VÄYLÄ

AUTOMATED DRIVING ON MOTORWAYS (AUTOMOTO)

Study of infrastructure support and classification for automated driving on Finnish motorways

Nordic WAY 3

Co-financed by the Connecting Europe Facility of the European Union

Results 23.9.2021

AIMS OF THE STUDY

- Assess the feasibility of the selected motorway section (Highway E12 between Helsinki and Tampere) for the operation of SAE Level 3 and 4 automated vehicles.
- Propose a way to classify Finnish road network from the automated vehicles operations' point of view, i.e. propose a framework for service level classification for automated vehicles.
- Prepare a proposal for further actions in research and development work, follow-up and international cooperation

PROJECT ORGANISATION

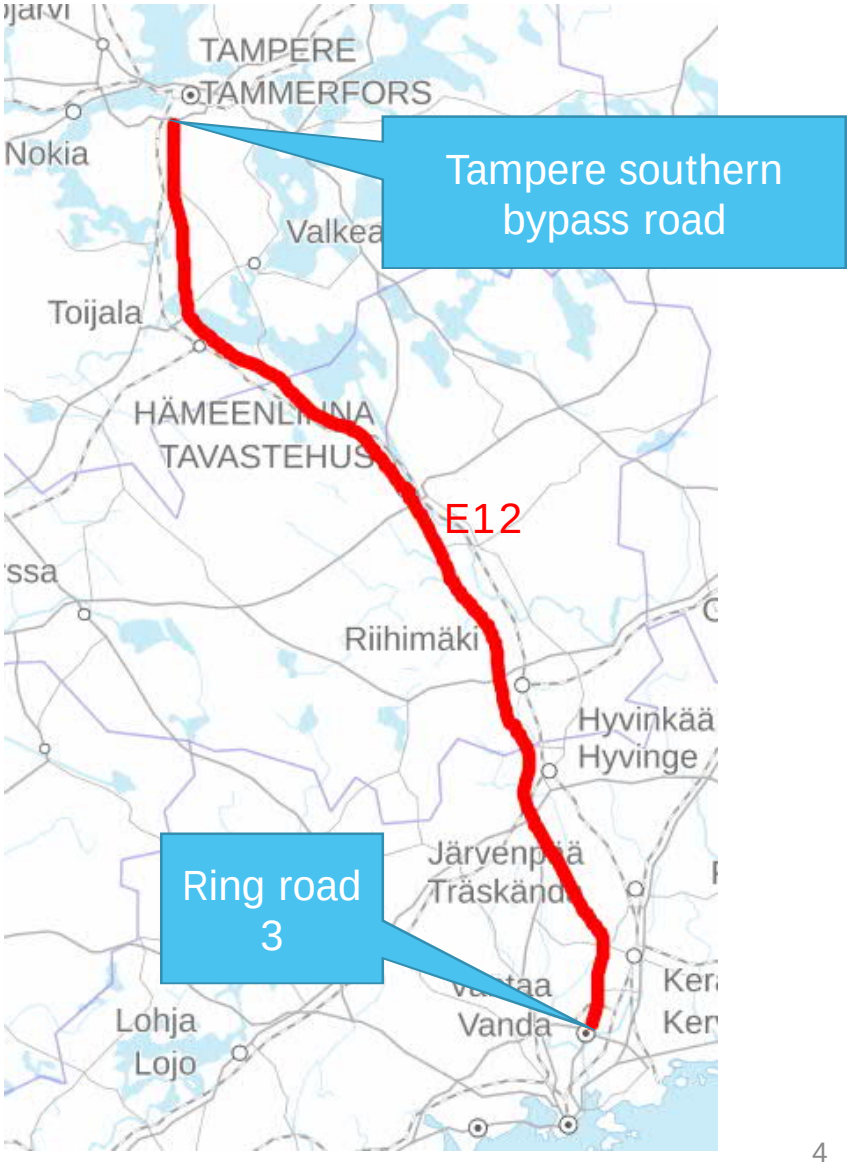
“The project was part of the Nordicway 3 project (www.nordicway.net) which is funded from the European Commission’s Connecting Europe Facility programme during 2019-2023. ”

- The project owner was the Finnish Transport Infrastructure Agency (FTIA). Project manager was Jari Myllärinen and the steering group consisted of experts from FTIA.
- The project work was divided between four Finnish consultancies and research organisations:
  - Traficon Ltd
  - VTT Technical Research Centre of Finland Ltd
  - Ramboll Finland Ltd
  - Sitowise Ltd
- A project follow-up group consisted of participants from the Ministry of Transport and Communications, The Finnish Transport and Communications Agency (Traficom), The Finnish Meteorological Institute (FMI), Fintraffic Road Ltd.

AUTOMATED DRIVING
ON MOTORWAYS
(AUTOMOTO)

STUDY AREA E12 HELSINKI-TAMPERE

"The length of the test section is 160 km"



PROJECT SUBTASKS

1. Assess the feasibility of the selected motorway section (Highway E12 between Helsinki and Tampere) for the operation of SAE Level 3 and 4 automated vehicles
   - 1.1 Physical infrastructure and the static and the dynamic features based on an ODD classification
   - 1.2 Communication networks and their attributes
   - 1.3 Positioning and services
   - 1.4 Weather and driving conditions
   - 1.5 C-ITS and other transportation and driver's services
   - 1.6 Road network features' field measurements
2. Framework for service level classification for automated vehicles
3. Further actions for research and development work, as well as in international cooperation

- The feasibility assessment focused on the road attributes that have effect on the Operational Design Domain (ODD) for automated vehicles i.e. the circumstances in which the SAE L3 and L4 vehicles are able to operate automatically.
- Inventory contained both analysis of data from the current road and traffic databases as well as field measurements regarding e.g. positioning services, telecommunication services, road structures and their condition.

RESULTS AND CONCLUSIONS FROM THE ASSESSMENT OF THE CURRENT FEASIBILITY

PHYSICAL ROAD FEATURES

"Used design requirements are likely to be sufficient for level 3 and 4 automated vehicles."

- The provision of sufficient space for Minimal Risk Manoeuvres (MRM) is important and on the right shoulder the continuous width of 3 m or more is sufficient space for automated trucks as well as for passenger cars and vans
- MRMs to the left shoulder are not recommended in the Finnish motorway environment with 2 lanes in each direction, but an MRM to the right shoulder is considered safer
- The future recommendation of the MRM policy needs to be formed in close cooperation with automotive industry and following international standards. Today there is still no need to make any changes into the motorway planning guidelines nor practices in this respect.
- Another future concern regarding the design principles of motorways is the possible need for specific areas for coupling and uncoupling of truck platoons.
- The Road registry data definitions should be updated and defined according to the automated driving perspective (e.g. definition of the width of carriageway, width of edge).

Results and conclusions from the assessment

ROAD MAINTENANCE

"The current road surface maintenance service level in this test segment is sufficient."

"No changes to the maintenance standards is proposed."

- There are no major concerns regarding rut depths exceeding the set limit of 20 mm for automated driving, as less than 2% of lane length had rut depths exceeding the limit.
- The lane keeping systems currently on the market recognize reliably the lane markings even in early spring conditions when the condition of the markings is at its worst
- Due to winter conditions and snowfall, there will be recurrent periods, when the lane markings are totally covered with snow, so the AV operation cannot be dependent on this feature alone.
    - Currently some AV developers are using cameras and some are moving away from them, relying more on radars and point cloud maps in the accurate positioning of the vehicle.
    - The latter development path would remove the necessity to introduce higher winter maintenance standards, but on the other hand, introduces a need for permanently fixed roadside structures that support lidar-based lane-keeping functionality.

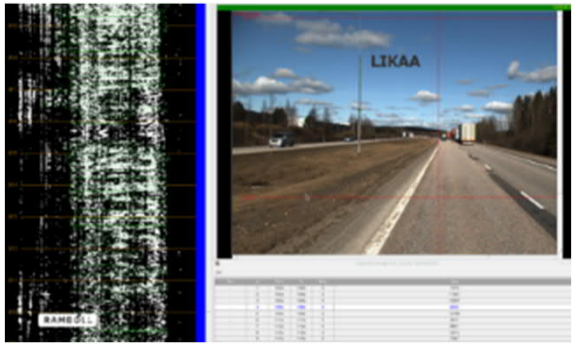


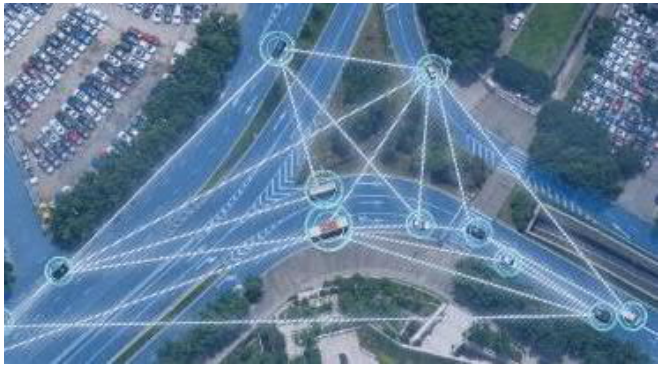
Figure: Sand on line is shown as missing marking on a 10 m long analysed section.

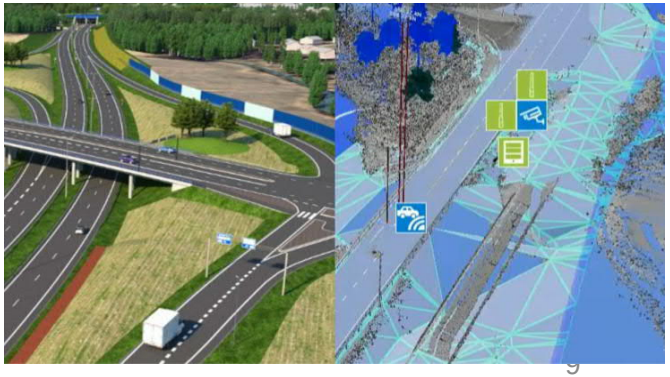
Results and conclusions from the assessment

TRAFFIC MANAGEMENT

"To provide full support, the current traffic management systems should support C-ITS communications standards."

- The current traffic management systems in the test section provide useful data support for AVs.
  - Aim for higher quality of traffic and road weather monitoring and thereby better situation and environmental condition awareness
  - the existing electricity and communication supply for the traffic management devices can be utilized to serve also highly automated driving support purposes.
- Deployment of detours for a certain motorway section may occur due to a severe incidents, and in the tunnel section also due to occasional but recurring maintenance works.
  - In the short and medium-term future the solution in such occasions is that the driver needs to take responsibility of the driving task
  - the planned detours include varying road types and it is not realistic to instrument the whole detour network to fully support automated driving.





COMMUNICATION NETWORKS

"It is crucial to differentiate the capacity that a single vehicle requires and the capacity of a mobile network cell."

- The test results show that the speed rates vary from below 1 Mbit/s to above 500 Mbit/s. It should be taken into account that the existing 3G networks were not included in the test.
- If the test is repeated in the end of 2023 it is likely that there will be more continuous capacity of at least 5 Mbit/s both directions (uplink/downlink), a sufficient capacity for the basic use-cases of automated driving.
    - In practice, a 5 Mbit/s upload capacity may be hard to achieve in 4G networks
- The most demanding use cases, namely cooperative driving and tele-operated driving, require at minimum 100 Mbit/s capacity in both directions, and some of them also an end-to-end latency below 10ms. Such speeds are currently supported only in the proximity of largest urban areas.
- Existing passive infrastructure is on a good level in the proximity of the test motorway sections, which means decreasing cost estimates for the possible future investments.
- Follow-up work on European level is proposed to study and understand what increased number of users and requirements of new use cases mean for connectivity in general and for mobile networks.

POSITIONING SERVICES

"The service quality of the current positioning services is high in the whole motorway test section regarding the needs of automated vehicles."

- The GNSS-based positioning accuracy is on centimetre level 83 % and at least decimetre level 96 % of the time, when the vehicle is using all satellite constellations (in this test Galileo, GPS and Glonass) together with correction service
- The best positioning accuracy requires good signal strength (Signal-to-Noise Ratio 40 dB or above). The test proved that there are only few locations, where the signal strength drops below the limit value, and these are explained by physical shadows or hindrances such as hill cutting, overpass or tunnel.
    - In case the signal strength falls for a longer period of time, positioning can be managed with other technologies. Specific landmark structures may be deployed on the most problematic sections.
- Different positioning correction services may use different coordinate frames, so the need for coordinate transformations must be addressed and facilitated

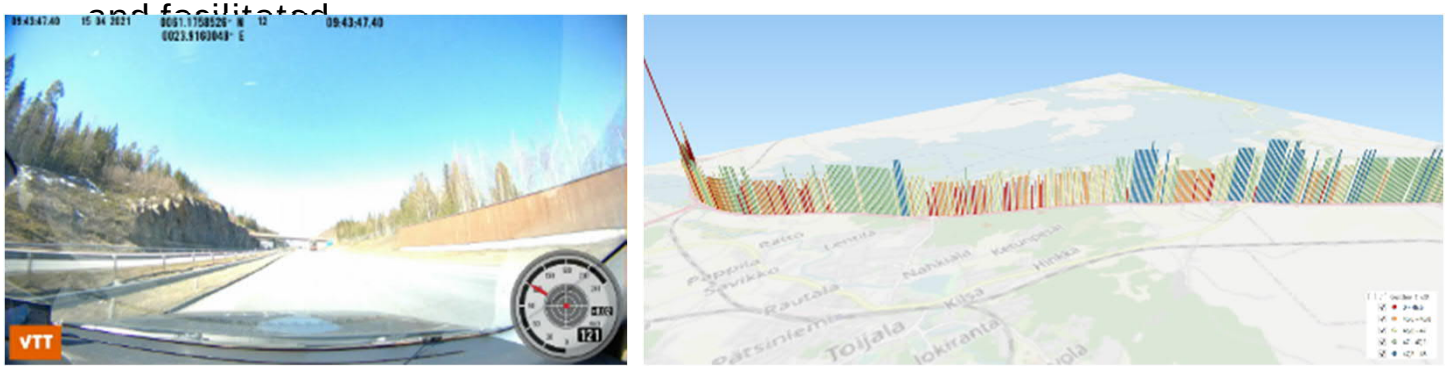


Figure: Galileo signal strength nearby Nahkialanvuori hill, Toijala (dB).

WEATHER CONDITIONS

"Weather condition is a critical factor concerning the continuity of ODDs."

- Airborne fog, mist, rain or snowfall reduce the perception capability of the vehicle sensors, or the road surface becomes very slippery due to forming of ice.
- In the autumn months (September-November), difficult weather conditions for AVs exist on average 25 hours/month (3.5% of time), mainly due to formation of fog.
- In the winter months (December-February) difficult conditions exist on average 35 hours/month (5% of time), dominant reason being the formation of icy road surface.
- The automated vehicles, and their users, could be provided with accurate information and prediction of critical weather conditions to enable them to make preparations for timely take-overs or MRMs.
  - Even though it is likely that the next-generation AVs will be independent in their real-time follow-up of weather-related ODD attributes such as friction and visibility, external support can be beneficial
- The current type of fixed road weather stations already provide relevant information and are located on motorways densely enough also for automated vehicles, but this information should be enhanced to provide better support.
  - Follow-up of the European level development

Picture:
Radar (blue) & Lidar/camera-based system (orange) detection ranges (=how far can they detect different obstacles).

TRAFFIC INFORMATION SERVICES

"The accuracy of information content needs to be improved to be sufficient for AVs, and to meet the agreed C-ITS standard requirements."

- A variety of public and private information services are available that provide relevant information regarding weather and traffic conditions.
  - The currently used standards and quality levels are aligned towards informing a human driver instead for the use of automatic control system of an AV.
- It is recommended to follow closely the development of data provision standards for AV's and to develop the information dissemination services accordingly, especially for
  - Incident information
  - Road works information
- It can be assumed that certain changes in the information production processes will be necessary as well.

SERVICE PROVIDER	SERVICE	DATA			OPEN DATA
		*Traffic, disturba-nces	Weather & road weather conditions	Other	
FINTRAFFIC	DigiTraffic	x	x	x	x
FTIA	Digiroad			x	x
FMI	Open data		x		x
FMI	Road Weather Forecasts		x		
INFOTRIPLA	DATEX2 Premium Feed	x	x		
INFOTRIPLA	Crowdsourced traffic warning data	x	x		
EEE	E3 REST API	x	x		
SAFETY4TRAFFIC	Accident, Crosswind, Elk, Deer, Reindeer, Road weather and Road work warning services	x	x		
ROADCLOUD	Premium connected vehi-cle data service		x		
SITOWISE	Carrio, Routa	x	x	x	
HERE	Traffic API	x			
TOMTOM	Intermediate Traffic ser-vice, Traffic API	x			
WAZE	Transport SDK, Connected Citizens Pro-gram	x			
OEM & PUBLIC AUTHORITIES	Safety Related Traffic In-formation Ecosystem	x	x		

* Event, incident and other hazardous location information, roadworks information (stationary and mobile), etc.

Table: Identified traffic information services.

SERVICE LEVEL CLASSIFI-CATION FOR HIGHLY AUTOMATED DRIVING ON MOTORWAYS

OBJECTIVE

"To propose service level classification for the Finnish road network from the automated vehicles operations' point of view"

- The proposed classification was validated utilizing the data collected from the E12 motorway connection between Helsinki and Tampere
- More specifically, the purpose of the road network classification was
  - to provide basis for authority and road operator views about what parts of the road network should be prioritised with regard to conditionally or highly automated driving
  - to inform the owners, drivers, manufacturers and developers of conditionally and highly automated vehicles about the current state of the physical and digital infrastructure on a specific road section or connection
  - to provide a level of service hierarchy for the motorway network's support to conditionally or highly automated driving.
- The authority and road operator views on targeted service level influence also the actors, actions and processes in traffic management, road and winter maintenance, road planning and building. Hence, the classifications should also give implications to such actors.
- For the use by automated vehicles, the classifications should describe the road network's properties in relation to the Operational Design Domains (ODDs) of conditionally or highly automated vehicles.
  - It is acknowledged that the ODD is different for different automated driving systems. Thus, attributes of likely relevant factors are considered in the classification.
  - In practice, the automated vehicles will instead of a network classification need to know the exact values of numerous classification attribute values to assess their ODD.

Service level classification for highly automated driving on motorways

REQUIRE-MENTS FOR CLASSIFI-CATION

"specify five different service levels, where the requirements towards the physical and digital infrastructure will get higher as the service level increases"

- The road network to be prioritised in terms of facilitating conditionally or highly automated driving should reflect user needs.
  - Those needs are to be assessed primarily for the part of long-distance commuting and work-related journeys ("an hour to work in the car"), and the improved effectiveness and cleanness of heavy goods transports.
- The service level of the road network will be based on the current status of the ODD attributes on the Helsinki–Tampere motorway (E12 connection), classification objectives and the requirements of the conditionally or highly automated vehicles.
  - It is acknowledged that the ODD requirements won't be the same for all automated driving systems.
  - The ODD related requirements were acquired from projects, literature, and other existing sources, no new research on ODD requirements was carried out.
- The aim was to specify five different service levels, where the requirements towards the physical and digital infrastructure will get higher as the service level increases.
  - A consensus decision was made to utilise the existing ISAD level structure (Lytrivis et al. 2019, Sigl et al. 2021) as a basis for the service level framework as that has been widely discussed e.g. in CEDR and ERTRAC.

SERVICE LEVEL FRAMEWORK

- Attribute classes
  - Physical infrastructure
  - Digital infrastructure
  - Environmental conditions
  - Dynamic elements

- Levels of service
  - E: Conventional (physical) infrastructure only, no AV support
  - D: Static digital information / map support
  - C: Dynamic digital information
  - B: Cooperative perception
  - A: Cooperative driving

Service level classification for highly automated driving on motorways

SERVICE LEVEL DEFINITIONS (1/2)

Service level	Interpretation			
	Physical infrastructure	Digital infrastructure	Environmental conditions	Dynamic elements
E: Conventional (physical) infrastructure only, no AV support	Physical infrastructure designed according to current design guidelines (made for manually driven vehicles)	No support from digital infrastructure, i.e. road geometry and road signs have to recognised by AVs on their own	Road side stations may measure environmental condition but no direct access to the data available	Traffic management provided according to current operational guidelines
D: Static digital information / map support	Infrastructure easily perceived and identified by AVs	Digital map data (incl. static road signs) complemented by physical reference points; Traffic lights, short-term roadworks and VMSs have to be recognised by AVs on their own	Historic information on environmental conditions available in machine readable format	Traffic management measures and plans provided in a way correctly perceived by AVs, self-diagnostic TMC hardware
C: Dynamic digital information	Enhanced physical infrastructure for AVs with regard to improved infrastructure maintenance	All static and dynamic information can be provided to the AVs in digital form; AVs receive infrastructure support data	Infrastructure-based weather information available	Dynamic traffic and incident management including connectivity, self-healing TMC hardware

Service level classification for highly automated driving on motorways

SERVICE LEVEL DEFINITIONS (2/2)

Service level	Interpretation			
	Physical infrastructure	Digital infrastructure	Environmental conditions	Dynamic elements
B: Cooperative perception	Improved physical infrastructure for AVs with regard to MRMs	Infrastructure is capable of perceiving microscopic traffic situations; AVs receive infrastructure support data in real time (C-ITS Day-1)	Detailed cooperative weather information (V2I): obtained via processing and sharing perception sensor findings by vehicles present on the particular road segment and infrastructure-based information	Enhanced dynamic traffic and incident management, self-learning TMC hardware
A: Cooperative driving	Improved physical infrastructure for AVs with regard to positioning support and vehicle supervision	Infrastructure is capable of perceiving vehicle trajectories and coordinate single AVs and AV groups; Infrastructure helps to coordinate vehicle manoeuvres to optimise traffic flow (C-ITS Day-2+)	Individual trajectory recommendation available taking into account the prevailing environmental conditions	Local traffic management arrangement provision for AVs, self-management TMC systems

SERVICE LEVEL DEFINITIONS PER ODD ATTRIBUTE

See Task 2 Report for

- ODD attributes and their relevance
- Definition for proposed classification per attribute
- Resulting classification for the Finnish motorway E12 Helsinki-Tampere

Service level classification for highly automated driving on motorways

CLASSIFI-CATION FOR MOTORWAY E12 HELSINKI-TAMPERE

"Almost all attributes meet the category E demands except for short-range communications and ODD/ISAD management information, which both are non-existent now"

- The results of the inventories carried out by the project
  - The inventories were carried out separately for both carriageways or driving directions.
  - Some of the inventories involved empirical studies and measurements while some were based on data bases and expert interviews.
- The inventories indicate that almost all attributes meet the category E demands
- Several attributes indicate infrastructure support for highly automated driving according to levels D, C and even B.
  - These include cellular network coverage and performance, satellite positioning, traffic flow information, weather condition information (visibility, friction, water on road, and wind), monitoring infrastructure, and traffic management centre systems.
- The support exists for most of the road with regard to shoulder width and existence of widenings or lay-bys sufficient for MRMs, and variable speed limits.

CONCLUDING REMARKS ON PROPOSED CLASSIFI-CATION

"The proposed classification was developed to be transferable to motorways everywhere, at least in Europe."

- The classification has utilised the ISAD (infrastructure Support for Automated Driving) levels (Lytrivis et al. 2019) as its starting point.
  - We have extended it according to the BSI (2020) ODD taxonomy to also the attribute areas of physical infrastructure, environmental conditions, and dynamic elements.
  - We have maintained the five ISAD levels from E to A while giving the level labels descriptions corresponding to those of the original ISAD oriented towards digital infrastructure.
- The proposed classifications have been aligned to the original ISAD level descriptions in terms of their achievability with regard to technology maturity and neutrality. Thereby, for instance, level A is regarded as a vision not to be realised within the next decades on the Finnish road network.
- The classification is made for motorways in the Finnish conditions only.
  - According to the E12 case study the Finnish motorway are likely corresponding quite nicely to the proposed classification, with most sections reaching level D and many even level C at least with regard to selected individual attributes.
  - For other main roads than motorways, the ISAD classification does not require many changes in terms of classification attributes.
  - The classification has no consequences on current investment plans or programmes. Neither is there a need to make any changes in the current road operations related planning practices.
- The proposed classification was developed to be transferable to motorways everywhere, at least in Europe.

IDENTIFIED FURTHER ACTIONS AND RESEACH

Identified further actions and research

PHYSICAL INFRA-STRUCTURE

What	Why
Clarify detailed requirements concerning the traffic management, road space and other road operator actions required by Minimal Risk Manoeuvres (MRMs) for the various automated driving use cases • to which MRMs road operator must be prepared for • which are infrastructure requirements of these MRMs (Follow actions on European level)	Otherwise MRMs may result in network lockdowns or major bottlenecks
Develop European solutions for lane and edge marking related problems like on non-motorway main roads at junction with widenings made for evasive actions of left-turning vehicles and for other typical similar challenging locations (Follow actions on European level)	If the right-hand edge line is painted according to the widening it may potentially cause confusion for the automated vehicle Relevant for all lane keeping automation
Investigate the impacts and demands of truck platooning on road structures and pavements, define related follow up actions if needed	To maximise the benefits of truck platooning and to minimise the harm on Finnish road network
To follow if MRMs cause crashes due to lack of safe space for it. For those locations, consider design and construction of new widenings and lay-bys or other solutions	Ensure safe MRMs
Introduce defect measurements on regular basis on sections provided for automated driving with automated pothole and other defect detection methods	Good surface condition supports safe automated driving. E.g. some potholes may be difficult to detect by vehicle sensors.
Investigate whether truck platoons require changes to road and bridge structures like the higher bearing capacity than traffic today.	Sufficient road and bridge structures support safe automated driving

Identified further actions and research

DIGITAL INFRA-STRUCTURE:

Digital infrastructure and communications networks (1/2)

What	Why
Enhance road registry data content and quality to meet the needs of automated driving support (agreed on European level) • Identify essential attributes for automated driving (ODD attributes) • Check the quality of those entries, define accuracy requirements for them (Follow actions on European level)	The current road registry data for all attributes is not accurate enough, and some features should be updated according to the needs of automated driving e.g. width of carriageway As the regulation/guidelines on road infrastructure change, the compliance with the current regulation should be registered
Study the effects of increase in (proportion of) traffic requiring high-capacity connectivity and requirements of new use cases (Follow actions on European level)	It is important to understand what increased number of users and requirements of new use cases mean for connectivity in general and for mobile networks
Study if a hybrid model using also other means that cellular communication would be cost effective in specific locations (Follow actions on European level)	The deployed solution must be in line with what is used by vehicle manufacturers
Study how identified use cases of digital infrastructure relate/localize to different road sections and how it might affect the service level requirements (Follow actions on European level)	To support automated driving the service level requirements might be different in different parts of the road, incl. tunnels, sections with roadwork
Study the use cases and requirements of mobile edge computation (Follow actions on European level)	Edge computation may support also communication with and between vehicles, possibly requiring localisation of the computation units close to the road

Identified further actions and research

DIGITAL INFRA-STRUCTURE:

Digital infrastructure and communications networks (2/2)

What	Why
Specify what is meant by "hot-spot" where short range communication is required and study how to set up a cost effective short range communication solution for them (Follow actions on European level)	To be able to communicate better the set requirement and their cost implications
Plan how to deal with fleet supervision centres and their communication needs including real-time video	The requirements for reliable communication of real-time video are demanding and require special attention. Willingness to pay for the communication may be higher than for other use cases. Some locations are more potential than others, like tunnels, moving roadworks, etc.
Develop global sharing solution for detailed ODD/ISAD attribute information among road operators, traffic managers, vehicles and vehicle fleet operators/managers including technical, operational, institutional, governance, cybersecurity and liability issues (Follow actions on European level)	The sharing of ODD information from vehicles to the road operator or traffic manager in real time is essential for safe road network operation as is also the real-time sharing of ISAD/ODD attribute values to the vehicles. The sharing of safety related information is a first but very small step to this direction.
Extend the current TN-ITS (2021) specification to cover the additional attributes identified in this work. (Follow actions on European level)	Sharing data of the detailed ISAD attributes with the vehicles is a crucial element of the ODD/ISAD

Identified further actions and research

DIGITAL INFRA-STRUCTURE:

Positioning/ localisation

What	Why
Identify road segments planned to be provided for automated driving where GNSS quality is not sufficient, i.e. it is lower than certain dB level (40dB) with 5 strongest satellites (e.g. tunnels, bridges)	Other positioning/localisation support should be provided on the segments with insufficient GNSS quality to ensure automated driving function use
Renew road markings every spring or provide landmarks for road segments with poor GNSS quality, like 2 km before and after Hämeenlinna tunnel	Together with good visibility road markings or landmarks the supporting machine vision system will work better
Specify landmarks required for positioning support concerning their properties including possible radio beacons in specified locations (Follow actions on European level)	The requirements are still unknown. Landmarks need to be cost effective to procure, install and maintain. They need to be high enough to be visible also in wintertime (higher than snow bank).

Identified further actions and research

DIGITAL INFRA-STRUCTURE:

C-ITS and information services (1/2)

What	Why
Study connectivity and capacity of mobile networks from viewpoint of reliability of information service provision (Follow actions on European level)	Communication affects the possibilities for use of C-ITS and other information services or OTA updates
Make traffic announcements on all the (mobile and stationary) roadworks which affect driving	All situations that affect the usability of the road should be informed about. TMC is now not aware of all roadworks nor on their exact timing nor location.
Present all information in traffic announcements according to harmonised metadata specifications instead of free-form text (Follow actions on European level)	Free-form text is difficult to use for automated vehicles. Everything should be provided in standardised and machine readable format.
Enhance the information on event location and driving direction affected, ensure that event information is provided to the road operator (of events affecting driving) (Follow actions on European level)	To be able to provide better quality information of the potential incident or other disturbance
Develop quality frameworks and specify requirements of C-ITS and data sources for automated driving (Follow actions on European level: standardisation organisations, C-ROADS, 5GAA and EU EIP)	The quality, accuracy and reliability requirements will increase as the focus moves from C-ITS services for drivers towards C-ITS and data sources supporting automated driving This quality framework will be needed to help AD (Automated Driving) developers to select suitable data and information sources, which can enable AD in variable conditions in the future.

Identified further actions and research

DIGITAL INFRA-STRUCTURE:

C-ITS and information services (2/2)

What	Why
Adjust data acquisition processes to meet standard quality requirements	To enhance the quality to match requirements related to data collection, fusion, enrichment, etc.
Make quality aspects a part of service-level agreements (SLA) between service providers and information or data users	The data quality may reflect to the liability issues related to automated driving in the future. Minimum quality must be defined if an automated vehicle relies on C-ITS.

Identified further actions and research

ENVIRON-MENTAL CONDITIONS

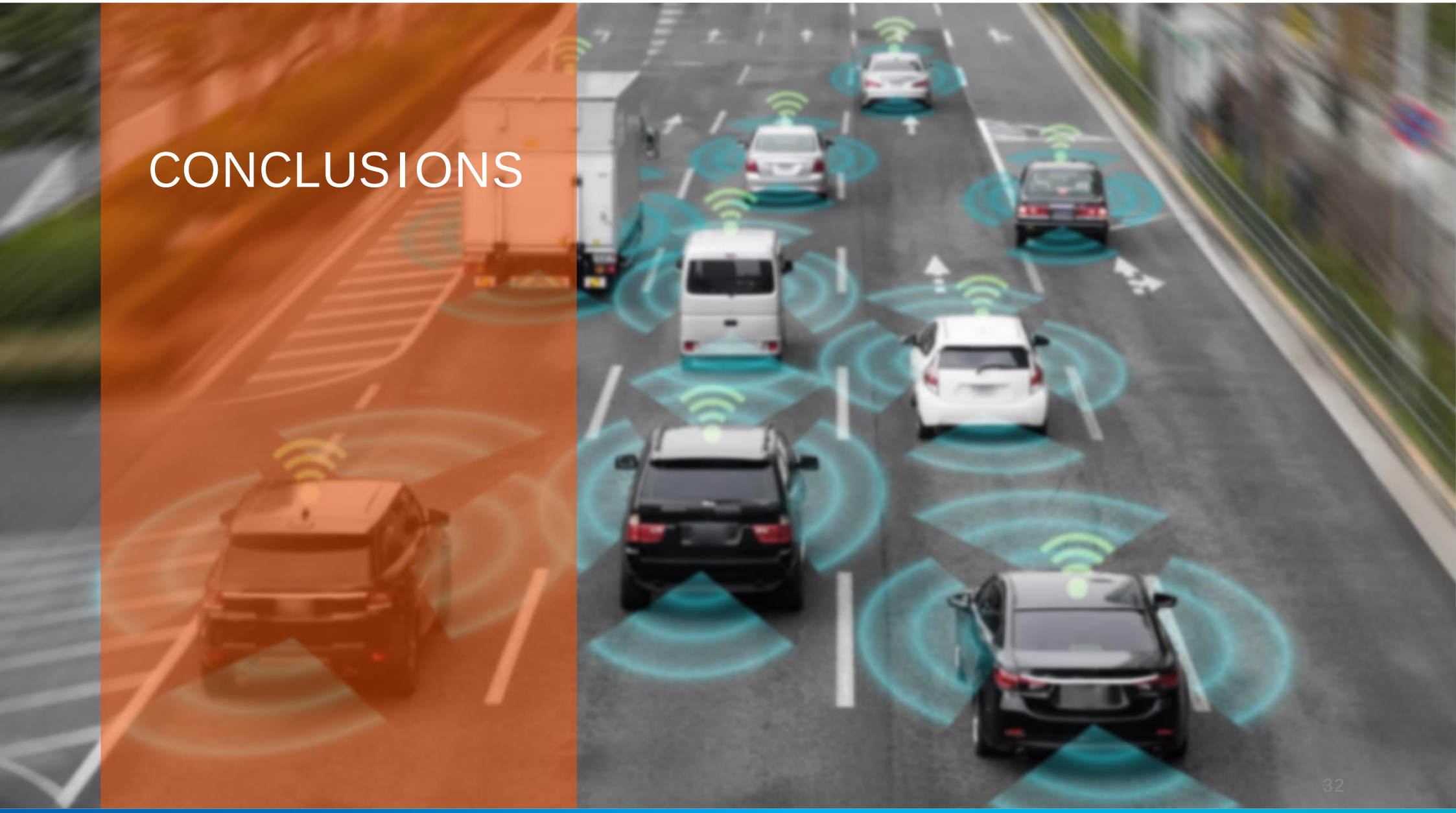
What	Why
Enhance the quality of stored weather and road condition data. If friction cannot be measured directly, at least reliable road surface category (icy, snowy, wet, dry, ...) should be systematically available. Also, reliable data about other simultaneous environmental conditions (like accumulation of snow, and when it has been cleared) becomes more interesting in the future. Enable combination of both road weather station data, appropriate measurements of the FMI, and information from road maintenance logs, since analysis needs will develop more complex in the future. (Follow actions on European level)	For the ODD analysis it is important that at least friction and visibility combinations are available at every time instant, so that their combinations are easily available. Visibility sets minimum requirements for friction and vice versa.
Develop road-side stations to measure visibility at each lane at about one meter height across the lane and to measure also the attenuation of non-visible wavelengths, to include at least 850 – 1550nm wavelengths used by lidars and some IR cameras. (Follow actions on European level)	This would enable monitoring of snow dust and water fog raised by the traffic in front of subject vehicle, not captured by road weather stations today. It is not sufficient to have the human view on the visibility but machine view is relevant for automated driving.
Utilisation of road weather sensors of vehicles to complement data from fixed road weather stations (Follow actions on European level)	Better coverage of weather information preferably containing at least friction, visibility, and precipitation would allow better understanding of prevailing conditions and support good road maintenance in winter

Identified further actions and research

DYNAMIC ELEMENTS

What	Why
Specification of markings and traffic management at roadworks according to the capabilities of AVs (Follow actions on European level)	The Automated Driving Systems of the AVs should be able to perceive correctly the road works and the intended trajectories to navigate through the road works site
Specification of markings and traffic management at incident sites according to the capabilities of AVs (Follow actions on European level)	The Automated Driving Systems of the Avs should be able to perceive correctly the incident sites and the intended trajectories to bypass or drive through the incident site
Legal framework for the use of automated maintenance vehicles	The appropriate use of automated maintenance vehicles is needed by their operators
Guidelines for the use of automated maintenance vehicles	The operation of the automated vehicles should be carried out in a safe and efficient manner

CONCLUSIONS



CONCLUSIONS

OVERALL FEASIBILITY OF E12 FOR AUTOMATED VEHICLES

- The current physical and digital infrastructures provide good support for the basic use cases of level 3 or 4 highway autopilot.
- Regarding the created classification, the tested motorway section on E12 provided the following results:
  - Almost all attributes meet the category E demands
    - short-range communications and ODD/ISAD management information do not exist now
  - Some attributes indicate infrastructure support for highly automated driving according to levels D, C and even B, namely cellular network coverage and performance, satellite positioning, traffic flow information, weather condition information (visibility, friction, water on road, and wind), monitoring infrastructure and traffic management centre systems.
  - The support exists for most of the road with regard to shoulder width and existence of widenings or lay-bys sufficient for MRMs, and variable speed limits.
- For safe and efficient use of level 3 and 4 autonomous vehicles, it would likely be beneficial to provide at least level D support on all elements of physical and digital support, environmental conditions and dynamic elements. This support would ensure that AVs correctly perceive, by their own means, the road infrastructure and the various dynamic elements that they may encounter.

USE AND FURTHER DEVELOPMENT OF THE CLASSIFI-CATION

"It may very well prove in the future that the targeted level of support is not any single ISAD-level, but a combination of support elements on different ISAD-levels, depending on the local circumstances and needs."

- The classification has no direct consequences on current investment plans or programmes.
- Further actions include:
  - Widen the inventory of the current Finnish motorway network against the classification (at least based on data available at various registries)
  - Develop similar type of infrastructure support level classifications to other road environments, especially to other main road network as well as city streets.
  - Test the proposed classification in practice, e.g. in European projects and actions to find out about the applicability of the classification in other countries and circumstances
- Developing of the classification towards more concrete (more quantitatively described) would possibly increase the applicability of the classification among AV developers.
- From operational point of view, the proposed sharing of ODD and ISAD information between the road operator or traffic manager and vehicles or vehicle fleet operators/managers is quite important for future traffic management.
- More analysis is needed to assess what is the cost for upgrading a certain attribute on e.g. motorway network from the current level to the next – and importantly – what is the obtained socio-economic benefit.
  - The first step in this respect is to analyse what are the costs and benefits related to improving the support over all elements from the current state to at least level D.
  - As the penetration rate of conditionally and highly automated vehicles may be low, the benefits from various improvements must be calculated both to manual "human-driven" vehicles and automated vehicles – what are the most obvious "no regret" actions?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