MANTRA

MANTRA: Making full use of Automation for National Transport and Road Authorities – NRA Core Business

Consequences of automation functions to infrastructure

Deliverable D4.1 Intermediate Draft – Structure and approach

June 2019

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CEDR Call 2017: Automation

Project Nr. 867448

MANTRA

MANTRA: Making full use of Automation for National Transport and Road Authorities – NRA Core Business

Intermediate Deliverable D4.1 – Methodology and Structure for Consequences of automation functions to infrastructure

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Executive summary

The development of automated vehicles and road network operation automation is progressing steadily. However, research on effects to physical and digital infrastructure due to automated functions and vehicles is still limited. As amendments to infrastructure are costly and timely, there is a strong need for research for them to be planned accordingly. Therefore, work-package 4 of project MANTRA analyses concrete consequences of selected automated vehicle functions to infrastructure up until the year 2040 in response to the CEDR Automation Call 2017.

Building on initial results after the thorough analysis of deployment and the road authorities' selection of most significant automated functions and use cases, their operational design domains (ODDs) and penetration rate, their interplay with infrastructure and following consequences shall be tackled.

Work-package 4 focuses on the consequences of automated driving to infrastructure, where research on impact and consequences to infrastructure is still limited. Following the MANTRA principle of close cooperation with the PEB and the CEDR CAD working-group to achieve the expected results, this intermediate deliverable has the sole purpose of explaining the methodology, approach and expected outcome of this work-package to get early feedback on the direction of the work. This approach of early testing of assumptions proves valuable equally in research projects and development projects.

While this intermediate report presents solely the approach of this work-package 4, the expected results are named already. Results are potentially new requirements for infrastructure and their financial implications to give road authorities and operators a guideline for future infrastructure investments and amendments.

[This presents only the Executive Summary for this intermediate draft. Throughout the document comments that are just explanatory on what will be done in the final report D4.2 are formatted this way.]

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Glossary of Terms

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
aFAS	aFas is the German acronym for driverless safety trailers
AI	Artificial Intelligence
CACC	Cooperative Adaptive Cruise Control
CCAV	Cooperative Connected Automated Vehicles
CAD	Connected and Automated Driving
CBA	Cost Benefit Analysis
ENPV	Expected Net Present Value
ERTRAC	European Road Transport Research Advisory Council
ISAD	Infrastructure support levels for cooperative connected automated driving
MANTRA	Project Acronym: Making full use of Automation for National Transport and Road Authorities – NRA Core Business
NRA	National Road Authority
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
PEB	Programme Executive Board
PMS	Pavement management system
SAE	SAE International (Society of Automotive Engineers)
V2V, V2I	Vehicle-to-Vehicle, Vehicle-to-Infrastructure communications
VMS	Variable Message Sign

1 Introduction

The CEDR Transnational Research Programme was launched by the Conference of European Directors of Roads. 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 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 made up of experts in the topics to be covered. The research budget is jointly provided by the NRAs as listed above.

MANTRA is an acronym for "Making full use of Automation for National Transport and Road Authorities – NRA Core Business". MANTRA responds to the questions posed as CEDR Automation Call 2017 Topic A: How will automation change the core business of NRA's, by answering the following questions:

- What are the influences of automation on the core business in relation to road safety, traffic efficiency, the environment, customer service, maintenance and construction processes?
- How will the current core business on operations & services, planning & building and ICT change in the future?

An earlier CEDR project DRAGON (Vermaat et al. 2017) already looked at the impacts of three automated driving use cases in specific sites revealing the need to carry out a comprehensive study on the impacts on the road authorities and operators on the European scale.

MANTRA work started with the analysis of vehicle penetrations and Operational Design Domain coverage of NRA-relevant automation functions up to 2040. This part is reported in MANTRA Deliverable D2.1. Following this, work-package 3 concentrates on the impacts of connected and automated driving, and how the impacts relate to the role and policy targets of NRAs. The first deliverable in Work-package 3 summarizing a comprehensive state of the art on the impacts of connected and automated driving on travel demand, travel behaviour, traffic flow, safety and energy has been also finished as D3.1.

Building on these initial results, work-package 4 focuses on the consequences of automated driving to infrastructure. Research on impact and consequences to infrastructure is still limited. Following the MANTRA principle of close cooperation with the PEB and the CEDR CAD working-group to achieve the expected results, this intermediate deliverable has the sole purpose of explaining the methodology, approach and expected outcome of this work-package to get early feedback on the direction of the work. This approach of early testing of assumptions proves valuable equally in research projects and development projects. PEB suggestions and requests for clarification are welcome after handing in this deliverable officially via the consortium coordinator to Christian Pecharda, FFG.

1.1 Objectives

NRAs are generally aware of the ongoing development in automation. However, today, this development and its effects are difficult to assess. Work-package 4 seeks to overcome this challenge. Key target of work-package 4 therefore is to formulate concrete consequences of and necessary changes due to selected automated functions to infrastructure as well as the operation and maintenance of it.

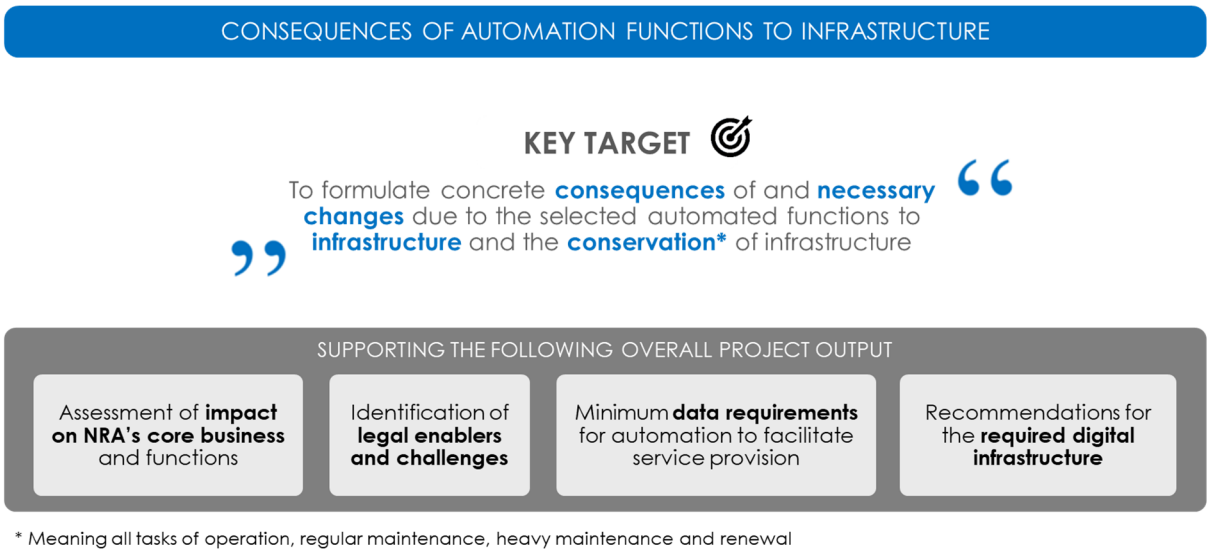

Figure 1. Key target of work-package 4

The results of work-package 4 provide significant input for work-package 5, where the core research question of this project *"How will the current core business on operations & services, planning & building and ICT change in the future?"* will finally be answered. The following Figure 2 provides an overview of NRAs core business.

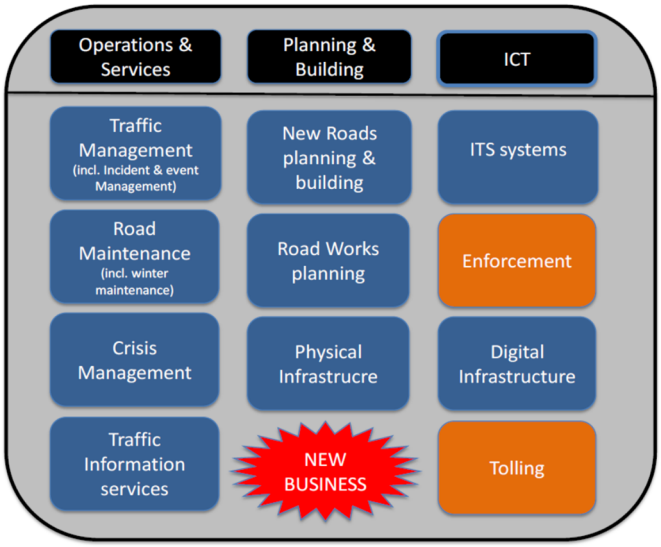

Figure 2. Overview of NRAs' core business (source: DoRN, CEDR Call 2017)

The blue coloured boxes of Figure 2 will be analysed in this work-package 4 in terms of infrastructure.

After the selection of the most significant automated functions in a mini-workshop held with CEDR, the impact and consequences of these use cases and their interplay with infrastructure and following consequences are tackled. Potentially new requirements for physical as well as digital infrastructure will be collected structurally.

In correlation with work-package 3 close attention will be paid to potential effects of infrastructural requirements on NRAs policy targets. The collective results of work-package 3 and this work-package 4 will then form the basis for the changes to road operators' core businesses. Following the approach as described in chapter 1.2, the results feeding into answering the key research question of how NRAs core business will change are summarized in chapter 6 following the structure of Figure 2.

Today's solutions can quickly become a problem in a tomorrow with automation functions. MANTRA as a whole considers the global impact of automation on infrastructure and the associated changes for NRAs. This deliverable is putting its focus on the technical changes to the infrastructure itself. Construction, maintenance and structural changes during the lifecycle of infrastructure are not only an expensive undertaking for the NRAs but always comprises impairment to network users at the same time. To minimize consequences on both, costs and traffic, measures are formulated structurally considering timing implications.

1.2 Approach and methodological framework

The overall methodology follows the process as shown in Figure 3. Starting with the current status quo on European highways, inputs from several sources form the basis of the assessment. These are collected in chapter 2 utilizing literature research. Key infrastructure requirements to date for physical and digital infrastructure form the starting point.

With the input of work-packages 2 and 3 impact and consequences are going to be addressed in 3 categories (see Figure 4) as well as the resulting required changes which will then provide the input for work-package 5.

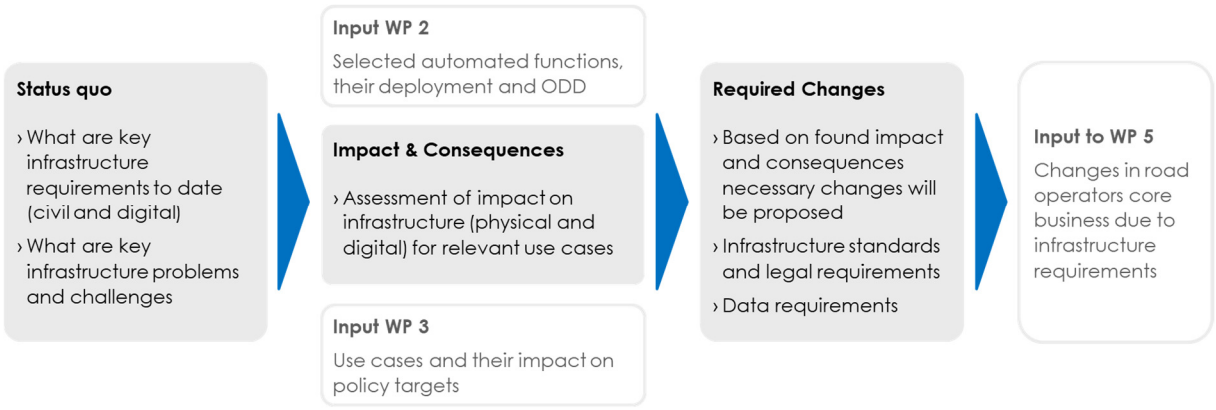

Figure 3. Overall approach work-package 4

The impact and the resulting consequences and therefor necessary changes to infrastructure will have various sources. Analysis is tackled from three directions in order to structurally cover the crucial ones, referred to as impact categories, as shown in Figure 4.

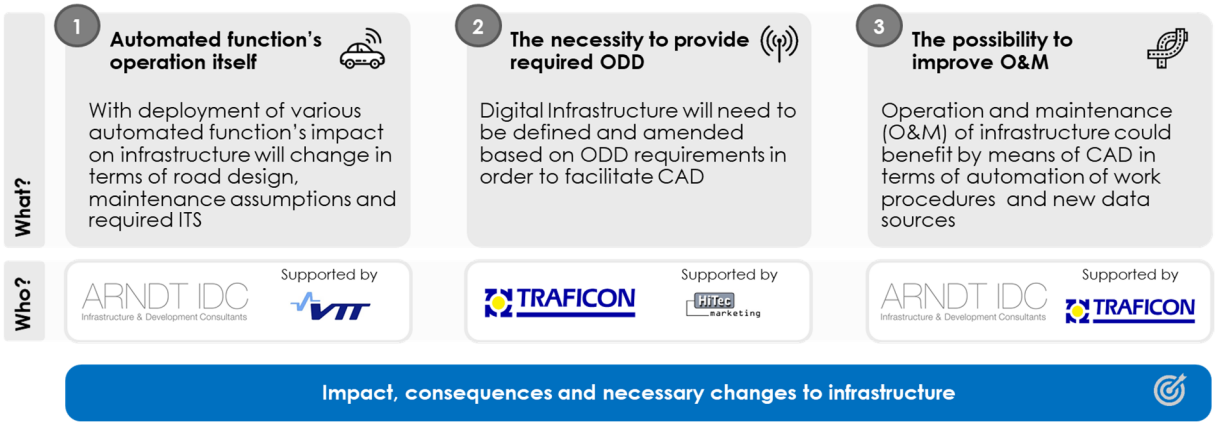

Figure 4. Assessment of impact from three different angles

The assessment of these three impact categories will include literature analysis, expertise of the consortium as well as structures interviews with selected experts and workshops with CEDR CAD WG and a workshop with experts from road authorities, operators, automotive, civil design and construction companies, telecommunications industry and research/academia stakeholders. The approach for each impact category is described in the dedicated respective chapter:

1. Impact through automated function's operation itself, approach see chapter 3.1
2. Impact by ODD requirements, approach see chapter 4.1
3. Impact due to possible O&M improvements, approach see chapter 5.1

The analysis will focus on highways and their physical and digital road-side infrastructure. However also extended aspects of infrastructure, including the back office and off-roadside infrastructure such as e.g. traffic centre operations, information management systems and databases, cellular networks and base stations, and land stations ensuring the accuracy of satellite positioning will be considered.

After the detailed assessment of consequences to infrastructure for each of the impact categories in chapters 3 to 5 the results and recommendations for necessary technical and legal changes as well as their overall implication for NRAs are described in chapter 6. In case of negative consequences, specific advice will be given in order to mitigate such consequences.

The field of analysis of infrastructure consequences due to automation is still very open. Therefore, work-package 4 tries to capture the overlying opinion through a general set of questions that is discussed with experts in various field throughout the work on work-package 4. The following questions are discussed and the results added to the introduction of the respective chapters:

General questions on automation and infrastructure

- Thinking of physical and digital assets of a highway – where do you see the greatest consequences of automation functions to infrastructure?
- Which road infrastructure assets will be affected most by the use of automated functions wear and tear, necessary adaptions, etc.)?
- Which kind of investments to amend infrastructure would actually benefit NRAs rather than simply support the implementation of automation?

Impacts on infrastructure through automated functions itself (impact category 1)

- In your opinion, will deployment of L4 highway autopilots and L4 automated freight vehicles on European highways be possible without any adaptions of the highways infrastructure (physical and digital)? Please explain.
- What kind of adaptions to the infrastructure would benefit the safe implementation of L4 highway autopilots and L4 automated freight vehicles most?
- A rather advanced use case would be the use of L4 winter maintenance vehicles. How could their implementation be supported by physical and digital infrastructure?
- Which automated functions and use cases will have the most significant impact on infrastructure and how what impact will it be?

Impacts on infrastructure by ODD requirements (impact category 2)

- ODD requirements potentially will make changes to infrastructure necessary, so the automated functions can be deployed safely. What is your opinion on necessary changes to infrastructure (that need to be financed by NRAs) to providing the appropriate ODD?
- How can standardization of ODD requirements in particular on infrastructure be done through-out Europe?

Impacts on infrastructure due to possible O&M improvements (impact category 3)

- In current highway operation, which tasks are the biggest safety hazard (for workers as well as users) or the biggest cost driver (for highway operators)? And do you think any of those could be performed by automated systems?
- Thinking of connected and automated vehicles in highway operation and maintenance – how could infrastructure support the automation of these processes?

2 Status quo of road infrastructure in Europe

2.1 Road infrastructure in Europe

[Brief overview on the heterogeneous road infrastructure throughout Europe. Particular focus on highways – ARNDT IDC]

2.1.1 Road infrastructure network

[Length of highway network in each country – ARNDT IDC]

2.1.2 Current road infrastructure standards

[Naming European standards for physical and digital infrastructure as a basis – ARNDT IDC]

2.1.3 C-ITS

[Status of C-ITS developments in Europe– ARNDT IDC]

2.1.4 European Legislation

[European legislation relevant for MANTRA, e.g. Vienna Convention, Delegated Act on C-ITS, Tunnel Directive – ARNDT IDC]

2.2 Research results on effects of automated driving on infrastructure

2.2.1 Automated driving in general

[Brief introduction in achievements in CAD – ARNDT IDC]

2.2.2 Highway autopilot including highway convoy

[Research results on effects of highway autopilot to infrastructure – ARNDT IDC]

2.2.3 Highly automated freight vehicles on open roads (including platooning)

[Research results on highly automated freight vehicles and in particular platooning effects to infrastructure – ARNDT IDC]

2.2.4 Commercial vehicles as taxi services

[Research results on commercial vehicles as taxi services to infrastructure – ARNDT IDC]

2.2.5 Driverless maintenance and road works vehicles on highways

[Research results on driverless maintenance vehicles to infrastructure – ARNDT IDC]

2.3 Classifications

2.3.1 SAE Levels

[Brief current SAE and their limitations – ARNDT IDC]

2.3.2 Operational Design Domains (ODDs)

[ODD parameters of D2.1 relevant for infrastructure – ARNDT IDC]

2.3.3 Infrastructure Support levels for Automated Driving (ISAD)

[Research on ISAD levels and their interplay with ODDs – ARNDT IDC]

3 Impacts through automated functions itself

[Lead ARNDT IDC, Support VTT, traficon, HiTec]

3.1 Approach

The initial starting point was a set of candidate automation functions all based on the latest definitions in ERTRAC (2017). Through scientific analysis of deployment and the collective selection with CEDR of most significant automated functions and use cases during workshops, the following functions shown in Figure 5 have been chosen to be further studied.

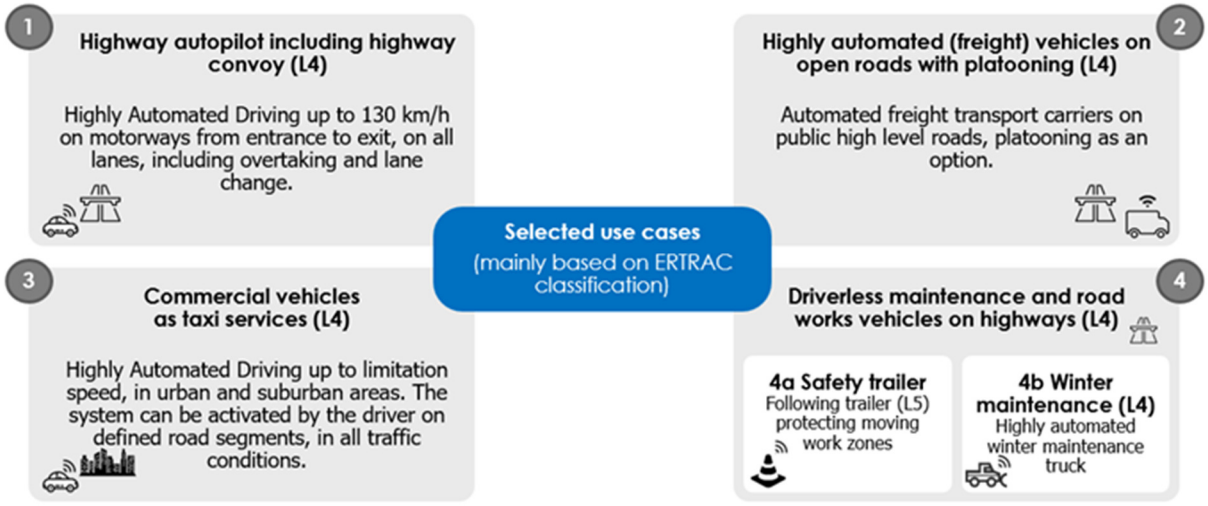

Figure 5. Selected use cases including level according to SAE J3016

In this category impacts due to the use of the selected automated functions operation themselves are tackled. This involves changes to pavement lifecycles due to accelerated rutting by convoy driving as well as additional requirements for emergency bays, tunnel fire protection and such. Figure 6 shows the process how this is approached. The selection of functions and ODD has been done in work-package 2. In an expert workshop with CEDR CAD WG (Tallinn, 07.03.2019), the functions have been mapped with physical infrastructure assets to identify which assets are affected by which function the most.

With these results concrete consequences to these identifies road infrastructure assets are identified as a desktop study. The results will be discussed based on a questionnaire with selected experts to validate the assumptions.

Following this, changes are identified in another workshop with CEDR CAD WG members and experts in the respective fields to be held in Vienna on 10.09.2019. The results of this workshop will be consolidated and the final suggestions formulated.

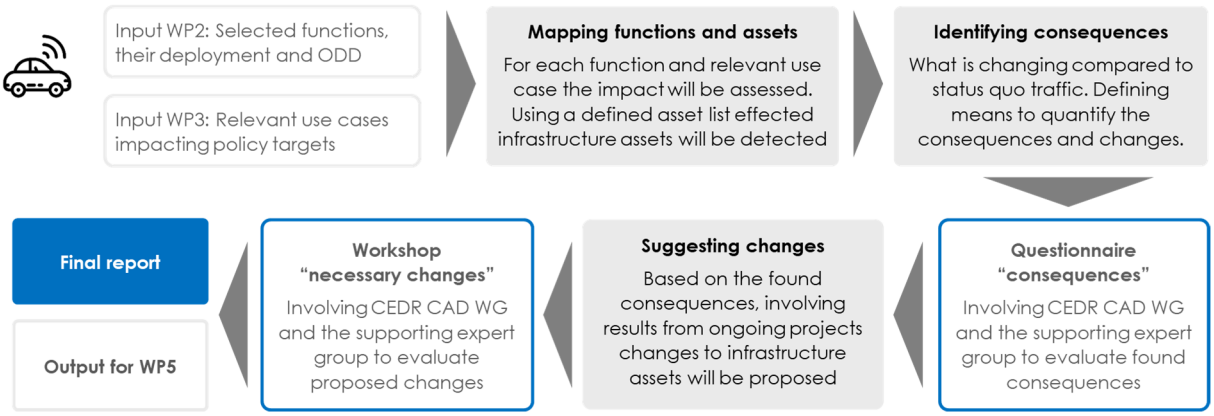

Figure 6. Assessment of impact by automated function itself

3.2 Identifying affected infrastructure assets

The starting point to define automated function's impact on road infrastructure is by finding out which types of road infrastructure assets are affected by the selected automated functions. As a basis MANTRA prepared a road infrastructure asset list (based on the EU Road OTL). This asset list has been presented to the participants of the expert workshop in Tallinn. For each automated function the participants of the workshop have rated whether or not these have an impact or specific requirement on the individual assets that differ from use of regular vehicles.

The overall workshop results are summarized in Figure 7.

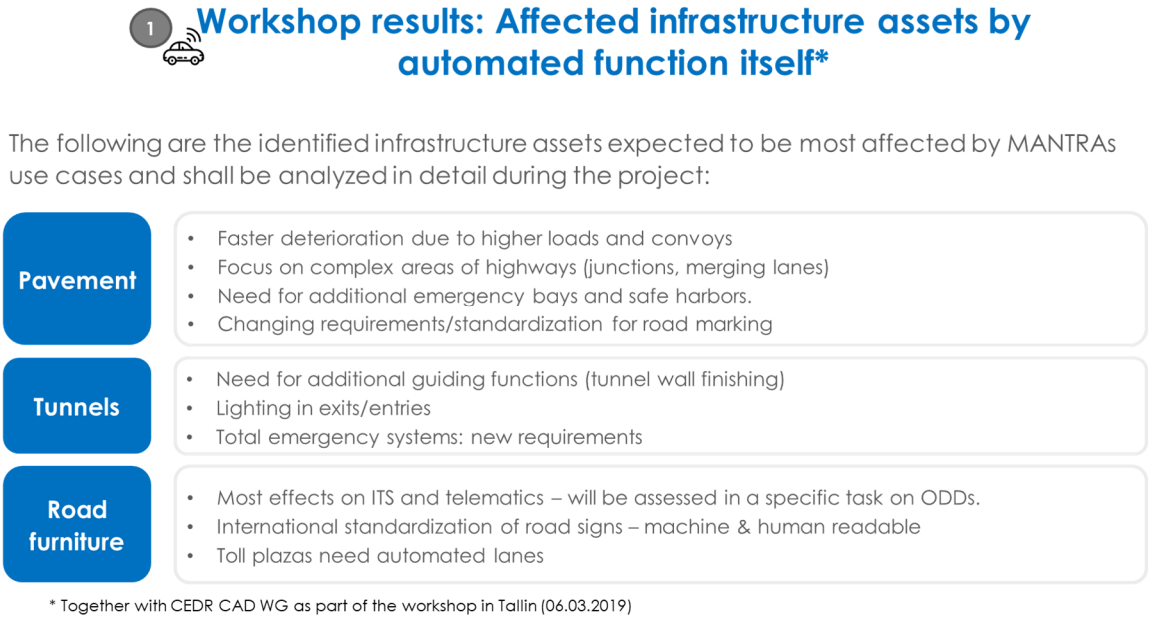

Figure 7. Key results of workshop on affected infrastructure

3.3 Consequences of highway autopilot including highway convoy

[Expected consequences, resulting expected changes, cost – traficon]

3.4 Consequences of highly automated freight vehicles on open roads

[Expected consequences, resulting expected changes, cost particular focus on truck platooning - Hitec]

3.5 Consequences of commercial vehicles as taxi services

[Expected consequences, resulting expected changes, cost - VTT]

3.6 Consequences of driverless maintenance and road works vehicles on highways

[Expected consequences, resulting expected changes, cost – ARNDT IDC]

3.7 Conclusions on suggested changes

[all – lead ARNDT IDC]

4 Impacts by ODD requirements

[lead traficon, support by HiTec]

4.1 Approach

The operational design domain describes the specific operating conditions in which the automated function is designed to properly operate. ODD requirements are strongly linked to infrastructure also through ISAD levels. The approach to tackle the consequences is described in three steps.

1) Mapping of the infrastructure needs in 2030 and 2040 based on the ODD tables from work-package 2 and listing the needs by infrastructure attribute, utilizing the ODD attributes list. For the analysis however this will go much deeper than the attributes list using sub-attributes (e.g. shoulder or kerb to be divided at least into a) safe stopping for minimum risk, and b) passenger pick-up or drop-off) through utilizing literature
2) Assessment of the needs for different infrastructure in different parts of the road network (motorways, other main interurban roads, rural roads, city arterials and rings, city streets, critical spots such as tunnels/bridges/etc. – again for 2030 and 2040 – as a desktop activity
3) Discussing the results with road operator, telecom operator, industry and external experts (such as Prof Kawashima and Steve Shladover), taking on board especially industry/expert views on ODD evolution during the next decades, telecom operator view on land connection and base station needs, and the road operator view on road planning, building and maintenance evolution. This is started at ITS Europe in June, then continued in our workshop in September.

The following chapters present the intended structure to document the steps and results of this approach in the final deliverable D 4.2.

4.2 ODD requirements

4.2.1 ODD requirements today

[Description of the ODD requirements use case by case – traficon, Hitec]

4.2.2 Physical infrastructure

[The changes needed into current infrastructure, Likely development scenarios in time – traficon, Hitec]

4.2.3 Digital infrastructure

[The changes needed into current infrastructure, Likely development scenarios in time – traficon, Hitec]

4.3 Effects on different road networks

[status of ODD according to the attributes, situation in 2030 and 2040 – traficon]

4.4 Responsibilities for establishing and operating/maintaining the ODD

[by each attribute and road network type - traficon]

4.5 Costs of establishing ODD

[unit costs, and their likely evolution, costs for the likely deployment scenarios - traficon]

4.6 Conclusions on suggested changes

[traficon]

5 Impacts due to possible O&M improvements

[lead ARNDT IDC, support by traficon]

5.1 Approach

Core of this impact category forms the possibility to improve infrastructure related operations as a result of utilizing automated functions or new data provided by these functions. This involves for example improved maintenance and operation carried out by automated vehicles or new ways of data provision on assets' condition. As shown in Fig. 6 this is again tackled through a structured process.

The starting point here is to define the gap which O&M processes are even worth optimizing. Operation and maintenance of infrastructure could benefit by means of CAD. In a workshop with CED CAD WG (Tallinn, 07.03.2019), the participants define those tasks of operation and maintenance that are either big safety hazards for operational workers or road users during road operations works or improve the road availability or reduce cost of O&M. MANTRA has prepares a list of crucial O&M tasks on road networks today. These tasks are rated by the participants in terms of their impact on safety, road availability and cost. The results of this rating provides the ground for the further analysis of potential improvements by automation in O&M.

The following workflow shows the whole process to identify the possibilities to improve O&M by automation. The workshop focuses on the blue box for which flipcharts and handouts listing the crucial operational tasks will be prepared by MANTRA. For those identified potential efficiency improvements a gap analysis was performed to find out which of those improvements could be done with the help of automation.

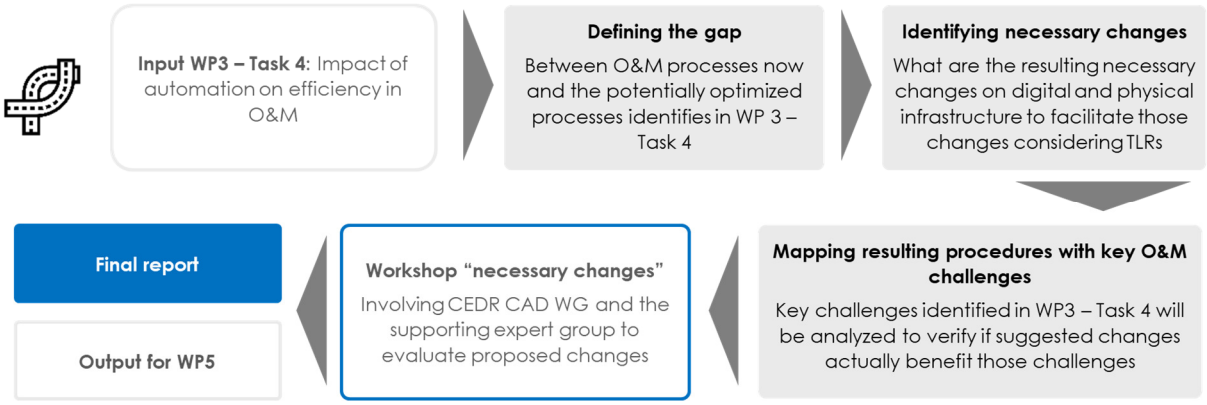

Figure 8. Assessment of impact due to possible O&M improvements

The following chapters present the intended structure to document the steps and results of this approach in the final deliverable D 4.2.

5.2 O&M processes worth optimizing

[Analyzes of typical O&M processes identifying those who are worth optimizing the most based on their impact on safety, availability and cost – ARNDT]

5.3 Optimization of traffic management through new data sources

[Analyzes of new methods to collect road condition, traffic flow, etc. data to be used for traffic management – traficon]

5.4 Necessary infrastructure changes

[Resulting necessary changes – ARNDT, traficon]

6 Consequences and recommendations

[ARNDT IDC & traficon]

[Recommendations for necessary changes and in case of negative consequences, specific advice how to mitigate such consequences, will be given in the final report D 4.2 together with rough assumptions on financial consequences. This will also provide the main input to work-package 5.]

6.1 Traffic management

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.2 Road maintenance

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.3 Crisis management

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.4 Traffic information services

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.5 New roads planning & building

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.6 Road works planning

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.7 Physical infrastructure

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.8 ITS systems

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.9 Digital infrastructure

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

6.10 New core businesses

Technical consequences and recommendations

Necessary changes of legal framework

Recommendations for implementation of changes

7 Conclusion

Final conclusions

Sources