part, digital infrastructure. As identified above, Highways England have investigated the potential for a 'naked road' with infrastructure stripped back. The roadmap should identify common themes to determine both the physical infrastructure that could most easily be replaced and the digital infrastructure that would offer the greatest benefits to the overall transport system, noting that there will be a mixed fleet for some time.

Timeline for implementation

The roadmap could be produced in a period of around 12 months, with a timeframe looking towards 2030-2035 for implementation.

Barriers to implementation

There are few specific barriers to producing a roadmap, assuming funding could be made available.

¹⁶ <https://www.highwaysmagazine.co.uk/UK-highways-to-go-naked-by-2027-as-infrastructure-is-stripped-back-says-Zenic/8206>

The main challenge for implementation will be a mixed connected and unconnected fleet which is likely to remain in place for some time to come. Here, NRAs, technology companies and vehicle manufacturers could usefully work together to develop common solutions or standards for in-vehicle signage that could be accessed from the dashboard, infotainment display or could be connected through smart phones to retrofit 'standard' vehicles. There will be a requirement to cover cross-border issues generally, and specifically for Northern Ireland and the Republic of Ireland who measure in miles and kilometres, respectively.

Practical Learnings

There are numerous trials taking place on this already. In the UK, trials are underway¹⁷ at Midlands Future Mobility, Millbrook, and Smart Mobility Living Lab (SMLL) in London. Primarily, these cover 5G connectivity providing that connection can be maintained, and data can be exchanged at high speeds

TRANSPOLIS has a unique tool which is 'phygital' (combination of physical and digital), connected, reconfigurable. It facilitates the staging of mobility in all its forms (motorway, country road, ring road, avenue, street, etc.) in a controlled and secure way to ensure the highest standards of reproducibility and metrological accuracy. In addition, its 'digital twin' allows the validation of the vehicles of tomorrow thanks to a hybrid approach of calculations-test.

The facility offers a digital infrastructure of 320 km of optical fibre that interconnects more of 150 real time computers. It allows precise synchronization of measurements characterizing simultaneously the behaviour of users, vehicles, the state of infrastructure and signalling. It also proposes the various technologies of connectivity: IoT, ITS G5, 5G, Cellular or Wi-Fi.

The researchers created the 'Flex-City®' to achieve real and risky scenarios, in a simple and repeatable way. For this purpose, TRANSPOLIS benefits from means of control and supervision (traffic, test vehicles, robotic and synchronized mobile targets) which ensure easy implementation experiments of "critical scenarios"

The A2/M2 trial running from London to Dover is testing in-vehicle signage, whilst Brainport in Eindhoven has a well-connected ecosystem with 4G and cooperative units with the focus mainly being autonomous truck platooning.

5.4.5 Not considered in detail

| Category | Subject | Votes |
|---------------------|---|-------|
| Data | Privacy issues for data collected on public roads | 3 |
| | Further improvement of the road data | 3 |
| | Cross-country data sharing, standardization | 2 |
| Applications | Mixed traffic trials at various speeds | 3 |
| Process | Roadmap for removal of traditional infrastructure | 3 |
| | Process for getting licence for testing | 3 |
| | Remote guidance for CAVs | 2 |
| | Human factor considerations in trials | 2 |

¹⁷ <https://www.intelligenttransport.com/transport-articles/92700/the-naked-highway-digital-signage-and-safety/>

6 Conclusions

The STAPLE project has identified test sites in Europe and beyond, categorised these and investigated certain sites in greater detail. The project team has participated in workshops with the CEDR CAD group and others in selecting sites for further review and validating and adding recommendations.

6.1 Project Outputs

As part of the first technical work-package (WP2), over 70 test sites in Europe and elsewhere were identified through personal contacts and knowledge of the project team, web searches and discussion with the CEDR CAD group and industry contacts. The outputs of Work Package 2 were presented in deliverable D2.1 Catalogue of connected and automated driving test sites. February 2019, identifying and categorising 37 test sites in Europe (information on 39 were collected, but two sites wished for their details to be anonymous).

The sites are also presented in a Google map page which is available to CEDR which gives the locations of the test tracks and approximate extent of road-based test sites.

A preselection of 14 test sites for further investigation was made by the project team, prioritising sites based on factors including; provision of information to the team in the first phase, the type of track or roads involved (excluding low speed pods in campus environments for example) and sites or projects that would be operational beyond the lifetime of the project. This preselection was discussed at a workshop with the CEDR CAD group in Tallinn with an additional 2 sites added.

The results were considered in a further internal workshop with the project team and project officers and visits were made in the summer of 2019 to:

- Horiba MIRA in the UK, on June 19th, 2019 with 2 members of the project team and one CEDR project officer,
- Alp.Lab in Graz, Austria on July 3rd, 2019 comprising 5 members of the STAPLE project team and representatives from Asfinag and Rijkswaterstaat.
- TRANSPOLIS in France on July 9th, 2019 with two members of the project team.

To coincide with the visit to Horiba MIRA, those present also met the Highways England lead on the Midlands Future Mobility test road to learn about the plans for this 20-year project. The findings are detailed in Deliverable 3.1, Summary of Findings from Interviews and site Visits, September 2019.

In work-package 4, the project team took the learnings from the test sites initially categorising the test sites by road / track type, for example urban, interurban, simulations, detailing the practical implications for each and noting test sites in each category and occasions where NRAs were directly involved. The sites where priority areas for NRAs (safety, traffic efficiency, customer service, maintenance and construction and data / C-ITS) were discussed and implications for NRAs presented. In the absence of data provided directly provided by test sites, the impacts of CAVs, CVs and AVs for these priority areas were detailed in relation to potential impacts, benefits, or infrastructure requirements for NRAs in the future. This was supplemented by four cases with more in-depth analysis to provide a concrete overview of activities at specific sites or specific projects addressing aspects that align with the work of NRAs. These were:

- Highways England: Construction and maintenance vehicles, work zone safety,
- TRANSPOLIS test site: cyber security and data case study and self-driving vehicle cyber security testing capabilities,
- ENSEMBLE truck platooning project, and

- ZENZIC: CAVs cyber security testing capabilities

From the work undertaken, a series of findings were made, which are presented joint Deliverable 4.1 and 4.2, Practical learnings from test sites and impact assessments, March 2020.

From the work undertaken in the previous work-packages, and the key findings in work package 4, a series of recommendations were developed, validated, and improved through a series on online workshops as outlined in the previous section of this report.

6.2 Key findings

It was found that test sites are reluctant to share data except where there is either direct government involvement (e.g. TRANSPOLIS) or direct agreements in place.

CAVs have not developed at the pace initially expected at the outset of the project, however the test sites are undertaking tests for various use cases, some of which (e.g. autonomous white line pre-marking robot) are beginning to be deployed.

Whilst CAVs may not have developed at the pace expected, CVs could help with many NRA priorities around congestion, efficiency, and safety through a combination of cooperation with themselves and the infrastructure. As the penetration levels of CVs increases, it could enable the gradual removal of physical infrastructure through in car messages particularly related to incidents and speed limits. There is a requirement for 100% transference of roadside information to drivers, solutions to cover non-connected users (e.g. through aftermarket parts or other mechanisms such as mobile phones) will need to be found.

A mixed traffic fleet will be in place for some years to come, so there will be a requirement for physical and digital infrastructure.

6.3 Key recommendations

The following key recommendations were developed and expanded upon, as presented in the previous section of this report:

- NRAs and auto industry could benefit from talking with each other more.
- More work needs to be undertaken around privacy on data collected from public roads.
- Work needs to be undertaken on cross-country data sharing and standardisation of testing.
- NRAs should identify the main construction and maintenance operations with a view to robotising tasks and removing road workers from live carriageways.
- Interactions between ODDs should be investigated, and particularly for minimum risk manoeuvres: other than stopping. Useful lessons learned on ODD could be further investigated based the PEGASUS Project results
- Mixed traffic trials at various speeds should be undertaken.
- Guidance for CEDR to become involved in EC Research and Innovation projects should be provided.
- A roadmap for removal of traditional infrastructure should be prepared, noting the requirement for 100% transference requirement for key information.

6.4 How do test sites address NRA needs?

In the areas investigated, there are a variety of simulation, visualisation, test tracks and test beds that address NRA needs across Europe. One area that is possibly lacking is road trials that traverse international boundaries and work on this should be undertaken to ensure interoperability of systems across Europe. Depending on specific NRAs needs there is a variety of testing scenarios available (refer to the Catalogue), NRAs can become mutual partners and participate in consortia together with the OEMs and other relevant data and service providers to be able to obtain and exchange data and best practices. Since the test site performance and safety information resulted from specific tests and trials undertaken by each site is typically confidential it is proposed that NRAs join such initiatives or join ventures and become a mutual partner.

Road owners and operators, auto manufacturers and OEMs have share objectives around safety, security, traffic efficiency and customer service. By communicating more openly and working together they could undertake trials that address these needs and potentially accelerate the deployment of connected and autonomous vehicles for various applications and use cases.

As the penetration rate of connected vehicles (in the short to medium term) increases, there will be requirements for increased V2I and I2V communication, which in turn will need increased interaction between NRAs, auto manufacturers and OEMs.

The C-ROADS and CCAM platforms are relevant to many of the recommendations, including this one as a means of taking forward a cross sector approach to the deployment of CAVs and as such could be useful in the development of joint research projects.