Finnish Transport and Communications Agency

NordicWay 3 Final report: Coordinated pilot on cooperative, connected and automated mobility

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Abstract
The NordicWay 3 project dealt with Cooperative, Connected, and Automated Mobility (CCAM) through 19 pilot projects conducted in cities and on main road networks across Finland, Sweden and Norway. These pilots demonstrated and tested CCAM services, focusing on the development of technology, infrastructure, and business models in real-world conditions.
Key achievements included:

- Innovative CCAM Pilots: Pilots explored urban, interurban, and motorway environments, integrating traffic management operations with connected vehicles. Services used passenger cars, heavy goods vehicles, buses, and nomadic devices, connected via cellular and ITS G5 communication.
- Technical Advancements: The pilots provided insights into Operational Design Domain (ODD) requirements under Nordic weather conditions. Automated methods for road network and pavement condition data collection proved faster, cost-effective, and user-friendly.
- Harmonization and Interoperability: All services complied with C-Roads specifications, promoting the standardization of C-ITS services in Europe.
- Stakeholder Collaboration and Ecosystems: Involvement of national and city road authorities, telecom providers, vehicle OEMs, and research institutes fostered the creation of a CCAM ecosystem.

Significant findings included:

- Centralized platforms for intersection data (e.g., MAPEM data) are necessary for C-ITS solutions.
- LTE-V2X and 4G/5G networks proved viable for C-ITS messaging
- Automated driving systems require better public understanding of their limitations and safe use.
- Automated vehicle testing in Nordic weather conditions supported deployment readiness and infrastructure requirements.
- Developing real-time data models and integrating them into platforms like the NordicWay interchange node.
- Encouraging public transport organizations to adopt standardized data formats (e.g., NeTEx, SIRI) to enhance multimodal services.

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Tiivistelmä NordicWay 3 käsitteli yhteistoiminnallista, verkottunutta ja automaattista liikkumista (CCAM=cooperative, connected and automated mobility) 19 pilottiprojektin kautta, jotka toteutettiin kaupunkiympäristöissä ja pääteillä Suomessa, Ruotsissa ja Norjassa. Pilotit esittelivät ja testasivat CCAM-palveluita eri näkökulmista: • Innovatiiviset CCAM-pilotit: Pilotit tutkivat kaupunkiympäristöjä sekä moottoriteitä, yhdistäen liikenteenhallinnan toiminnot ja verkottuneet ajoneuvot. Palveluissa hyödynnettiin henkilöautoja, raskaita ajoneuvoja, busseja ja nomadilaitteita, jotka yhdistettiin matkapuhelin- ja ITS G5 -viestinnän avulla. • Teknologiset edistysaskeleet: Pilotit tuottivat tietoa automaattisen ajojärjestelmien suunniteltujen toimintaympäristöjen vaatimuksista pohjoisissa sääolosuhteissa. Automaattiset menetelmät tieverkon ja päällysteen kunnon tiedonkeruuseen osoittautuivat nopeammiksi, kustannustehokkaammiksi ja käyttäjäystävällisemmiksi. • Harmonisointi ja yhteentoimivuus: Kaikki palvelut täyttivät C-Roads-spesifikaatiot, edistäen C-ITS-palvelujen standardointia Euroopassa. • Sidosryhmäyhteistyö ja ekosysteemit: Kansallisten ja kaupunkien tieviranomaisten, teleoperaattorien, ajoneuvojen ja ITS-laitteiden valmistajien sekä tutkimuslaitosten osallistuminen edisti CCAM-ekosysteemin vaatimusten ymmärtämistä. Keskeisiä tuloksia olivat muun muassa seuraavat: • Keskitetyt alustat liittymätietojen (kuten MAPEM-datan) hallintaan ovat välttämättömiä C-ITS-ratkaisuille. • LTE-V2X ja 4G/5G-verkot osoittautuivat toimiviksi vaihtoehdoiksi C-ITS-viestinnälle. • Kuluttajille tulee tiedottaa paremmin automatisoitujen ajoneuvojärjestelmien rajoituksista ja turvallisesta käytöstä. • Automatisoitujen ajoneuvojen testaus pohjoisissa sääolosuhteissa selvitti käyttöönoton valmiutta ja infrastruktuurivaatimuksia. • Reaaliaikaisten datamallien kehittäminen ja niiden integroiminen alustoihin, kuten NordicWay Interchange -solmuun. • Joukkoliikenteen organisaatioiden rohkaisemisen standardoitujen dataformaattejen (esim. NeTEx, SIRI) käyttöön multimodaalisten palveluiden parantamiseksi.			
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Sammandrag
NordicWay 3-projektet behandlade kooperativ, uppkopplad och automatiserad mobilitet (CCAM=cooperative, connected and automated mobility) genom 19 pilotprojekt i stadsmiljöer och på huvudvägar i Finland, Sverige och Norge. Dessa pilotprojekt demonstrerade och testade CCAM-tjänster med fokus på utveckling av teknik, infrastruktur och affärsmodeller under verkliga trafikförhållanden.
Huvudsakliga resultat var:

- Innovativa CCAM-piloter: Piloterna undersökte stads-, interurbana och motorvägsmiljöer och integrerade trafikledning med uppkopplade fordon. Tjänsterna använde personbilar, tunga fordon, bussar och nomadiska enheter som kopplades via mobilnät och ITS G5-kommunikation.
- Tekniska framsteg: Piloterna gav insikter om ODD-kraven i nordiska väderförhållanden. Automatiserade metoder för datainsamling av vägnät och vägkondition visade sig vara snabbare, kostnadseffektiva och användarvänliga.
- Harmonisering och interoperabilitet: Alla tjänster följde C-Roads-specifikationer och bidrog till standardisering av C-ITS-tjänster i Europa.
- Samarbete mellan intressenter och ekosystem: Deltagande av nationella och kommunala vägmyndigheter, teleoperatörer, fordons- och ITS-leverantörer samt forskningsinstitut främjade skapandet av ett CCAM-ekosystem.

Viktiga insikter var till exempel följande:

- Konsumenterna behöver bättre förståelse för begränsningarna och säker användning av automatiserade körsystem.
- Testning av automatiserade fordon i nordiska väderförhållanden stöder implementeringsberedskap och infrastrukturkrav.
- Centraliserade plattformar för korsningsdata (t.ex. MAPEM-data) är nödvändiga för C-ITS-lösningar.
- LTE-V2X och 4G/5G-nätverk visade sig vara välfungerande för C-ITS-kommunikation.
- Utveckling och integration av realtidsdatamodeller i plattformar som NordicWay Interchange.
- Uppmuntran av kollektivtrafikorganisationer att använda standardiserade dataformat (t.ex. NeTEx, SIRI) för att förbättra multimodala tjänster.

Kontaktperson	Språk	Sekretessgrad	Sidoantal
Anna Schirokoff, Traficom	Engelska	Offentlig	75

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Foreword

The Nordic countries Denmark, Finland, Norway and Sweden decided to further develop their C-ITS cooperation, which started with the NordicWay action in 2014 and continued with the NordicWay 2 (2016-2020) through extended joint pilot activities with the NordicWay 3 - Urban connection project. Driven by ministries and road authorities, NordicWay 3 carried out a pilot deployment of Day 1 and Day 1.5 C-ITS services as defined by the C-ITS Platform in addition to selected CCAM services.

NordicWay 3 was a five-year (2019-2023) real-life pilot deployment project which, in close collaboration with the C-Roads Platform, drove harmonisation of services to end users coming from different countries and provided the possibility to collect and use data from vehicles regardless of their origin.

This is the results report of Activity 6 (Coordinated pilot on cooperative, connected and automated mobility) of the NordicWay 3 project, co-funded by the Connecting Europe Facility (CEF) Programme in 2019–2023. The Finnish Transport and Communications Agency lead the Activity 6. An overview of the results compiled under NordicWay 3 are collected into this report.

Helsinki, 25 April 2024

Anna Schirokoff
Chief adviser
Finnish Transport and Communications Agency Traficom

Alkusanat

Norja, Ruotsi, Suomi ja Tanska päättivät syventää NordicWay-hankkeessa vuonna 2014 aloitettua ja NordicWay 2 -hankkeessa (2016–2020) jatkettua pohjoismaista C-ITS-yhteistyötä vielä NordicWay 3 – Urban connection - hankkeessa yhteisten pilottihankkeiden muodossa. Ministeriöiden ja liikenneviranomaisten johdolla toteutetussa NordicWay 3 -hankkeessa pilotoitiin C-ITS Platform -ryhmittymän määrittelemiä nopeasti saataville tulevia C-ITS-palveluja (Day 1 -palvelut) sekä pidemmällä aikavälillä saataville tulevia C-ITS-palveluja (Day 1.5 -palvelut). Lisäksi pilotoitiin erikseen valikoituja CCAM-palveluja.

NordicWay 3 -hanke toteutettiin viisivuotisena (2019–2023) käyttöönottoa pilotoivana hankkeena tiiviissä yhteistyössä C-Roads Platform -ryhmittymän kanssa. Hankkeessa tavoitteena oli yhdenmukaistaa palveluja, joita tarjotaan eri maista tuleville loppukäyttäjille, ja varmistaa, että ajoneuvojen tietoja voidaan kerätä ja käyttää ajoneuvon alkuperästä riippumatta.

NordicWay 3 -hankkeeseen saatiin rahoitusta Euroopan unionin Verkkojen Eurooppa -ohjelmasta vuosina 2019–2023. Tämä raportti koskee NordicWay 3 -hankkeen osaa 6 (Coordinated pilot on cooperative, connected and automated mobility), jota johti Liikenne- ja viestintävirasto. Yhteenveto tuloksista esitetään tässä raportissa.

Helsinki, 25. huhtikuuta 2024

Anna Schirokoff
Johtava asiantuntija
Liikenne- ja viestintävirasto Traficom

Förord

De nordiska länderna Danmark, Finland, Norge och Sverige beslöt att vidare utveckla sitt C-ITS-samarbete vilket startade 2014 med NordicWay och som fortsatte genom NordicWay 2 (2016–2020) och med gemsamma pilotaktiviteter i projektet NordicWay 3 – Urban connection. Under ledning av ministerier och trafikmyndigheter utförde NordicWay 3 ett pilotförsök med snabbt tillgängliga C-ITS-tjänster (Day 1-tjänster) och C-ITS-tjänster (Day 1.5-tjänster) som kommer att bli tillgängliga på längre sikt enligt CITS Platform-grupperingens definitioner. Dessutom pilottestades separat utvalda CCAM-tjänster.

NordicWay 3 var ett femårigt (2019–2023) pilotprojekt för verkställande i verkliga livet som i nära samarbete med C-Roads Platform strävade efter en harmonisering av slutanvändarens tjänster från olika länder och som erbjöd möjligheter att samla och använda data från fordon oavsett var de härstammar.

Detta är rapporten av resultaten från Aktivitet 6 (Coordinated pilot on cooperative, connected and automated mobility) i NordicWay 3-projektet som fått samfinansiering av Fonden för ett sammanlänkat Europa (CEF) 2019–2023. Transportoch kommunikationsverket ledde aktivitet 6. En översikt över resultaten som skapades i NordicWay 3 är sammanfogad i denna rapport.

Helsingfors, den 25 april 2024

Anna Schirokoff
Ledande sakkunnig
Transport- och kommunikationsverket Traficom

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Contents

1 Introduction

NordicWay 3 – Urban connection was a five-year (2019-2023) real-life pilot deployment project which, in close collaboration with the C-Roads Platform, aimed to drive harmonization of services to end users coming from different countries and to provide the possibility to collect and use data from vehicles regardless of their origin. It focused on upfront investments required both on the vehicle and the infrastructure level to enhance cooperation needs and synchronisation of actions to be established before any benefits will occur.

NordicWay 3 also aimed to support the long-term development of a safe, secure and efficient road transport system allowing for an innovative management of cross city as well as cross border traffic, ensuring that the implemented C- ITS services will be interoperable and continuous from one city to another.

NordicWay 3 was divided into six Activities. This activity ´Coordinated pilot on co-operative, connected and automated mobility (CCAM)' aimed to deploy pilots in urban areas, in interfaces between urban and interurban areas, and in motorway sections. In these pilots, the experiences from the automated driving studies in Northern conditions, conducted in NordicWay 2, were to be utilized. The aim was to pilot these functions in real traffic under naturalistic conditions.

The activity focused on CCAM services which had not been piloted in NordicWay 2 and were thus more explorative innature, and specifically, on demonstrations of proof of concept on technology, architecture, and business models. However, it was ensured that they were set up in a similar, coordinated way in the Nordic countries and aligned with C-Roads. NordicWay 3 aimed to set up at least three CCAM related services with a minimum of 15 vehicles.

This activity aimed to address key innovations of NordicWay3 related to connected and automated mobility as well as its pre-requisites, and to mobility as a service (MaaS). It also aimed to make relevant data from cities and public transport operators publicly available through the NordicWay interchange nodes.

While testing and demonstrating the interoperability of C-ITS services, both for passenger and freight, NordicWay 3 real-life deployment pilots were expected to have a strong impact in improving the safety and efficiency of the European Core and Comprehensive road transport network, including parts of urban networks and urban-interurban transport linking to the northern part of the "Scandinavian-Mediterranean Core Network Corridor".

All in all, this activity included 19 projects. The focus of the pilots was in both services related to Mobility as a Service (MaaS) and public transport and services for future automated driving. Pilots were set up in Finland and Sweden, in cities as well as on the main road networks, within urban areas, on the interfaces between urban and interurban areas, and on specific motorway sections.

The projects are described in detail in the following chapters having a similar structure. Projects related to CCAM are collected in Chapter 2.1, and the projects related to MaaS or public transport are collected in Chapter 2.2. Chapter 2.1.1 focuses on digital and physical infrastructure requirements for automated vehicles. Chapter 2.1.2 is about real-life automated vehicle trials. Chapter 2.1.3 looks for the user perspective of automated driving assistance systems. Chapters 2.1.4 - 2.1.8 focus on processes developing static and dynamic data into digital format to enable automated driving. Chapters 2.1.9-2.1.14 present studies and pilots supporting the use of communication infrastructure for CCAM and C-ITS. The final chapters 2.1.15 and 2.1.16 look for impacts of automated driving and mobility as well as the future needs for CCAM implementation. Chapter 2.1.17 gives insight to platooning trials in Norway. Chapters 2.2.1 - 2.2.3 describe MaaS and public transport studies focusing data from cities and public transport operators and making relevant data publicly available through the NordicWay interchange nodes.

2 Pilots and supporting studies

2.1 Services for automated driving CCAM

2.1.1 Service level framework for automated road transport

2.1.1.1 Background and aim

One of the main goals in the project was to develop a service level classification for highly automated vehicles in motorway environment. The classification framework builds on the already established infrastructure support for automated driving (ISAD) classification (Lytrivis et al. 2019). ISAD classification was originally designed for digital infrastructure but was also considered suitable for other areas (physical infrastructure, environmental conditions and dynamic elements) of automated vehicle support.

In Finland a national study on automated driving on motorways aimed to
- assess the feasibility of a specific Nordic motorway section (Highway E12 between Helsinki and Tampere) for the automated operation of SAE Level 3 and 4 vehicles
- propose a framework for service level classification for automated vehicles (including arctic conditions)
- prepare a proposal for further research, R&D, and international cooperation.

2.1.1.2 Methods and equipment

The feasibility of the current roadway network for automated vehicles was assessed via a detailed inventory of a selected motorway section along the E12 highway, with an overall length of 160 km per direction.

The service level attributes were first collected from existing sources (BSI 2020, Kulmala 2020, Ulrich et al. 2020, CCAM WG3 2021) and later modified based on the input from the various task leaders of the project utilising their own expertise and lessons learned during the E12 connection inventory. Over 100 attributes were classified.

The inventory focused on physical, digital and operational road infrastructure attributes relevant for the Operational Design Domain (ODD) for automated vehicles, i.e. the circumstances in which SAE L3 and L4 vehicles are able to operate in automatic mode in the North and in Nordic weather conditions.

The study contained both an analysis of data from the current road and traffic databases as well as field measurements regarding, e.g. GNSS positioning services, 5G telecommunication services, and road structures and their condition.

Based on the inventory and earlier research, a proposal for the service level framework was developed. The service level framework provides information of the main physical, digital, and operational infrastructure features of the Nordic motorway network that should be provided in order to facilitate the operation of Level 3 and 4 automated vehicles. The classification focused on motorway-oriented vehicle automation use cases, such as highway chauffeur, highway autopilot, automated freight vehicles on open roads, and truck platooning as listed by ERTRAC (2019).

The designed service level classification was tested on E12 motorway between Helsinki and Tampere (Figure 1) based on the data derived from databases, field measurements as well as from expert interviews.

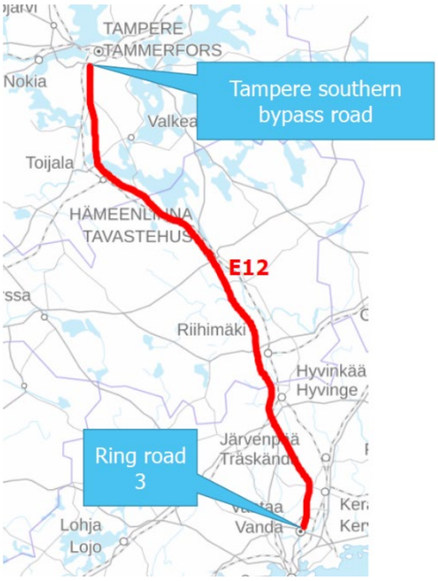

Figure 1. Pilot motorway section.

The study participants and their roles were:

- Finnish Transport Infrastructure Agency as a beneficiary and owner of the project
- Project advisory group: Traficom, Fintraffic, Finnish Meteorological Institute and Ministry of Transport and Communications
- Project consultant team: Traficon Ltd., Ramboll Ltd., Sitowise Ltd and VTT.

2.1.1.3 Results

The key deliverable of the project was the service level classification framework for highly automated and connected vehicles in a motorway environment. The following basic service levels were set:

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

These levels were in line with the ISAD classification. These ISAD levels were originally set for digital infrastructure, but they were considered suitable also for other areas (physical infrastructure, environmental conditions and dynamic elements).

The inventories indicate that almost all attributes meet at least the category E requirements except for short-range communications and ODD/ISAD management information, which both are non-existent now.

Some attributes indicate infrastructure support for highly automated driving, according to levels D and C. These include cellular network coverage and performance, GNSS positioning and positioning support services, traffic flow information, weather condition information (visibility, friction, water on road, and wind) as well as 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.

Link to the publication: https://www.doria.fi/handle/10024/182620

2.1.1.4 Conclusions and recommendations

The accomplished work gives national authorities and operators increased understanding of the most critical parts of the infrastructure regarding conditional or highly automated and connected driving. The framework directs attention to the most relevant attributes and sheds light on how improvements may affect the levels of service. It would be extremely useful to test the proposed classification for roads in other countries in practice, e.g. with European projects and actions to evaluate the applicability of the classification in other countries and circumstances, even though the classification was designed especially with Nordic conditions in mind.

The created classification and the mapped current state invite a discussion about service levels that ought to be targeted in the future. The framework provides a good basis for such discussions and targets the attention to infrastructure elements that have the most significance to automated driving. However, more analysis is needed to assess the cost for upgrading specific attributes on networks from the current level to the next as well as to critically study the obtained socio-economic benefit. As the penetration of conditional and highly automated vehicles may be slow, focus should be at first on the so-called "no-regret" actions benefiting both manual and automated driving that have been identified

As a result of the project, the needed actions to improve conditions for the automation of road transport were identified. The actions were study-type in nature and aimed at identifying the development needs of various processes and the related costs and timetables. Several of these identified actions were conducted in NordicWay 3 and described in this report. Topics for these recommended actions were:

- Physical infrastructure, road maintenance and related data (see Chapters 2.1.6 and 2.1.8)
- Digital infrastructure (telecommunications, positioning and HD maps) (see Chapters 2.1.5, 2.1.7, 2.1.9 - 2.1.12, 2.1.14)
- Knowledge management (see Chapters 2.1.4, 2.1.8, 2.2.1 and 2.2.2)
- Stakeholder cooperation (national, EU and international level) (see Chapters 2.1.2 and 2.2.3)
- Road network service levels (see Chapter 2.1.12).

These actions were further elaborated in a CCAM action plan in 2023 (see Chapter 2.1.16).

2.1.2 Enabling automated vehicle trials and transport services in urban areas

2.1.2.1 Background and aim

Applying permits for automated vehicle trials in real traffic has been a slow and difficult process in many countries. They may have included, e.g. extensive closed area tests and not allowing a driver/controller to be outside the vehicle.

In Finland, international road traffic agreements were interpreted to allow a driver outside a vehicle as agreements do not specify the location of a driver. Furthermore, using test plate certificates for vehicle testing has been a normal procedure for decades.

In Norway, normal number plates are used for the automated driving trial. However, there is a remark in the vehicle owner document and in the registration data about the trial permission. These special registrations are based on exceptions in the trial regulation for automated driving and are valid for a limited time, depending on the test plan. In Sweden there is a similar kind of process.

In Finland, an automated vehicle driving test process has been deployed. Testing of automated vehicles is possible in road traffic using a test plate certificate. In testing automated vehicles, the vehicle must have a driver either inside or outside the vehicle. An enterprise, agency or other organisation engaged in research and development of automated vehicles may apply to Traficom for a test plate certificate. The certificate entitles the bearer to drive test vehicles, to a limited extent and on a temporary basis, both in road traffic and off-road.

The aim of Finnish Transport and Communications Agency Traficom was to enable a smooth application process, by developing test plate certifications for automated vehicle trials in real traffic. As a result, an applicant clearly knows which reports are needed and the decision-making process of uniform applications is faster than before. The other aim was to gain insights on how to bring about more scalable and impactful tests and pilots which would eventually turn into permanent services that facilitate mobility in Finland.

2.1.2.2 Methods and equipment

For testing in road traffic, Traficom issues test plates. For this purpose, an application process, including the following documents was further developed:

- Traficom test plate certificate application
- A Trade Register extract from the company's country of incorporation not more than three months old
- A trial plan including
    - a general description of the trials
    - technical specifications of the test vehicles
    - information on the road area where the trials are intended to be conducted
    - research plan
    - proof of insurance cover for third party liability
    - description of how road safety will be ensured

The test plates may be used to transport unregistered vehicles and decommissioned vehicles. When using test plates, vehicle register plates must be removed or covered. Test plates may only be used by the holder of the certificate for business-related purposes (no lending) in the following situations: test driving a test vehicle for the purposes of examining the vehicle or its devices, or for product development purposes.

The test plate certificate holder must submit a report to Traficom on the trial results. The report should describe e.g. how the trial plan was implemented and what kind of deviations from the plan were encountered.

Additionally, Traficom conducted a series of interviews with actors who had been involved in pilots regarding the automation of transport and mobility as a service (MaaS). Mainly the interviewees had experiences of road transport - automated bus trials and pilots in particular. Many of them had also applied for a test plate certificate from Traficom. The aim of the interviews was to gain a more comprehensive understanding of how Traficom's processes regarding the test plate certificates were perceived and what kind of overall opportunities and barriers exist regarding the scale-up of transport services based on automation.

2.1.2.3 Results

First automated vehicle trials were conducted with minibuses which were not type-approved and had no traditional steering equipment at all. The routes in trials were predefined and a safety driver was onboard to take control if necessary. These types of tests have continued and are becoming more and more integrated part of public transport system. Finnish Transport and Communications Agency Traficom issued 23 test plate certificates for automated vehicle trials in 2020-2023 and they involved 16 automated minibuses or similar purpose vehicles. Other vehicles in trials included automated passenger cars or last-mile delivery service robots. Some trials were conducted even in winter conditions. The trials themselves were conducted as independent projects (not as a part of NordicWay 3).

Based on the interviews with automation and MaaS actors, to improve the prerequisites for scaling test and pilots and to create more permanent services and solutions to Finland, five key themes were identified that need further attention:

- A clear, commonly shared view and goals are needed in Finland regarding for which transportation problems and consequently use cases automated driving should be used.
- A better understanding of the roles and responsibilities in the automated driving value chain is needed. Actors have differing views of e.g. who gains from automation and therefore they also have differing views of who should be funding possible pilot activities.
- While there is state-of-the-art technological knowhow in Finland, there is still a lack of understanding of the actual problems for which new solutions and technologies would be the most relevant. Most tests and pilots have been used for testing technology rather than testing how automated solutions work as a part of an actual service offering or as a part of a wider system.
- There is inadequate understanding of funding opportunities available and therefore it can be problematic to get new tests and pilots to Finland.
- More purposeful and target oriented get-togethers regarding automation are needed to discuss the abovementioned topics. In the recent past, the number

of actors working with the automation of transport has increased and therefore dialogue has become more difficult.

2.1.2.4 Conclusions and recommendations

The legislation on Vehicles Act has been revised for automated driving trials. In the future (1 April 2023 onwards), Finnish legislation has rules about automated vehicle testing using professional plates. Even though automated vehicle testing was possible in Finland earlier, new rules include more exact amendments about the process on how to apply for an automated vehicle testing permission. In scaling-up trials, an important change in the revised legislation entails a possibility to collect payments from consumers if the test is part of daily transport services. Revised Vehicles Act also makes test reporting obligatory.

Based on the findings of the interviews, the Ministry of Transport and Communications in Finland set up a series of round table discussions, to which a set of interest groups were invited to discuss and create a shared vision and goals for the use of automated transport in Finland.

2.1.3 Educational films on automated driver assistance systems

2.1.3.1 Background and aim

Over the past decades, developments in vehicle safety have contributed significantly to the overall reduction in the number of road fatalities and severe injuries. Technical progress in the area of advanced vehicle safety systems offers new possibilities for reducing casualty numbers. Advanced driver assistance systems (ADAS) can be effective in reducing fatalities, decreasing the number of road accidents and mitigating injuries and damage. Several ADAS will become mandatory for all new motor vehicles with the new EU safety regulation, which will gradually enter into force in 2022-2029. Many of these systems will form the basis of technologies, which will also be used for the deployment of automated vehicles. As automation increases, the role of the driver will gradually change and it is important to keep public informed and to ensure the high acceptance of these new functions of the automated vehicles.

Safety features and warnings used in assisting driving should be easily perceivable and understandable by every driver, including the elderly and persons with disabilities. The functioning of those systems and features and their limitations should be explained in a clear and consumer-friendly manner in order to promote a safe use of these systems. In certain situations, ADAS, when activated, can possibly surprise the driver and make him/her react in a dangerous way. Drivers able to use ADAS provide a foundation for deployment of connected and automated driving also in challenging road and weather conditions.

The goals of this project were to

- raise consumer awareness of ADAS and strengthen drivers' awareness and understanding of their responsibility as a driver despite vehicle assistance systems
- prevent driver’s over-confidence on vehicle assistance systems
- inform drivers about the properties of ADAS and how to use them safely
- ensure that advanced driver assistance systems have a high acceptance, which is a requirement for fast societal take-up.

2.1.3.2 Methods and equipment

The project included producing educational videos of selected ADAS systems that are available for consumers. A separate web page was also launched which contains written descriptions of systems, their functions, information how to use the systems and a safe approach to getting to know ADAS in your own car. The information in the web page is available in Finnish, Swedish and English. The educational videos are linked on each written description of ADAS system.

Use cases selected for the videos were:

- Blind spot warning/monitoring system
- Automatic light-on function system
- Adaptive cruise control
- Emergency lane keeping system
- ISA, intelligent speed assistance system
- Advanced emergency braking system
- e-call.

The project group had two workshops and several meetings to plan the content of videos, to decide which vehicle types and models to be used in order to highlight the functioning of each ADAS best. The group discussed in great detail each advanced driver assistance system under work, how to explain the functioning of each system in a clear and technically neutral way, how to portray the positive impact on safety and how to pay attention to possible problems for using each ADAS in certain circumstances that might pose a danger. The group wrote manuscripts for video productions. Experts in Finnish Transport and Communication Agency Traficom produced the information in the special web page.

Project partners and their roles were:

- Association of Automobile Industry in Finland
- Hyundai Motor Finland Oy provided a demonstration vehicle
- Audi/K-Auto Oy provided a demonstration vehicle
- Peugeot/ Bassadone Automotive Nordic Oy provided a demonstration vehicle
- Nissan Nordic Europe Oy provided a demonstration vehicle
- Riihimäen ajoharjoittelukeskus Oy provided the test location.

2.1.3.3 Results

All the videos and a special web page (https://www.traficom.fi/fi/nakymatona-pukuski) were published on the 13th of September. On the web page the used languages are Finnish, Swedish and English.

All videos have three versions with subtitles; in Finnish, in Swedish and in English. The videos are available for public on our Youtube channel https://www.youtube.com/c/liikennejaviestintavirastotraficom.

2.1.3.4 Conclusions and recommendations

ADAS systems are developing fast and it is very important to make consumers understand the limitations and safe use of these system. This project was the first one in Finland that is explaining to consumers the functioning of ADAS systems and their limitations in a clear and consumer-friendly manner.

It will be extremely important to keep consumers aware of the newest systems in the market and how they affect their role as a driver and make sure that new systems will be used in a safe manner.

Manufacturers are, for example, already preparing to bring new systems into the market, such as the so called DCAS (Driver Controlled Assistance Systems) which will make it possible for a driver to be driving a car in certain conditions without keeping his/her hands on the steering wheel, but they do demand the driver's constant attention to traffic. This type of system can easily be interpreted as an Automated Driving System (ADS).

In many cases there are safety issues, especially when it comes to the challenging road and weather conditions prevailing in Nordic countries. This type of project that aims to bring awareness to the consumer about systems, is also preparing consumers for the future deployment of connected and automated driving.

2.1.4 Digitalised traffic rules and restrictions

2.1.4.1 Background and aim

In the long run, automated vehicles need traffic rules and restrictions in machine readable format in order to be able to operate effectively. Hence in 2021, a pre-study of the digitalisation of traffic regulations and restrictions was conducted.

The aim of the study was to describe the digitalisation process and identify digital abilities needed for the interpretation of traffic rules. Also differences between traffic rules in Finland, Sweden and Norway were examined from the perspective of use cases and the prospects for legislative progress in Finland and Sweden and from the perspective of UNECE and the RTTI regulation were identified. Safety legislation was examined, especially from the perspective of data protection and cyber security. European and global standards are needed to ensure that the architecture, systems and services that are put in place are interoperable, in line with European and global developments and developed in close cooperation with industrial partners.

1.1.1.1 Methods and equipment

With regard to the technical implementation of digitalisation, practices related to the production of different data types and actors involved in the process were studied. Vehicle-specific rules, static and dynamic data produced by traffic control equipment and temporary traffic data were examined in this connection. Relevant standards and reports on the topic produced by working groups were also reviewed. Technical implementation was also studied from the perspective of identified use cases

Ways to implement digitalised traffic rules and restrictions were examined. Practices for service trials were also recommended. Most of the data used in the work was collected from literature, and the functional concept defined by the ISO/TC 204/WG19 working group in the METR work proved particularly useful. The steering group's expertise in national road and traffic data collection practices and systems was also utilised.

In November 2022 in Helsinki, a workshop was arranged where the NordicWay 3 partners together with invited industry representatives worked on defining the most crucial rule content to be digitalised to support information, ADAS and in the end CAD services. The process of digitalising traffic rules was discussed in detail. One potential implementation method was presented, and it was studied from the perspective of use cases.

The following stakeholders participated in the study:

- Finnish Transport Infrastructure Agency as a beneficiary and owner of the project
- Project advisory group: Traficom, City of Tampere, City of Vantaa, Fintraffic Ltd
- Project consultant team: Traficon Ltd., Ramboll Ltd., FLOU Ltd and MH Roine Consulting Ltd.

2.1.4.2 Results

In the functional concept of the METR work, the following activities have been identified in the generation and distribution of digital rules:

- Translator:
    - Human-readable text format of the rules must be interpreted or translated to machine-readable format
- Compiler:
    - Compiles the rules and regulations into packages to be sent for distributors.
- Distributor:
    - Distributes the machine-readable rules and regulations to vehicles or terminal equipment
- End-user:
    - For example, an automated vehicle. Interpretation of the rules and regulations may need additional information of external conditions, such as weather, from sensors, C-ITS-service or information from other service providers, like for instance from OEM:s or other private parties with helpful information for the vehicle.

Figure 2 describes one possible distribution chain of traffic rules from a valid or coming into force law or regulation and the forwarding to automated vehicles or other users of digital rules, i.e. appliers.

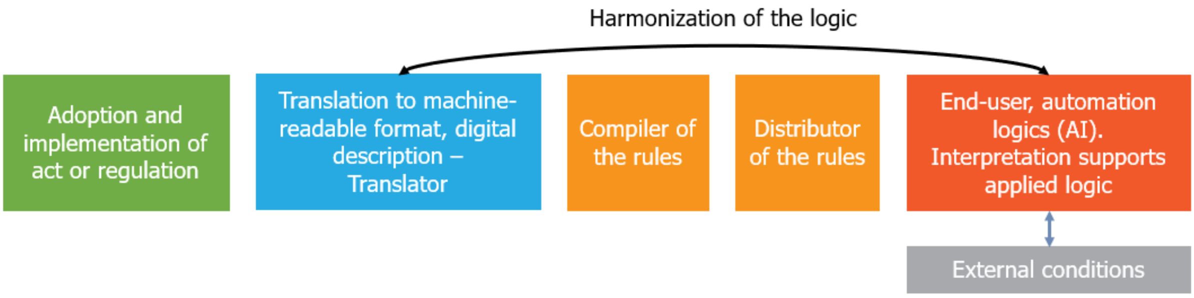

Figure 2. The distribution chain of traffic rules.

There are no established processes for distributing the information. The actors in the process of digitalisation and distribution of the traffic rules can be current parties and the actors related to the compilation and distribution can be new public or private entities (Figure 3). The activity must be supervised by authorities and follow mandatory and accepted processes.

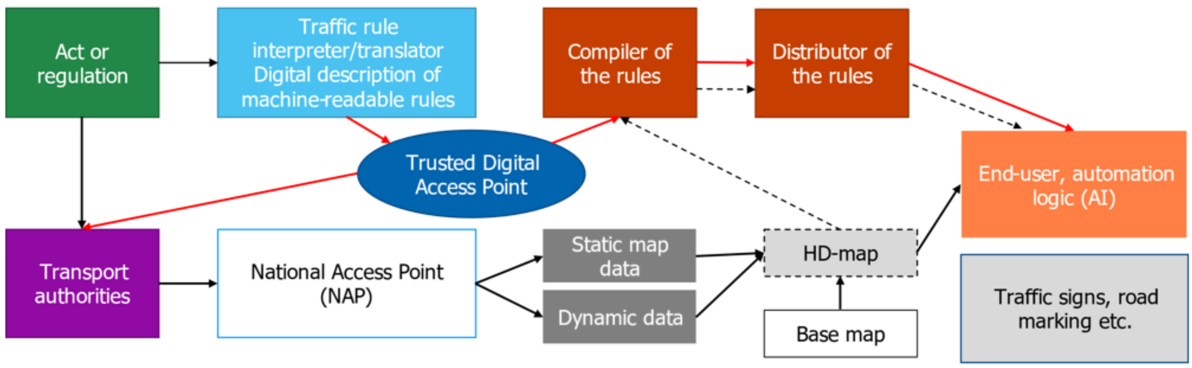

Figure 3. A possible description of the actors in publication, distribution and application of digital traffic rules.

The digital traffic rules could be published for all actors through a digital access point (Trusted Digital Access Point). In addition to the road network description, road authorities also publish static information related to traffic rules, such as speed limits and road markings. Information about road transport routes, traffic management information and the traffic situation should be published via the national access point (NAP) or similar information alternatively using other approved information sharing methods. Map producers add traffic control and situation information to the HD maps they produce for use in vehicles or for terminal equipment. Traffic control as well as other traffic users and vehicles that are a part of the traffic must also be taken into account when distributing the rules. The feedback loop is a crucial part of the process between end-users and the producer of the information. The whole process is shown in Figure 4.

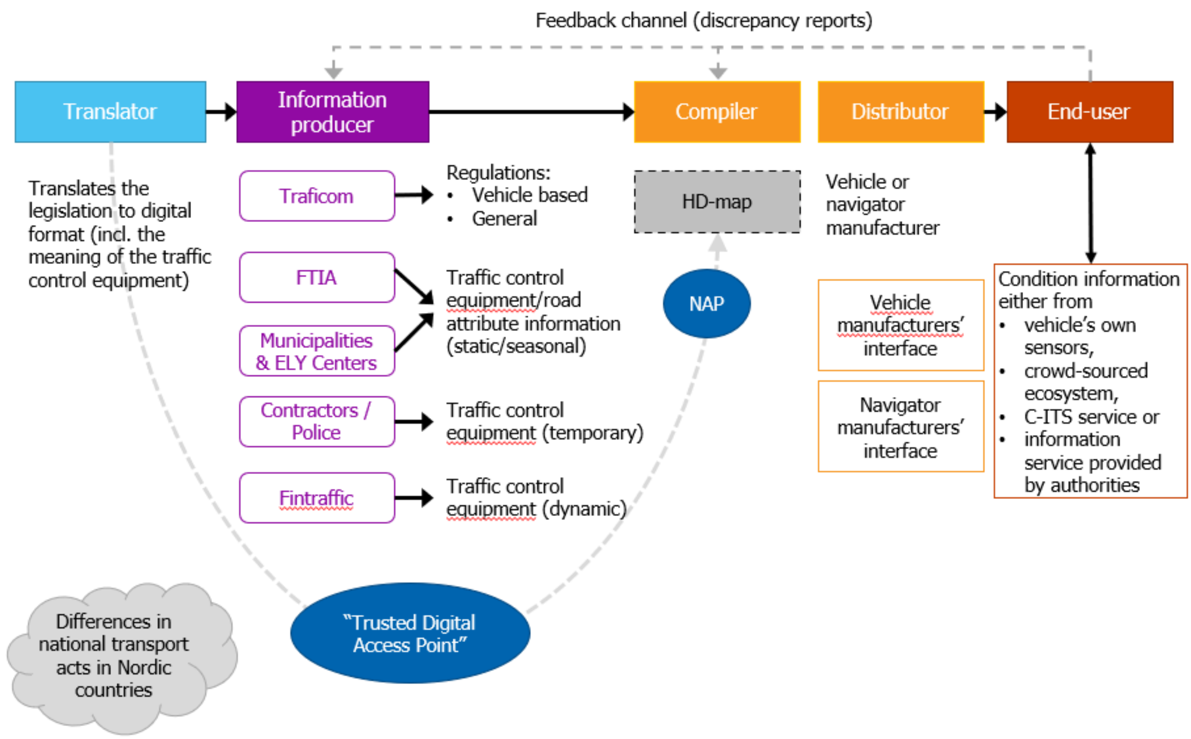

Figure 4. Translating the traffic rules to a digital rule set can be divided into subtasks.

2.1.4.3 Conclusions and recommendations.

In the pre-study four recommendations for further measures were presented:

- identifying and prioritising information needs
- process description and definition of responsible parties
- presenting the Road Traffic Act in a machine-readable format
- service trials.

Focus on initial extensive digitalisation of traffic rules ("rules of the road") is recommended to be on those rules that are included in the delegated regulation on RTTI. Priorities from the industry should also be considered. The METR specifications developed in ISO/CEN standardisation are essential and should be taken into account when processes, roles and responsibilities are defined.

It is further recommended that the traffic authorities look into the legal aspect and further develop the process for the digitalisation and assigning of traffic rules.

2.1.5 Generic MAPEM process

2.1.5.1 Background and aim

Findings from NordicWay 2 proved that the current process to produce and maintain digital traffic rules is slow and inadequate. It is complex and consists of several manual steps which increases the risk for human errors, long lead times and huge costs. Before the road authorities in Sweden can scale-up and safeguard interoperable high-quality C-ITS services, the MAP process, both on national and international level needs to be improved and harmonized.

In all C-Roads signalized intersection use cases, digital intersection topology data is a prerequisite. The topology data is formatted into a MAPEM file which is used as a message from the infrastructure to the road user. MAPEM data is a digital description of the surroundings of a traffic signal, such as roads, stop lines, traffic directions etc. and is necessary in all C-ITS communication that involves traffic signal data. Another relevant description is "digital traffic rules".

The objective of this pilot was to agree on a joint recommendation for a future generic MAPEM (Intersection topology message) process. The process is valid for all production of MAPEM data, which is needed for all C-ITS services that involve traffic signals. We strongly believe that a standardized MAPEM process is needed to ensure that production and maintenance of MAPEM data is systematically and organizationally completed and leads to quality over time.

Hence, the reason for this pilot was to learn how to work more efficiently and to make sure that each step leads to a qualified MAP data that is also easy to be updated when changes in infrastructure occur.

2.1.5.2 Methods and equipment

The development of the MAPEM process included production, maintenance and quality assurance of the MAPEM data over time, as well as a definition of MAPEM data requirements.

Since the budget and time allowed the project to continue the work after delivery, a pilot was conducted to test and validate the recommended process and MAPEM data in real life. As time went by, MAP was eventually changed to MAPEM, since we learned that MAPEM indicates ETSI standard which is a NW3 requirement. (i.e. the J2735 message has been completed with a Header that explains which type of data the file contains. MAP does not include a header).

The pilot participants and their roles were:

- Road owners' representatives from the Swedish Transport Administration, and the cities of Gothenburg, Uppsala and Stockholm
- RISE contributed to the setup of a MAPEM Certification Process that will be used to certify MAPEM approvers
- Monotch joined as a provider of the MAP Repository and the Self Test MAPEM tool.
    - The test tool was developed by DTV consultants working for Monotch.

The participants tested to produce MAPEM files according to our recommended process, contributed to the discussions and creation of a standardized Test Tool Schema and collaborated in the work of setting up a certification process.

2.1.5.3 Results

MAPEM Process

The key result was a technology neutral recommendation for a generic MAP process including road authorities' MAP data requirements, that could serve as input for a technical solution in a later stage.

The recommended process and requirements enable a generic approach to produce and maintain qualified MAP data. It is beneficial for all road owners that certain rules and procedures are followed. The generic approach requires that all MAPEM data providers must act according to the road authorities' common rules for MAPEM data, which are aligned with the C-Road Standard (see "C-roads message profile 2.0.7 and .C-Roads Handbook MAPEM-SPATEM_2.0.7).

The MAPEM data must be validated by a proposed self-test program before it is sent for a final quality check, by a certified MAPEM expert, to achieve an efficient process.

All requirements agreed upon in the pilot have been compiled in a common requirement list for MAPEM data.

Figure 5 presents the draft architecture developed by the pilot. Note that no technical equipment was deployed in this stage of the pilot:

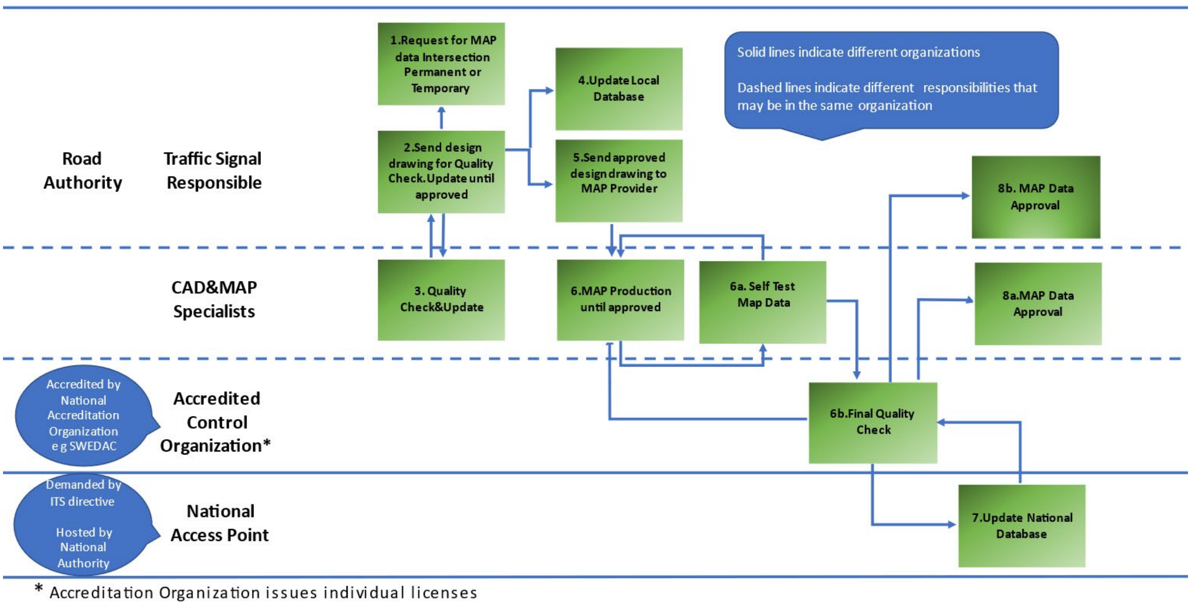

Figure 5. MAPEM Process flow.

Detailed description of the MAPEM process:

1. Request for the MAPEM data (including Validity Start and Stop date). For temporary changes: An automatic reset is made in National Database when Validity Stop date kicks in (returns to original version).

2. Quality check of a relevant design drawing (e.g. CAD) is optional and can be performed by staff or a service provider, depending on which resources are available.
3. Quality check is performed. The basic input needed to produce MAPEM are design drawings with coordinates, ordnance survey map and signal groups. Hence, if any of this is missing, the design drawing needs to be updated before it is ready for MAPEM production.
4. Updated design drawing is stored locally in the Local Authority's Traffic Signal Database
5. Qualified design drawing is sent to a MAPEM specialist
6. MAPEM Specialist produces MAPEM data and, if needed, improves it until it passes the Self-Test (6a).
   Eventually, a final test is performed manually by an accredited person to establish a two-party independent quality assurance (6b).
   Sometimes a verification on-site may be needed to make sure that the data corresponds to the physical environment.
7. When the MAPEM file is approved, it is it stored in the National Database and is valid from the date requested in step one. Automatic Reminder is proposed to be sent to the Requester three days before the Validity Start Date.
8. MAP File Approval is sent to a MAPEM Specialist(a) and to Road Authority(b). Road Authorities must be able to log into the National Database, to change the start and stop date etc.

The MAPEM process continued with a Solution pilot in 2022, with the following three main deliverables

1. MAPEM Repository
2. MAPEM Certification Process
3. MAPEM Self Test Program (Web based)

MAPEM Repository

A MAPEM repository was set-up in collaboration with Monotch who offered a standalone solution connected to the Swedish Interchange. Gothenburg verified the uploading of MAPEM files that are sorted per city. When you upload a file, the software will automatically rename it with the road authority id + intersection ID. The 4 last digits are the original intersection ids (see Figure 6: 031 for Gothenburg and 6001-6004 for Intersections).

A MAP repository was set-up in collaboration with Monotch who offered a standalone solution connected to the Swedish Interchange. Gothenburg verified the uploading of MAPEM files that are sorted per city. When you upload a file, the software will automatically rename it with the road authority id + intersection ID. The 4 last digits are the original intersection ids, see Figure 6).

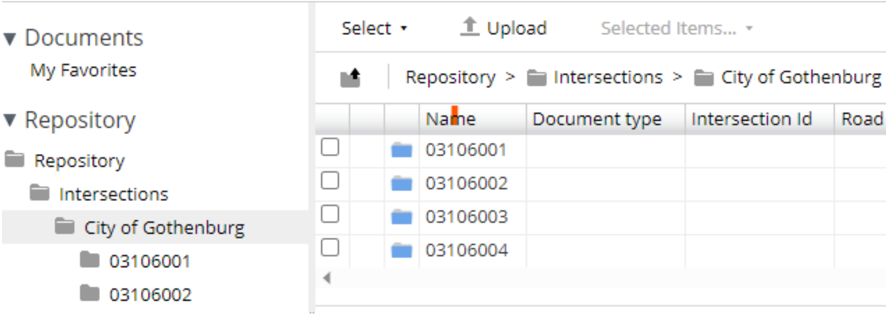

Figure 6. A MAP repository.

MAPEM Certification Process

A certification process for "MAPEM approvers" was setup in collaboration with RISE. It is ready to be uploaded to RISE's automatic database once an agreement has been made. A set of questions, answers and distractors, have been compiled. Other important deliverables to manage the certification procedure are requirements documentation, literature references and a cooperation model. The certification is self-financed through a certification fee paid by the customer.
Due to confidential reasons we cannot share questions and answers in this report. However, the knowledge requirements to be certified are listed below.

1. When is MAPEM applicable within C-ITS
2. Read and understand a Signal Plan
3. Understand MAPEM's properties (Lanes, Egress, Ingress, Connections etc.)
4. Traffic signal Knowledge
5. Knowledge about TSFS 2014:30 & TS (Swedish Traffic Signals Enactment provided by the Swedish Transport Agency)
6. Knowledge about SKL, Kör när det är grönt (Traffic Signal Guideline provided by the Swedish Association of Local Authorities and Regions "Drive when it is green"
7. How to find traffic rules och local traffic regulations (ref RDT)
8. TF 1998:1276 & VMF (Swedish Traffic Ordinance & Swedish Road Signs Regulations)
9. Standards and standard organisations (C-Roads, ETSI, SAE, ISO)

MAPEM self-test program

A web based self-test program was developed in collaboration with Monotch and DTV consultants. The aim was that this program can be used to quality assure MAP files before they are sent to and approved by a MAPEM certified person and uploaded to the MAP repository. The program checks for logical errors and omitted information required by C-Roads standard (C-ITS message profile). It has been hard work to identify what is really a "C-Roads standard" since we have learned that this so far has been interpreted in many different ways in the European countries. We have discussed with C-Roads management and agreed with Monotch and DTV upon a final profile for the MAPEM files. Added functionality has also been included such as a bus priority solution developed within NordicWay 3.

2.1.5.4 Conclusions and recommendations

Given that MAPEM data is a necessary component in all C-ITS solutions including traffic signals and that upcoming EU directives require us to safeguard a good quality of the infrastructure data in order to support the autonomous vehicles, we have agreed upon the following conclusions and recommendations.

- It is important that the road information comes from the road authorities. It assures the same MAPEM data access rights for all citizens.
- The road authorities should be responsible for the MAPEM data roles, process and to procure required resources.
- To speed up the implementation, public support for small municipalities is needed.
- Cities need a centralized platform where they can upload MAPEM data. From there it can be downloaded by multiple service providers who can build C-ITS services and share with the end users.
- A MAP repository provider needs to be procured according to our recommended "MAPEM Process Requirements List"
- A MAP final approver needs to be procured according to our recommended "MAPEM Process Requirements List"
- The self-test program is proposed to be located on a web page owned by the MAP repository provider and needs to meet the requirements in our "MAPEM Process Requirements List"
- A link to the self-test program is proposed to be placed on the already existing NAP (National Access Point)
- Our proposed certification process is ready to be agreed with RISE. It is self-financed by certification fees.
- MAPEM training can be procured using specified requirements in "MAPEM Process Requirements List"

Outstanding questions that should be further explored (relates to internal processes and cannot be solved in this project)

- Road owners need a routine for checking the MAPEM files conformity with reality.
- Road owners need a routine for producing all signal plans with the same layout.
- How do we verify that the design drawing (that is input to the MAPEM production) is correct over time during ongoing road constructions and urban developments? These things delay new data to become available and there is a huge backlog before new documentation is available.

2.1.6 Digital analysis of pavement conditions and road network assets

2.1.6.1 Background and aim

In the Nordic countries, especially winter weather conditions and studded tires are harmful for road pavements. The aim of this pilot was to develop a comprehensive and objective analysis of pavement conditions for enhanced road management. Although automated vehicles have several sensors to detect the road surface, additional information on pavement conditions in digital format supports automated vehicles to navigate safely beyond the sensor horizon.

Traditional road pavement condition surveys are mostly performed manually, subjecting the process to human errors and delays, and further draining limited resources. Vaisala has developed a RoadAI service tool, which enables quick, complete and objective digital analysis of pavement conditions and road network assets through an automated survey methodology. RoadAI combines geospatial videos, driver-made annotations, and computer vision analysis into a highly functional tool to support road maintenance.

2.1.6.2 Methods and equipment

The used service is called Vaisala RoadAI pavement inventory. Vaisala RoadAI service offers an Android phone application that allows any of the staff to collect video material from the road/street network, which is uploaded/transferred to the RoadAI servers and processed automatically, and road condition information is generated from it.

Data was collected through the RoadAI Android application. Collected data, i.e. georeferenced high- definition video was automatically transferred to RoadAI cloud for storage and processing. The uploading process initially uses the phone's SD card for temporary storage, meaning the data collection works without Internet connection. Once the phone was connected to the Internet using a mobile plan or Wi-Fi, the phone uploaded the data to RoadAI cloud and automatically freed up the space from the SD card. In the cloud processing phase the artificial intelligence system analysed the collected video data. Collected videos as well as analyses can be viewed in the RoadAI online user interface. Before the data is available for viewing, RoadAI automated anonymization removes all identifiable visual material, such as vehicles and pedestrians from the footage so that the system is compliant with the GDPR regulation.

Partners and their roles were:

- Helsinki City Construction Services, Stara (project leader)
- Vaisala Oyj (RoadAI service).

2.1.6.3 Results

Pavement condition data collection is four times faster and at half the cost compared to conventional visually inspected methods. Time saving comes from being able to drive at normal traffic speeds and because the condition assessment is automated, you only need a driver to collect data.

Pavement condition and road asset data extracted with computer vision algorithms can be exported from the service using various export formats to further import to

GIS or asset management softwares. For more advanced integrations, RoadAI provides low-level API access and an open-source python-library implementation. The service is provided as software as a service (SaaS) to the customer. The components and features of the service i.e. inclusions and exclusions regarding the content of the delivered service are agreed in the contract between Vaisala and the customer.

2.1.6.4 Conclusions and recommendations

The next goal is to expand the use of the system to other service sectors. For example, increased use on motorways and cycle paths means Road AI can be used for viewing reports online and at the same time execute inspections of the road network. This reduces field work. Road AI also collects traffic sign data and offers status reporting tools, which can be used for making remote assessments with a daily performance of up to a 1000 traffic signs. In addition, Road AI provides automatic analyses and condition reports of road markings, which provides full street network-based road marking condition monitoring and maintenance planning. Data processing with Road AI is fully automated.

2.1.7 Drone as a service

2.1.7.1 Background and aim

High-definition maps are essential for automated driving and extend their Operational Design Domain (ODD). The goal of the Drone as a service project was to photograph streets in Helsinki and make 3D models of the Helsinki street space. The second aim was to develop a data delivery platform for professional drone services. On 3D models, the condition and capacity of the street space can be seen. Information on street network conditions supports automated driving.

2.1.7.2 Methods and equipment

Drone as a service pilot project included street mapping flights and automatic drone operations in connection with sand lifting, and drone service platform piloting.

The project included the following parts:

1. Mapping in the field
   a) Measurement accuracy mapping flights as cleaning work progresses.
   b) Mapping photos on 9 street sections in Helsinki.
   c) Each mapping flight is designed to cover a street section within an approximate duration of 4 minutes.
2. Construction and testing of automatic flight missions (piloting) on the Fleet management application (FMA) platform.
   a) The core of this phase was to implement and test as automated process as possible, which includes ordering flight mission from the FMA system, creating a mission for the drone, automatic completion and finally, ending the task.
   b) Creating tasks and routing an automatic task using the Helsinki digital twin material.
   c) Autonomous operation of the drone and execution of the filming task.
3. Drone mapping data processing, browser use and data interfaces on the FMA platform.
   a) Data processing in photogrammetry applications.
   b) Further development of the drone source order management platform.
4. Support service and other expert work during the implementation

Pilot participants were:

- Skydata (Street mapping)
- Fleetonomy (Construction and testing of automatic flight missions in the target area)
- Pointscene (On the platform: Drone mapping Data processing, browser use and data interfaces)
- Geosprint (Support service and other expert work during the implementation and pilot)

1.1.1.2 Results

Standardized processes for drone tasks were implemented for the city of Helsinki. This includes ordering drone services and processing order materials on the web platform.

A drone task order management system was defined and piloted, taking into account the following areas:

- Common drone tasks suitable for the typical locations of customers, including task scheduling and recurrence.
- Data transmission, storage of collected data, and processing into an applicable format.
- Visualization and analysis of data in a web service, presented on a map basis.
- Centralized storage of customer data and collaborative use through data interfaces in the subscriber's systems.
- Specification of quality factors for data in different use cases (detail/resolution, location accuracy, etc.).
- Subscriber responsibility process and assurance of service providers' task-specific expertise.
- Automatic generation of flight and imaging tasks on the platform, task transmission to the drone for autonomous operation.

Regional scope (mapping descriptions + autonomous operation):

- Nine flights were conducted over cleaned street sections for mapping purposes, in addition to three flights with autonomous operation. The work progressed in line with other cleaning activities.
- The actual performance pace of the drone team could be 3-4 times higher than that of the pilot, potentially exceeding 15 flights per day.
- The amount of data collected on the platform was approximately 25 GB for nine street sections. This includes raw images, processed ortho aerial images with a 3cm resolution, surface models, and point clouds.

2.1.7.3 Conclusions and recommendations

The customer's ordering skills related to drone tasks improved. The procurement of drone services was facilitated by creating standardized tasks and simplifying the order processes.

Additionally, opportunities for collaborative use of materials were developed, and the benefits of their utilization were identified across multiple customer applications:

- Industries: Maintenance, construction, logistics, healthcare.
- Avoidance of Redundant Work and Data Collection: Minimizing duplication of effort and data collection, anticipating tasks, and improving the quality of work.
- Updating digital twin data within the framework of the subscriber's normal workflow processes.

The Pointscene service was found to be easy and beneficial for the construction services of the City of Helsinki. The accuracy and versatility of the data were deemed sufficient for the needs of all customer units. Compatible subscriber systems identified included, among others, Louhi/Paikkatietovipunen, Autocad Civil/Map, Trimble Connect, Bentley Microstation.

A more detailed analysis is needed regarding the costs of data usage and storage. The data size for pilot areas was approximately 2.75 GB per street section (15 GB per kilometre of street), including drone images and processed detailed mapping data.

2.1.8 Digitalization program for maintenance processes

2.1.8.1 Background and aim

The adverse weather conditions are challenging especially for automated vehicles. In Nordic conditions effective winter maintenance processes (e.g. snow ploughing) are essential for the useability of road network in adverse weather conditions.

The aim of the project was to develop a mobile reporting and work management system called m-reporting, which includes hourly reporting, work management and digital solutions for vehicle fleet management. The electronic mobile reporting platform was also expected to enable more cost- and resource-efficient processes and to give employees the opportunity to check their own hourly reports, which are the basis of salary payment for hourly employees.

The benefits pursued by the project were intended to be measured through the increase in the overall utilization rate of vehicles, cost benefits from reorganization, and depreciation. In addition, significant cost savings could be achieved through the centralized location of vehicles in relation to the job description, the elimination of unnecessary driving and stops, as well as the handling of damage reports and verification of driving events.

The service was made suitable for the company's (Helsinki City Construction Services, Stara,) use.

2.1.8.2 Methods and equipment

The vehicle fleet was tracked. The Teltonika FMC640 tracking device was installed in the trucks. GPS location information about vehicle movement and different kind of vehicles (e.g. snow ploughing or sanding) was stored in the cloud service. Information can be visually seen on the application about the location of the fleet, driving routes and work tasks.

The digitization program was started by making department-level needs mapping based on IT services. After this part, workshops were established based on the implementation of hourly reporting.

Project participants were:

- ProTieto Oy
- GsGroup Oy
- Stara (City of Helsinki)

2.1.8.3 Results

As a result of the implementation project, it was proved that it was possible to unify the practices of hourly reporting and get rid of paper reporting. In the final trainings, it was possible to test the use of an hourly reporting system on a mobile device with end users. As a result, a fully electronic and uniform hourly reporting system was started.

As a result, a modern, digitalized and streamlined work management system was implemented for Stara's use. Digital operating models enable more transparent and cost-effective work and the comprehensive department-level utilization of resources. In the system, it is possible to compare the utilization rate and current demand for vehicle resources, allowing an impact on identified needs and work situations, as well as future recruitments. Monitoring is done with metrics for data-driven management. In the context of process reengineering, operating models become standardized and digitized, which is identified as one of the most significant cost-benefit factors. Processes are standardized, and variation is eliminated when they are directed and documented in the same way electronically. Production monitoring and control are carried out with metrics for data-driven management.

2.1.8.4 Conclusions and recommendations

The owner of the project is required, after the project's completion, to continually set and monitor annual goals and appoint a product owner responsible for achieving the goals related to the value generation of the service. The product owner ensures that the basic processes and user hierarchy with their respective responsibilities and obligations, as described during the service's implementation, are implemented by the main users of the production unit.

Building interfaces in Financial and Human Resources Management Software should be carefully planned or, if possible, avoided if problems still exist.

It is not worthy adding the time tracking service to the working time tracking in the ERP-system, because the collective labour agreement does not recognize flexible work time. This applies to the requirements related to the design of these interfaces.

It was also suggested to establish a cooperation forum with the city of Espoo, which uses the same ERP-system. The exchange of experiences and possible development work on the application can help in solving problems and in further plans related to the use of the service.

2.1.9 Transport infrastructure authority as a user and enabler of fast data connections

2.1.9.1 Background and aim

The purpose of the study was to identify the benefits, needs and challenges of digital infrastructure in the activities of the transport infrastructure authorities, and to find out how the Finnish Transport Infrastructure Agency (FTIA) can enable and promote the development of telecommunications networks for future automated driving purposes. The objective of the study was to provide input for the planning and development of FTIA's activities, increase the awareness of various parties with regard to infrastructure management connected with the impact of telecommunications issues on operating methods, and identify the division of duties between public and private actors.

2.1.9.2 Methods and equipment

The study was conducted as a literature review and by using expert interviews. A workshop with mobile operators was also organised with all three major operators in Finland.

The study participants and their roles were:

- Finnish Transport Infrastructure Agency as a beneficiary and owner of the project
- Project consultant team: Sitowise Ltd.

2.1.9.3 Results

The future development needs of data connections in road traffic are mainly related to the increased communication by vehicles and the development of autonomous traffic. The current understanding is that the communication between future vehicles will not occur via mobile networks alone; rather, some of the applications that require delay-critical or large-scale data transfer rely on direct communication between vehicles.

In principle, however, many of the new services and development steps in traffic do not require a 5G network; instead, a large portion of the development in the near future can already be implemented using the current networks. For road traffic, network coverage can be considered a more important factor than significantly faster connections. One of the factors slowing down the development of data connections in road traffic is the lack of clear road traffic revenue models that would allow the operators to cover the costs of developing data connections.

Link to the publication: https://www.doria.fi/handle/10024/173472

2.1.9.4 Conclusions and recommendations

5G is the next generation of mobile technology, and it will be implemented more extensively during the 2020s. The 5G network does not eliminate the need for older network generations; instead, 3G and 4G connections will also be sufficient for many purposes in the future. In addition to the traditional mobile networks, operators have launched NB-IOT and LTE-M networks on the market; they enable the use of IoT sensors. These networks should be operational throughout Finland in the early 2020s.

According to the current understanding, the 5G network will most likely be built in three individual frequency ranges, the characteristics of which complement each other. The low frequencies enable a cost-effective way of implementing comprehensive 5G coverage, while the high frequencies enable a high data transfer capacity at specific sites. Users' needs and the costs of network implementation are the most important factors for the establishment of a 5G network.

In the current understanding, the 5G network will initially be built on the existing 4G and 3G base station sites. Using the existing base station sites does not require significant construction of masts or a fibre network, with some individual exceptions. The 5G network coverage will mainly be implemented by using low and medium frequencies. According to the current views of various actors, implementing an extensive and comprehensive high-frequency 5G network next to the main routes seems very unlikely in the near future. At most, high-frequency 5G base stations will be implemented at specific sites in order to offer a higher data transfer capacity than before.

During the study, methods that the Finnish Transport Infrastructure Agency can use to promote the realisation of the 5G network and other data connections along the main roads and railways were identified. However, in order to determine the measures having the right scope, the role of the infrastructure manager as a promoter of data connections should be clarified first. The measures in Figure 7 for promoting telecommunications issues were identified:

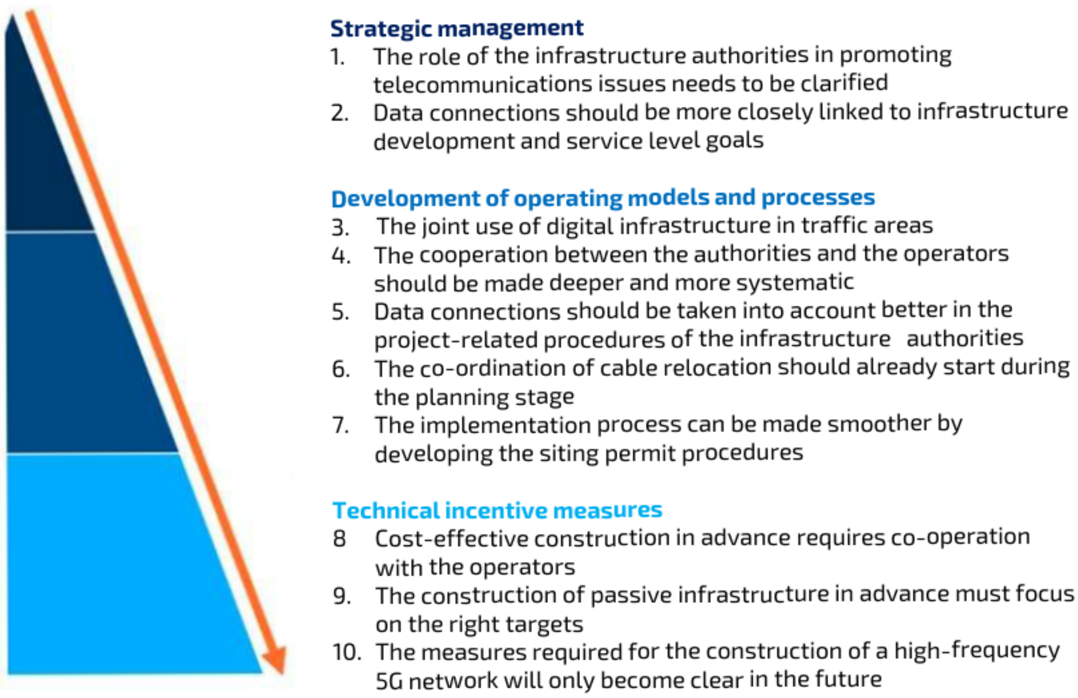

Figure 7. The identified measures for promoting telecommunications issues.

2.1.10 Combination of long- and short-range C-ITS communication in urban areas

2.1.10.1 Background and aim

In previous NordicWay work, the architecture has been based on cellular communication for all specified use cases.

This pilot aimed to evaluate how concurrent cellular long-range and ITS-G5 short-range V2X communication can be combined to increase the value of infrastructure data for automated driving functions with higher traffic safety value and increased efficiency. Second, the initiative explored new possibilities based on digital notification from an approaching vehicle to the traffic light controller. This initiative also wanted to compare ITS-G5 to cellular communication for traffic light intersection use cases and investigate usage of hybrid communication for Traffic Light Prioritization (TLP) for emergency vehicles and other connected vehicles. Lastly, this initiative wanted to evaluate the value of a cloud platform in a short-range setup.

2.1.10.2 Methods and equipment

This proof of concept pilot gathered a group of partners who shared the interest in exploring different aspects of shortrange communication and also the combined setup of cellular and shortrange usually called hybrid communication.

Use cases were tested with long range (IP based) communication vs. short range communication (ITS G5) and compared the technical results such as latency, accurateness of the data and if data was dropped.

One roadside unit (RSU) was deployed in Gothenburg, and using both short-range and long-range, and additional 6 more RSU were deployed that started producing data. Results from previous tests indicated some latency going through the cloud, thus short range will be faster at intersections. The experience from Holland was to use long-range communications and when the vehicle approaches the intersection, the vehicle can consume data via short range. The pilot gathered test data and validated data flow in the entire eco-system.

The pilot site corridor was located at 4 intersections in Gothenburg (Figure 8) where the initial test was set-up at the end of 2022, where OEM's tested their individual equipment. The aim of the pre-test was to validate communication flow.

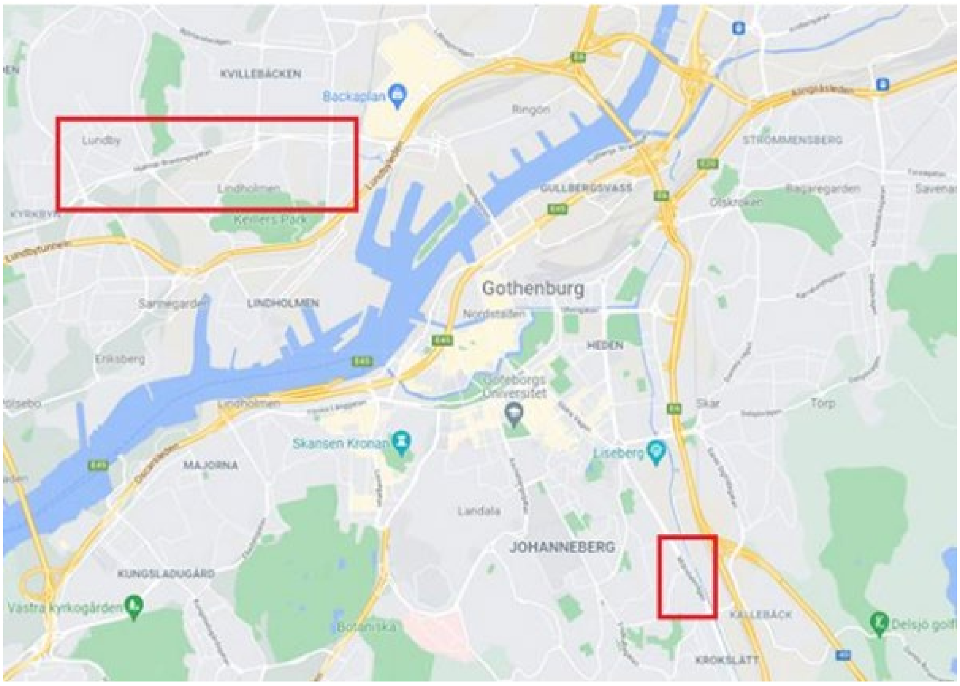

Figure 8. Map of pilot sites in Gothenburg city.

Starting in 2023, the pilot scaled up with test vehicles (Volvo and Knowit) to test five use-cases and validated data flow in the entire eco-system. Use cases selected for the pilot were:

- Autonomous driving, guidance for autonomous cars in traffic signals
- GLOSA, optimal speed for the vehicle
- Time to green,
- Digital notifications, virtual detection
- Probe data

The pilot involved the following C-Roads use cases:

- C-Roads 1.8
  - SI - SPTI – Signalized Intersection - Signal Phase and Timing Information
  - SI - GLOSA - Signalized Intersection – Green Light Optimal Speed Advisory
  - PVD –VDC – Probe Vehicle Data - Vehicle Data Collection
- C-Roads 2.0
  - change Node specification - Basic and Improved Interface
- C-Roads - Proposals for the new use cases
  - SI –DN - Signalised Intersection – Digital Notification
  - AVG – IM – *Automated Vehicle Guidance - Intersection Manoeuvres

In the pilot, the following equipment was installed:

- 7 upgrades of the Swarco ITC 2 Traffic Light Controllers, running both traffic actuated and fixed time plans.
- 7 short range communication devices (road-side units supporting ITS G5 communication)
- MyCity Connect, Interchange Node, RSU Management Software

Project partners and their roles were:

- Monotch was the supplier of the Interchange Node for C-ITS data exchange with roadside objects and compared ITS-G5 to cellular communication for traffic light intersection use cases.
- Actia provided hybrid communication on board units supporting pilot site C-ITS use cases.
- Swarco was the coordinator of the pilot, installed road-side units at pilot intersections and provided an end-to-end system fully supporting HMI implementation in vehicles.
- Volvo and Knowit provided a test vehicle, installed with an OBU to send CAM messages.
- Gothenburg City was the road owner for the selected pilot intersections.
- Scania aided to set up the test bed with hybrid communication.

2.1.10.3 Results

The positive conclusion is that the pilot provided a good opportunity to make practical progress with the V2X implementation. The collaboration with the other pilot members gave valuable insight into the challenges and complexities involved in the rollout of V2X. An overview of the pilot reference architecture (connected 3G, LTE and 5G) is visualised in Figure 9:

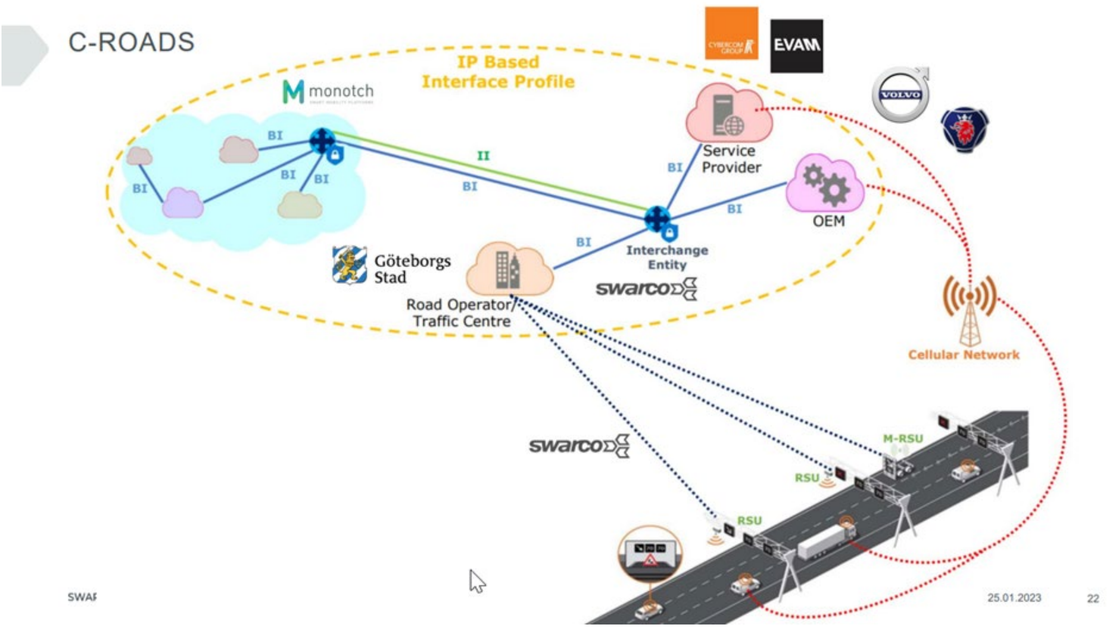

Figure 9. An overview of the pilot reference architecture (connected 3G, LTE and 5G).

2.1.10.4 Conclusions and recommendations

The project addressed key objectives, including understanding market-infrastructure discrepancies, defining site requirements, addressing security and privacy considerations, and making traffic data accessible to service providers. The utilization of Cooperative Awareness Messages (CAM) and digital notifications showcased practical applications, with messages proving useful for traffic light detection, signal operations, and broader traffic management objectives.

The investigation into a hybrid architecture demonstrated feasibility, particularly in leveraging cellular connections within the existing vehicle fleet. While challenges were encountered in comparing short-range (ITS-G5) and long-range (cellular) communication methods, and ensuring consistency of messages, the architecture stands validated for larger-scale deployment.

2.1.11 Cybersecurity, interoperability and mobile technology on C-ITS environment

2.1.11.1 Background and aim

In 2019, a study (see chapter 2.1.9) was conducted to identify the benefits, needs and challenges of digital infrastructure in the activities of the transport infrastructure authorities, and to find out how they can enable and promote the development of telecommunications networks.

The future development needs of data connections in road traffic are mainly related to the increased communication by vehicles and the development of autonomous traffic. The current understanding is that the communication between future vehicles will not occur via mobile networks alone; rather, some of the applications that require delay-critical or large-scale data transfer rely on direct communication between vehicles. However, a special emphasis must be put on security issues as shown in a pilot in Sweden (see chapter 2.1.10).

In 2022, a procurement for a pilot in a real transport environment in Finland on cybersecurity, interoperability and mobile technology on a C-ITS environment was started. The work conforms the 3GPP defined communication technologies to be applicable for the realisation of the C-ITS services defined in the C-Roads and demonstrates EU C-ITS credentials management system compatibility with this communication technology.

2.1.11.2 Methods and equipment

The communication technology used in the tests was short range LTE-V2X PC-5 -technology, as well as long range mobile communications network.

Cybersecurity piloting in this project included the tests and validation of the European Union C-ITS credential management system (EU CCMS). This project relied on EU CCMS Level 0 operational requirements and certificates obtained therefrom. These certificates are used to sign the C-ITS messages used in the projects from infrastructure to vehicles. The C-ITS credential management system obtained certificates are used to ensure safe and reliable communication between used RSU and OBU devices.

The tests were planned to be fully based on European and global standards. The work supported the development and implementation of C-ITS services in an urban environment in the Nordic countries. This test assessed the viability of cellular 5G technologies for time critical C-ITS applications and as such, compared short-range and long-range technology differences. The selected use cases were foundational types for connected and automated driving.

The short-range communication technical deployment contained traffic light signals in the city of Tampere, which communicated directly to the vehicles' on-board units (OBU) by using a road side unit (RSU). The RSU signed the messages and transmitted these to OBUs by using the LTE-V2X PC-5 interface.

Additionally, relating to the long-range solution in this pilot, the traffic light signals are transferred to the Tampere node (TLEX) by SPAT/MAP- C-ITS messages. The messages are transferred to a C-ITS service provider layer, and then further transmitted to a vehicle via 4G/5G mobile communication network.

Figure 10 presents simplified visualisation of the test environment used in the project. Upper part of the figure presents long range communication chain and lower part the short-range communication chain.

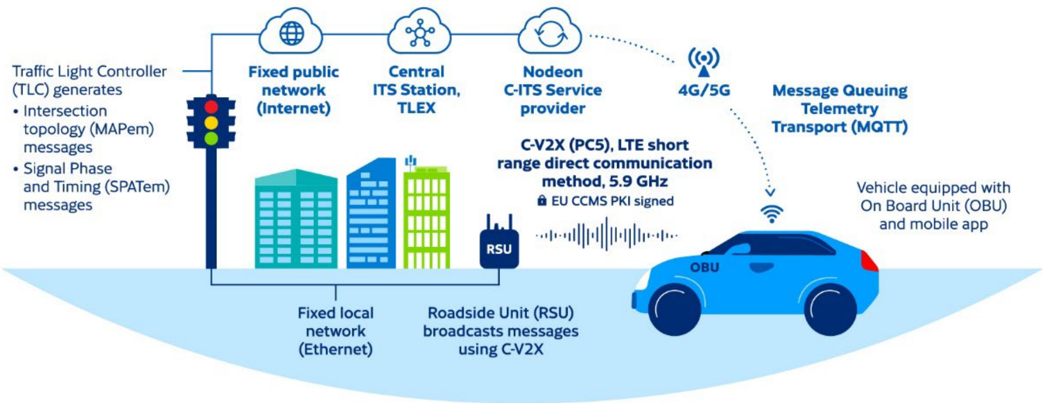

Figure 10. Simplified visualisation of the test environment.

Pilot participants and their roles were:

- Finnish Transport and Communications Agency Traficom - procurer
- Ministry of Transport and Communications - member of the project steering group
- City of Tampere - member of the project steering group
- Fintraffic Road Ltd - member of the project steering group
- Nodeon Ltd.: provider and contracting party
- VTT Technical Research Centre of Finland Ltd. - subcontractor with special focus on technical architecture and test specifications
- Normi Valaistus Ltd. - possible subcontractor with responsibilities regarding traffic light equipment

2.1.11.3 Results

The results indicated that both short- and long-range communication solutions provided a well-functioning platform for informative C-ITS applications. Each of these solutions had its own unique set of advantages and disadvantages.

The LTE-V2X technology used for short range communication was able to operate as the communication media to deploy C-Roads compliant C-ITS service. Results indicated average latency of 13 ms for the radio transmission between onboard unit and roadside unit. Total latency calculated from mobile app user interface inside the vehicle compared to actual traffic light signal change in the intersection was around 0.5 seconds. This demonstrates that the design and implementation of end-user application can significantly influence the overall performance of the service.

For the long-range communication, the tests conducted indicated end-to-end latency around 0.5 seconds. When compared to, for example, to Dutch national large-scale C-ITS deployment Talking Traffic, where a requirement for maximum end-to-end latency for traffic light related use cases was set at one second via telecom 4G/LTE networks. The results of this study, with latencies close to 0.5 seconds, indicate similar performance to those specified in the Netherlands. When considering the randomly selected test location, and when compared to other C-ITS deployments, the requirements set forth in reference literature, and the functional usage of C-ITS messages, the results could be considered very positive.

Overall, the results of the long-distance study were encouraging. When the usage of C-ITS messages is focused on informative C-ITS applications, it could be assessed that under the tested circumstances, the performance of the long-distance system is adequate.

Security related results show that current LTE-V2X units are compatible with EU CCMS L0. Both the OBU and RSU were able to be registered to EU CCMS L0 operation. The short-range system was proven to operate securely by testing it with unsigned messages. When the system encountered unsigned messages, while having security enabled, all the unsigned messages were dropped by the system.

2.1.11.4 Conclusions and recommendations

The LTE-V2X technology used in this project proved to be a well working option for implementing C-ITS services. However, it is expected to have a short lifespan and will likely be replaced by the newer NR-V2X technology, which is able to support more advanced V2X use cases.

To deploy these NR-V2X units in the future at the highest security level (Level 2) specified in EU CCMS, protection profiles need to be generated for NR-V2X stations.

Even tough results for long-range tests were positive it is also essential to understand the natural unpredictable nature of C-ITS long-range solutions. For instance, when incorporating commercial ”non-SLA” mobile networks into long-range solutions, an alteration in the selected test area can impact network coverage and quality.

To ensure resources for long-distance C-ITS-services in the future and enhance the quality of service across the entire communication chain, several potential actions can be taken. Some being relatively straightforward, involving the redefinition of the overall technical architecture of the C-ITS ecosystem. However, others may require more extensive efforts, such as regulatory tasks carried out by the public sector and cooperation between car manufacturers and public authorities to clarify the policies in the usage of more sophisticated future ADAS features (Advanced Driver Assistance Systems) of the vehicles, which utilize information from smart infrastructure passed to the usage of vehicles. This cooperation requirement applies to all C-ITS ecosystems, not only long-distance versions.

During the pilot security Level 0 was tested. The central elements for Level 1 are expected to become available in the beginning of 2024, and the two-year transition period towards Level 2 starts, ending at the end of 2025. The transition to Level 2 of EU CCMS will create requirements for C-ITS station operators and units. One of these requirements will be ISO 27001 compliance.

Overall, the project succeeded on testing and deploying C-Roads specified C-ITS service using LTE-V2X Direct technology and 4G/5G networks. The onboard unit and roadside unit were both successfully registered to EU CCMS and security of the system was tested.

2.1.12 Utilisation of commercial mobile networks in the implementation of C-ITS service

2.1.12.1 Background and aim

A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative, connected, and automated mobility, was published in 2016 by the European Commission. The strategy states that drivers expect to receive all information on traffic and safety conditions across Europe, and this can only be achieved through a hybrid communication approach which combines complementary communication technologies such as mobile networks and short-range communication. Flexibility on hybrid communication technology used eases inclusion of future technologies, e.g., 5G and beyond.

Cooperative Intelligent Transport Systems (C-ITS) mean intelligent transport systems that exchange real-time C-ITS messages with vehicles, other road users, infrastructure and other environments using European Union C-ITS security credential management system (EU CCMS). EU CCMS is the European Union C-ITS framework for trusted and secure C-ITS communication using Public Key Infrastructure (PKI).

The aim of this research was to study performance needs of C-ITS services in a mobile network as well as to define common service level framework criterion to cover various scenarios of use of services. The needs were described from the perspective of selected C-ITS services. This research continued the work described in Chapters 2.1.1 and 2.1.9.

The following research questions were studied:

- How are the service level framework Key Performance Indicators of mobile networks required by C-ITS services defined?
- What kind of methods can be utilized to prove the functionality of different types of C-ITS services in the commercial mobile networks?
- How are different mobile network technologies suited to serve the needs of different C-ITS services?
- How are current commercial mobile networks suited to serve C-ITS services and what are the key deficiencies/bottlenecks, if any?
- How can the network development progress for C-ITS services be assessed currently and what information is needed to assess the progress in the future?
- What kind of development needs, cooperation models as well as technical and regulatory solutions are needed in order to accomplish the C-ITS service levels in commercial mobile networks?

2.1.12.2 Methods and equipment

This study was divided into three main phases:

- Phase 1 included two parts:
  1.1: definition of service level framework and Key Performance Indicators
  1.2: development of methods measuring C-ITS services' KPIs in mobile networks.
- Phase 2: analysis of the current network performance
- Phase 3: implementation of C-ITS service levels in the mobile network

The work's research methods were literature review, interviews, expert knowledge, and collaboration in the project management group. The methods are presented in more detail below.

The literature review included scientific articles, standards, legislation, conference publications and reports, e.g. of pilot projects. The literature review was conducted by using search engines and scientific publications.

Knowledge of project team and management group members as well as expert interviews were utilised (including Finnish mobile network operators). The study included multiple iterative review rounds together with the members of project's phases. Additionally, during the work multiple peer reviewers from Europe have been used to gather knowledge on C-ITS and mobile network performance and quality indicators. Furthermore, combined mobile network coverage predictions and measurement information were received from Traficom to support the assessment of using currently available information as a basis for assessing the feasibility of C-ITS services in Finland.

An online workshop was also organised with stakeholders from national relevant authorities, mobile network operators and ITS service providers in order to gain insights on mobile network utilisation in C-ITS service deployment.

The project participants and their roles were:

- Finnish Transport and Communications Agency Traficom, chair of the management group.
- Finnish Ministry of Transport and Communications, member of the management group
- Finnish Transport Infrastructure Agency, member of the management group
- Traffic Management Company Fintraffic Ltd, member of the management group
- Finnish Meteorological Institute, member of the management group
- Sitowise Group Plc was responsible for the work,
- Nodeon Ltd, a sub-consultant
- Omnitele Ltd, a sub-consultant
- Traficon Ltd, a sub-consultant.

2.1.12.3 Results

Part A main results are C-ITS services related Key Performance Indicators (KPI). Three KPI categories were identified: Availability, Reliability, and Integrity. For the KPI categories, four KPIs were identified: network coverage, packet loss rate, throughput, and latency. Service Level Framework was defined based on the identified critical KPIs for C-ITS services to operate on mobile networks. The framework was divided into four levels of operability: level 1 Unreliable operability, level 2 Basic operability, level 3 Medium operability, and level 4 High operability. Quality of service minimum requirements were also recommended for the service levels. Additionally, the scenario framework was developed, drawing insights from scenario analysis and projections regarding C-ITS adoption in Finland up to 2030.

Part B main result is a measurement method framework which was developed as a process-like model. This model can be used to cost-effectively analyse large areas and carry out measurements where necessary. The studied area can be chosen based on e.g. traffic volumes and the development of mobile communication networks. The developed measurement method framework includes three phases: 1) Theoretical analysis, 2) Field measurements, and 3) Service level analysis.

Part C main result is the feasibility analysis of the estimated capability of commercial mobile networks to enable the deployment of C-ITS services. The feasibility analysis was conducted by comparing the defined C-ITS development scenarios (based on the scenario framework defined in Part A) to the performance metrics (by applying the measurement method framework developed in Part B). Based on the analysis, the capability of current mobile networks (mainly 4G & 5G technologies) to support the deployment of C-ITS services was found to be well suited for carrying the average expected C-ITS messaging data traffic levels.

Part D of the study presents proposed solutions to ensure the required mobile network capacity for C-ITS services and support the widespread adoption of these services. These solutions are: network expansion, neutral host networks, network slicing, network monitoring, and data traffic congestion mitigation.

2.1.12.4 Conclusions and recommendations

Considering all the digital mobile network technology generations, even 4G network technologies can provide the connectivity and capacity needed, and future developments for 5G technologies can potentially even improve the ability to serve high-device-density and high-message-frequency services such as in the C-ITS framework.

In general, from coverage availability and system capacity points of view, the mobile networks of today are well suited to carry the average expected C-ITS messaging traffic levels. In terms of latency, current network technologies are also capable when comparing the network latency threshold values to the service level framework defined in Part A.

However, the commercial mobile networks are inherently very much environment-dependent, and spots of poor service levels will persist, individually per each national operator, depending on their local network deployments (site/technology grid) and network strategy. This is important to consider for all development and planning of C-ITS service implementation.

This study recommends the establishment of cooperation model for developing shared vision and goals as well as developing national C-ITS implementation strategy and road map, as high-level actions to support C-ITS service deployment.

2.1.13 In-vehicle signage with motorway control system and variable message signs

2.1.13.1 Background and aim

As mobility is a key question in our society today, the effectiveness, safety and environmental issues are essential within the transportation sector, especially in the greater metropolitan areas with dense traffic on the main highways. Fast and proper reactions from drivers are also essential, especially on roads with stop-and-go traffic and large differences in speed between vehicles in different lanes.

The objective was to test motorway control systems and variable message sign functions directly in-vehicle-systems by using cellular communication and data exchange in accordance with the C-ITS and C-Roads standards. The piloted C-Roads services were IVS-Traffic Sign and IVS-Free Text. The potential of In-Vehicle Signage with motorway control systems and variable message sign is that data can be shared from 150 km of motorway control systems and from 100 variable message signs on the main roads in Sweden.

2.1.13.2 Methods and equipment

The services were tested in two of Sweden's largest cities Gothenburg and Stockholm on state highways owned by Swedish Transport Administration. The site in Gothenburg was on road 158 Söderleden, from E6 in the east to Gnistängstunneln in west. In Stockholm the site was located on Essingeleden, the link on E4 between Södertälje and Stockholm (Figure 11).

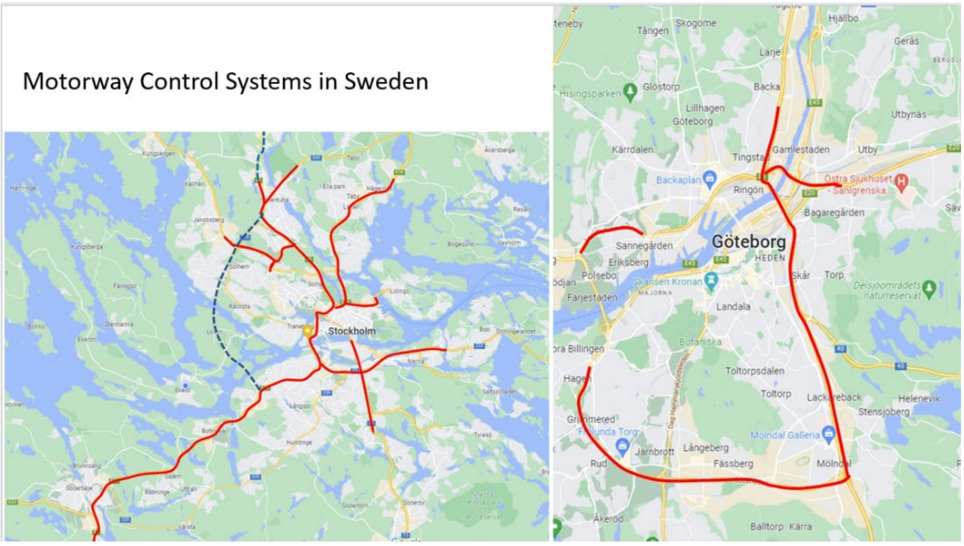

Figure 11. Map, installed MCS signs in Stockholm and Gothenburg area.

Both sites used motorway control systems and variable message signs. Examples of use-cases were delivering data from signs for lane closure, queue warning-functions, speed of different types to the vehicle HMI.

The pilot became limited due to a longer time for making data available from the MCS system. This was due to a reinvestment in a new system and technology by the Swedish Transport Administration (STA). This also means that all data from this type of system will now be accessible for the whole MCS-equipped road net in

Sweden. Service named IVS-Free Text became inaccessible at this time. However, the POC involved the following C-Roads Day 1 and Day 1,5 C-ITS services:

- Display warning sign or variable speed limit in-vehicle, IVS-Traffic Sign service, according to C-ITS Service and use case definitions version 2.0.5 and standards, such as ETSI and ISO. The technical parts in Stockholm and Gothenburg included:
- Technical aspects on data exchange from data platforms managed by Swedish Transport Administration, such as speed, queue warnings, and lane closure from motorway control system, to vehicle IT system/cloud and public transport IT system/cloud via the Interchange node. Additionally, quality of service, time consumption from signal/sign to OEM- and public transport cloud to minimise latency were investigated.
- Data to be exchanged from motorway control systems is lane closure, change lane, recommended highest speed, mandatory speed (Figure 12).

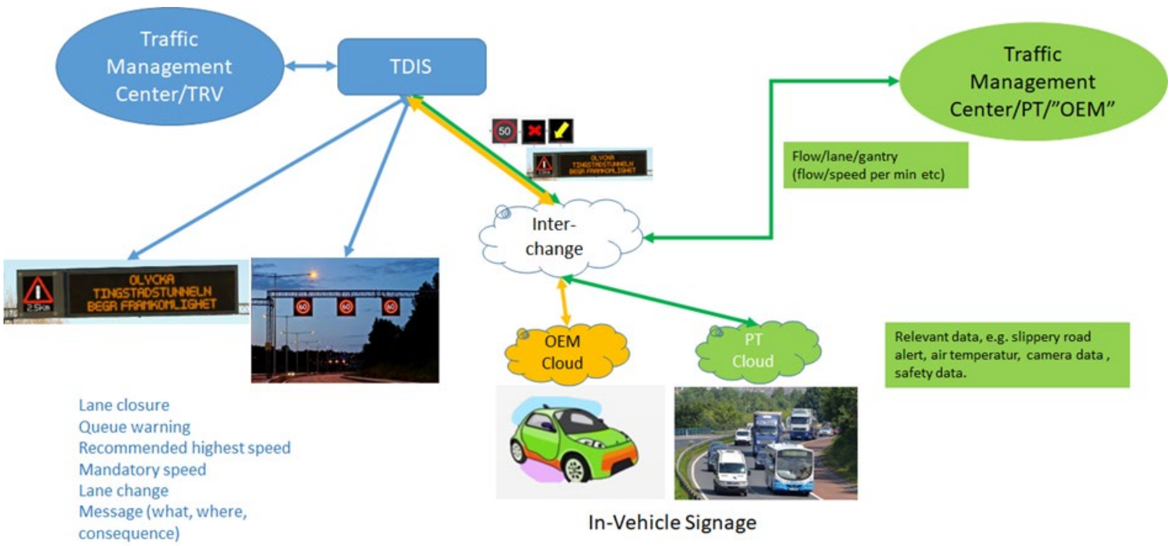

Figure 12. Illustration of data flow between stakeholders

Participants and their roles were:

- RISE was the coordinator of the project.
- Scania provided a test-vehicle to the Stockholm site.
- Volvo cars evaluated accessible data for future autonomous driving.
- Swedish Transport Administration provided MCS data in Stockholm and Gothenburg and road owner for the pilot sites via their Data Exchange Platform.
- ITxPT supported with a European PT Association knowledge and data sharing perspective
- Monotch was the supplier of the Interchange Node for C-ITS data exchange with roadside objects.

2.1.13.3 Results

Different technical parts and interfaces were connected to create a pilot eco-system:

- The first version in the data chain between STA and Interchange is data from STA "data exchange platform – the DUP" with aim to convert data from STA "red communication-net" to the open interchange Data is following DATEX standard in this stage. The next version will be based on ETSI standard and according to the vehicle industry. ETSI is mainly developed to support fast and smooth C-ITS messages and following machine reading standard. https://www.etsi.org/technologies/automotive-intelligent-transport

- STA is in the position to manage data transfer from the internal data communication system via the DUP – data exchange platform to the Interchange Node. The platform can manage both outgoing data and incoming data from OEM and SP's.

The data in the eco-system have been consumed:

- The pilot defines the interface to the OEM's cloud.
- The pilot is an operational test of the Advanced Driving Assistance System which is the first step to reach the goal of Cooperative Connected Autonomous Driving. The pilot manages data from different stakeholders.
- For effective data sharing between involved stakeholders, Nordic Way 3 establishes an Interchange Node. When the service becomes operational, other Service Providers (e.g., Wireless Car, Zenseact) can connect to the interchange node and provide smart routing services.

2.1.13.4 Conclusions and recommendations-

The POC identified the following challenges:

- How to determine and measure lanes, starting from right or left. Both options are used within Sweden and in DATEX and ETSI, even the bearing for the sign.
- There is a strong wish from the participants to have an Interchange Node, where data from many actors is shared and easily accessible.
- The DUP system does not have an interchange function.
- Real time and dynamic data from Swedish Transport Administration is vital. NVDB (National Road Database) would need to be developed to include traffic rules and traffic information for all Sweden's municipalities.

2.1.14 Enabling warning of approaching trains

2.1.14.1 Background and aim

Unattended level crossings are a common problem in many European countries. For example, Sweden has approximately 6500 level crossings where more than 3500 of them are unattended i.e. lacking safety grates and/or warning signals. Rebuilding all unattended level crossings takes time and costs money and is therefore not prioritized by the Swedish Transport Agency (Trafikverket). Therefore, Trafikverket initiated a pre-commercial procurement of alternate solutions, in order to increase safety at unattended level crossings. This additional information is essential for automated vehicles, to ensure a safe crossing of rails.

The aim of the project was to demonstrate a Warning of Approaching Trains (WAT) solution based on real-time positioning of trains and geofencing. The purpose of the WAT-solution is to support safe passage of road users at unattended level crossings. A road user may be a pedestrian, cyclist, car driver or similar.

2.1.14.2 Methods and equipment

The technical solution was based on high-precision and real-time positioning of trains via installed GNSS/GPS devices. The precise locations of the trains were then correlated to the locations of all (official) unattended level crossings. In the current implementation the geofence was fixed to 1000 metres for all unattended level crossings but this may be adjusted per level crossing based on local conditions. When a train passes into the level crossing geofence the unattended level crossing is flagged as red to warn of approaching trains. All red-flagged unattended level crossings were continuously published in the NordicWay 3 Interchange Hub via DENM messages (Usecase: Railway Level Crossing (HLN-RLX), CauseCode: Collision risk (97), SubCauseCode: Crossing collision risk (2)). The information may then be consumed by, for example, road users approaching an unattended level crossing. Please note that no crossings are ever marked as “clear to pass” or “green” in accordance with the standards.

Project partners and their roles were:

- Digital Tvilling (project leader)
- Monotch (support)
- KnowIT (information consumer)
- SJ/Krösatågen (railway operator, information provider)
- Region Kalmar (train owner, information provider)
- Volvo Cars (information consumer).

2.1.14.3 Results

The creation and publication of information on approaching trains as DENM messages in the NW3 interchange was successfully verified. Consuming the messages from the NordicWay 3 Interchange was also successfully verified. The Warning of Approaching Trains messages concerning targeted railway sections in Sweden (primarily Malmbanan and Stångådalsbanan) are currently continuously published in the NW3 Interchange. Via the NW3 Interchange, the information is currently continuously consumed by, for example, the KnowIT smartphone app as well as Digital Tvilling’s own backend viewable in a real-time map.

2.1.14.4 Conclusions and recommendations

The conclusion is that it is possible to generate, publish and consume information on approaching trains as DENM messages via the NW3 Interchange. Discussions are ongoing with Volvo Cars to test Warning of Approaching Trains information in their car navigation systems.

It is recommended to perform further field-tests to verify user behaviour related to Warning of Approaching Trains information provided via the NW3 Interchange e.g. actual driver behaviour when the driver is warned about an approaching train via the car navigation system.

2.1.15 Impacts of automation in road transportation

2.1.15.1 Background and aim

Comprehensive knowledge of the potential impacts of road transport automation is important to assess whether automation can support the objectives set for a safe and sustainable transport system. Road transport automation comprises several different concepts that are being developed in parallel. In addition, the potential impacts depend on other parallel developments such as the electrification of vehicles and the growth of digital services in transport. The impacts of road transport automation in the Nordic countries may differ from these in other countries, due to more challenging weather conditions than in many other regions, a road network largely based on 2-lane highways, lower traffic volumes, and relatively long distances in sparsely populated areas.

The purpose of this study was to summarise, based on review of scientific articles, the potential impact of road transport automation in different use cases and to assess the suitability of the literature results for the Nordic context.

The use cases considered were (personally owned) passenger cars, public transport, shared automated vehicles and demand responsive transport, automated logistics solutions, and truck platooning. The assessment covered the following impact areas: travel demand and modal split, traffic safety, road network performance, environment (emissions) as well as interaction between road users.

2.1.15.2 Methods and equipment

This study performed a literature review on the potential impacts of automation in road transportation for four different use cases (privately owned passenger cars, public transport, robotaxis and logistic solutions) and five dif-ferent impact areas (vehicle kilometres travelled and modal split, traffic flow, environment, traffic safety and inter-action between road users). The applicability of the literature results to the Nordic context was also assessed. In total, 122 scientific articles were analysed.

Project participants and their roles were:

- VTT Technical Research Centre of Finland carries out the work

2.1.15.3 Results

The impacts of automation on traffic flow and the environment have been studied mainly on motorways and at high traffic volumes. However, traffic volumes are typically not very high in the Nordic countries. In addition, the impacts of automation on motorways alone are likely to be limited due to the sparsity of the motorway network. Literature suggests that automation can improve traffic flow in congested situations if the time headways kept by automated vehicles are shorter than those kept by human drivers.

Interaction between road users is an important factor for efficient and safe traffic flow. Scientifically, this area of research is at an early stage, where the concepts and research questions are still taking shape. The most tangible research results to date include an understanding of the importance of so-called implicit information in the interpretation of vehicle movements and the identification of the factors that influence the effective communication of different types of external human-machine interfaces. The need for external human-machine interfaces has also been questioned. However, the ability of both automated vehicles and other road users to communicate and interpret each other's intentions will continue to be an essential issue, with the Nordic weather conditions providing their own specificities.

Both privately owned and shared automated passenger cars make car use more convenient and offer more opportunities to use travel time for fun and benefit. This can increase the mode share of car trips, extend car journeys and create new trips. A modal shift is likely, in particular from public transport to automated passenger cars. The magnitude of the impact is related to the penetration rate of automated passenger cars in the vehicle fleet. As automated passenger cars become more widespread, vehicle kilometres may increase by a few percentage points. When automated passenger cars become mainstream, vehicle kilometres could increase by dozens of percentage points. However, at this stage it should be noted that congestion on the road network, among other things, may start to limit the growth of vehicle traffic.

Similarly to automated private cars, robotaxis can facilitate mobility. They may, in principle, enable giving up car ownership, but kilometres driven without occupants can increase the vehicle kilometres travelled. The impacts of robotaxis depend on how they are integrated with public transport. Robotaxis can either compete with public transport or support it by providing feeder services to train stations, for example. However, the availability of robotaxi services in the harsh weather conditions and sparsely populated areas of the Nordic countries remains to be seen.

In terms of traffic safety, it is important to consider exposure, accident risk and accident severity. Studies on automation have not generally included the impacts on all these three factors but have focused on the accident risk. The results show that automation can be seen to reduce the risk of accidents in general, but the magnitude of the effect depends on the use case, the subject of the study and the methods used. The strongest research evidence is on the safety benefits of driver assistance systems, but their performance in more challenging environmental and weather conditions should also be further investigated to determine the safety impact. It is also worth noting that if the development of automation leads to new and longer journeys and a shift from public transport to less safe travel modes, safety benefits may be lost.

2.1.15.4 Conclusions and recommendations

In general, the results of research on the impacts of automation in road transport can be generalised to real traffic only, with reservations. This also applies to the generalisation of the results to Nordic conditions. In studies on the effects of automation, the background and assumptions used are often not described in detail. Most of the re-search has also been conducted in very simple conditions and environments, and variations in weather conditions, for example, have not been taken into account.

Increased automation in road transportation can contribute to many of the objectives set for the transport system in terms of efficiency, environment, accessibility, safety and health. However, progress towards these objectives cannot be taken for granted. Research suggests that the promotion of public transport and active travel modes, in particular shared rides in automated vehicles, is important. To ensure the vision for the future, more research, focusing in particular on the Nordic context, is needed to support regulation and policymaking on automated driving and its introduction.

2.1.16 CCAM implementation plan

2.1.16.1 Background and aim

In the end 2021, the Government of Finland issued a resolution on promoting transport automation and transport automation plan that included legislation and key measures in transport automation (MinTC 2021). This action plan described the key actions to accelerate the utilisation of automation in all transport sectors.

The Finnish Transport Infrastructure Agency (FTIA) had participated in the preparation of the action plan and had already investigated the potential of the existing motorway network in facilitating SAE Level 3-4 automated during systems in its study (see Chapter 2.1.1). The study had also identified the most significant factors to which the road authorities and operators should invest in the near future in their research and development as well as international cooperation activities. (FTIA 2021).

The study aimed to look at how the national action plan and the indications of the study should be implemented in an FTIA action plan for the next years taking on board the most current knowledge and results of the recent actions in the field of automated driving.

2.1.16.2 Methods and equipment

The study methods were literature survey and expert interviews, as well as one internal workshop involving Finnish Transport Infrastructure Agency experts.

The study participants and their roles were:

- Finnish Transport Infrastructure Agency as a beneficiary and owner of the project
- Project consultant team: Traficon Ltd.

2.1.16.3 Results

The result of the study was fifteen proposed actions for the development of road transport automation support for the Finnish Transport Infrastructure Agency. The proposed actions were classified in five categories:

1) physical infrastructure
2) digital infrastructure
3) knowledge management
4) national and international stakeholder cooperation & lobbying
5) road network service levels.

A roadmap was developed to support the implementation of the proposed actions. The proposed actions were classified into four categories (A–D) on the roadmap:

A. Essential: actions that have to be carried out during the next years anyhow as they are mandated by European and national regulations or strategies

B. No-regret: actions that are beneficial for both conventional and automated vehicles and will be needed in any case independent of the timing of the roll-out of automated driving

C. Technology evolution dependent: actions that are best to implement only when we are convinced of the required technology solution and thereby have minimal risk of misplaced investment

D. Monitoring of development: actions that need to be carried out on a continuous basis to remain aware of the development of ADS related technologies and their use, benefits, costs and feasibility for Finnish conditions.

The roadmap is presented in Figure 13. It should be noted that even though the roadmap does not include a time axle with specific years, the time is running from left to right. The necessary (A) and monitoring of development (D) actions should be started immediately. The no-regret actions (B) can also be started now or later based on the needs of FTIA, whereas the technology evolution dependent actions (C) need to wait.

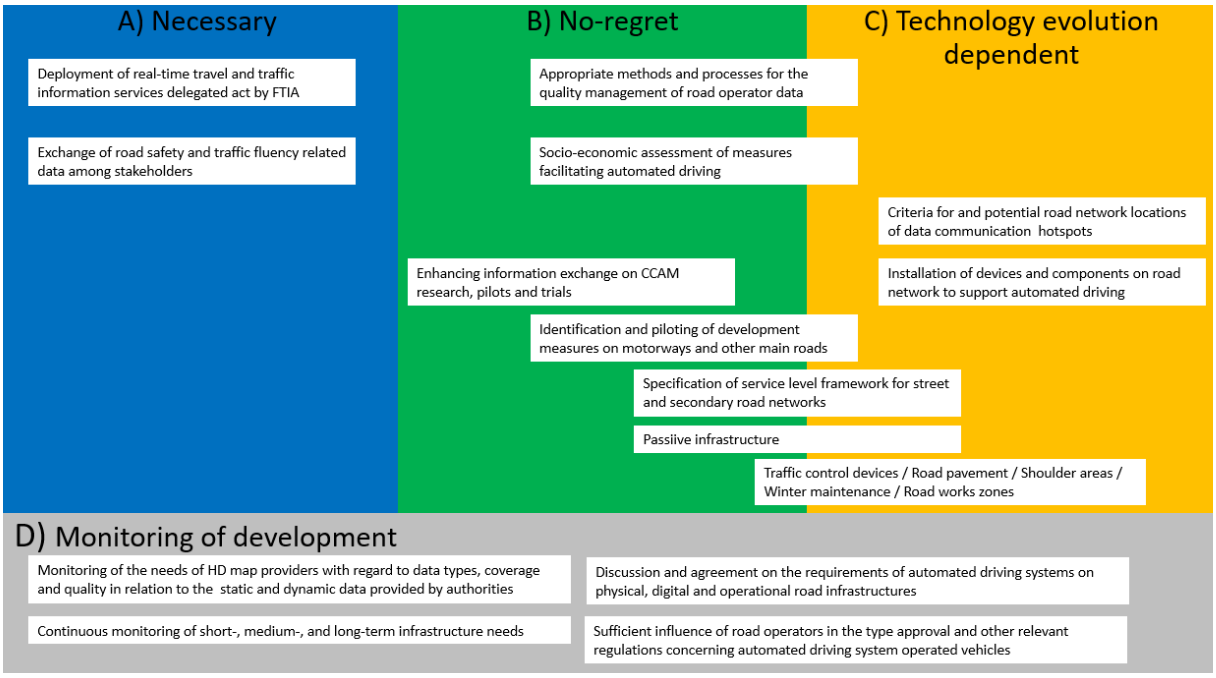

Figure 13. Roadmap

Link to the publication: https://www.doria.fi/handle/10024/186557

2.1.16.4 Conclusions and recommendations

The aim of the study was to find and identify the most essential actions for road operator at the moment to enable automated driving. The highest priority was given to actions mandated by law and otherwise deemed beneficial i.e., no-regret actions. Lower priority was given to actions dependent on vehicle technology evolution as well as other actions with uncertain feasibility.

The feasibility and implementation details for the actions are to be based on pre-studies and socio-economic cost-benefit analyses. This method of working is supported by the specific action of socio-economic assessment of measures facilitating automated driving. Feasibility evaluation of the actions can also be supported by regional or otherwise limited pilots. Pre-studies, impact assessments and results of pilots together serve as the basis to support road operator decision-making when enabling automated driving.

The next step is to separate the broader set of actions in the action plan's road map into individual actions, and determine their order of implementation, interdependencies, schedule and evaluate the related costs and other resource needs. These individual actions are then coordinated with the road operator's other activities and goals in short- and long-term operational planning.

The road operator can contribute to the favourable development and deployment of road transport automation, but its influence is limited; some of the actions are still waiting for technologically evolving automated driving systems' requirements for the infrastructure and road operator processes. The Finnish Transport Infrastructure Agency is already implementing development actions that partly support or relate to enabling of road transport automation, e.g., monitoring quality of road maintenance and development of digital models/twins.

When developing physical and digital infrastructure, the role of road operator is primarily formed by the tasks assigned to the authority in legislation and national strategies. As the technology of automated driving evolves, the road operator needs to evaluate in national and international collaboration the benefits and costs of the actions on case-by-case basis as well as continue to take into account the importance of the investment for human-operated road transport and traffic.

2.1.17 Operational and Infrastructure readiness for semi-automated truck platooning on rural roads

2.1.17.1 Background and aim

Truck platoons consist of virtually linked trucks that drive together in convoys with small headway distances and are forecasted to be among the earliest commercially available use-cases of road vehicle automation.

Field studies are useful for assessing whether platooning can deliver real-world benefits. Many have been undertaken, but mostly on multi-lane highways with forgiving horizontal and vertical geometry and ample space for overtaking. This study explored platooning on Norwegian roads, the added challenges of tunnels and mountain passes. The field study explored platooning system operation, driver interventions and road features.

The following research questions were addressed:

- How did the truck platoon perform and what challenges did rural road conditions pose?
- In what conditions did drivers intervene with the platooning system?
- Can technological and infrastructural solutions overcome the challenges?

2.1.17.2 Methods and equipment

Figure 14 shows the 380-kilometer test route, driven over 7.5 hours, between two toll stations on the Norway-Sweden border.

Figure 14. The test route.

The route was deliberately chosen for the study as it would challenge the platoon. Traffic, road alignment and different engine-to-weight ratios were expected to disrupt its stability, causing the gaps in the platoon to contract and expand, yielding high fuel consumption and issues related to keeping set speeds. This was presumed to necessitate driver input, or communication between drivers, which was achieved using VHF radios. Participants conveyed important information, e.g., ACC settings, over radio. Excluding the drive from Finland through Sweden to participate in the field study, the three truck drivers did not have experience from driving together, but they had all previously driven in Norway and had used ACC before. While encouraged to use the platooning system, the drivers were told to resume longitudinal control when deemed necessary for safety. They were free to use

Global Navigation Satellite System (GNSS) navigation or other aids. Each truck had a passenger serving as conversation partner and observer. While difficult weather is prevalent in this area, conditions during the trial were good. The road was mostly dry and free of ice, sleet and snow, with ambient temperatures around 0 °C. Sleet and snow were briefly encountered (15 minutes) on a mountain pass at the end of the field study.

The set-up was identical in each truck, and included a radar sensor which measured the distance to the preceding truck, and three action cameras which filmed the driving scene and all interaction of the driver with the pedals and the steering wheel. The cameras also captured dialogue in the trucks and over radio. The term preceding truck is relative, and refers to the truck located in front of the truck in question. Leading truck or leader refers to the first truck, and following trucks or followers refer to both the middle truck and last truck together.

The attitudes, expectations and experiences of the participants were collected qualitatively. Semi-structured interviews were conducted twice per driver; before the field study and midway through (15 and 30-minute durations, respectively). Moreover, participants freely conversed amongst themselves and over radio during the field study, and the researchers occasionally posed questions to elicit discussion. Qualitative data were transcribed, coded and organized into themes.

The fleet management system logged speed [km/h], fuel level [%] and GNSS position at an average frequency of 0.02 Hz. While driving, it logged around 500 data points for each truck. 84–85% of loggings were made once per minute, 14–15% were made twice, and 0.5–2% were made three times per minute or more often. Hence, loggings were rather infrequent and did not always temporally coincide for the trucks. Nevertheless, FMS data can be used as an input for exploring the overarching operational performance of the platoon.

2.1.17.3 Results

Speed and Separation

The mode speed was 62 km/h, i.e., significantly below the predominant 80 km/h speed limit, indicating the inherent difficulty of the route. The SINTEF Energy Module [Available online: https://mobilitet.sintef.no/energimodul/] provides a baseline average speed of 62 km/h for solitary trucks at 41 metric tons on the same stretch. Hence, platooning only briefly delayed the trucks, if at all.

Speed consistency is key for platooning and it is affected by road design and interactions with other traffic, which cause variations in separation distances between the trucks. Speed variability for the platoon was more than what is recommended, suggesting that adverse road geometry impacts platooning by lowering speed consistency. Similarly, the distance variability during the adverse stretch was more than recommended.

Fuel Consumption

The average separations between vehicles were smaller, at 37–41 meters (std. dev. 11–14 meters), but speeds were also lower (56–59 km/h), reducing the fuel-saving potential of platooning.

In fact, the truck 2 had slightly larger fuel use than the truck 1 (0.7–4.4% higher). Towards the end of the study, occupants in the truck 3 noticed that the platooning system and the eco driving functionalities seemed to conflict. The platooning trial appears to have caused no fuel savings and perhaps also increased the fuel use, since keeping the preset distances to preceding trucks on roads with constantly changing vertical grades causes excessive acceleration and braking.

Driver behavior

Excluding the first 15 minutes of the field study, where all drivers drove manually, the two followers used the automated system almost exclusively for longitudinal control, with little other input. Driver 3 intervened the least, as shown in Figure 15. The drivers used the initial period to acclimatize to the road and to obtain the correct distances between the trucks before activating the system. For both followers, most pedal interventions occurred in transition periods as the platoon entered or left the road. These interventions are not as interesting as those that occur during on-road driving. The second-most frequent situations where interventions occurred, involved the platoon having to slow down considerably, due to e.g., intersections or slow-moving traffic.

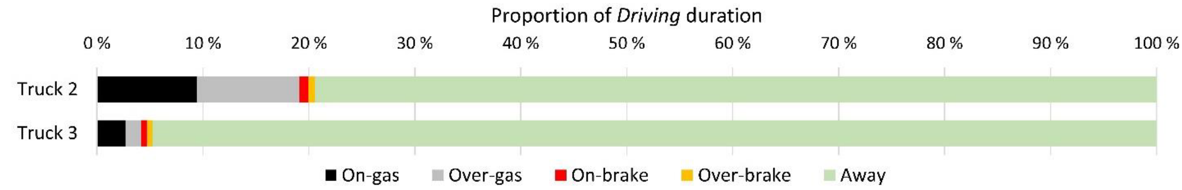

Figure 15. Proportions of driving duration for foot behaviors for the two followers.

The types of hand interactions differed between followers, presumably due to personal preferences. They did, however, have similar total numbers. As shown in Figure 16, driver 2 shifted gears manually more often than driver 3, who instead tended to adjust ACC settings. Truck 3 retarder use stems nearly exclusively from the 15-minute period of manual driving at the start of the study. For both followers, manual shifting occurred in upgrades, and when accelerating from standstill after breaks, but before having activated the ACC system. Combining actual interventions shows that, on average, trucks 2 and 3 had 1.1 and 0.5 interventions per minute, respectively. In contrast, truck 1 had 3.7, and he used the retarder more than 800 times.

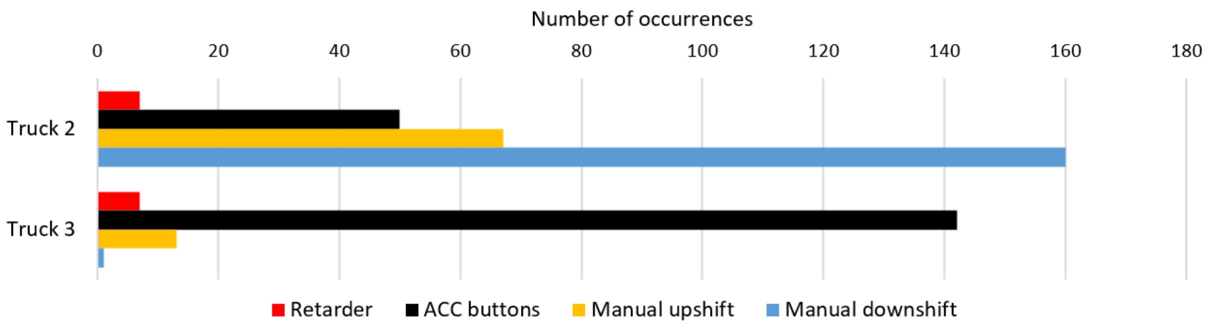

Figure 16. Number of hand behaviors for the two followers.

Vertical gradients

Correct and coordinated timing of gear shifts on steep ascents is found to be key for retaining platoon connection and for keeping a fuel-efficient speed profile. The trucks struggled maintaining speeds on steep grades (see Figure 17), frequently dropping below 40 km/h during strenuous climbs. Driver 1 often downshifted manually to retain speed uphill, while the followers mostly relied on their automatic transmissions to do so.

Figure 17. Upgrade seen from escort car.

Horizontal curvature

The platoon traversed horizontal curves of varying radii at different speeds and separations. While being rather rare, the curves with the sharpest radii (approx. 80–120 meters), and hairpin turns (below 80 meter radii) in particular, were the most adverse. If curves were moderately sharp, the platoon connection was often broken and regained repeatedly as the trucks negotiated the curve, since the system was occasionally unable to determine the type of vehicle preceding it. However, ACC still detected the preceding vehicle, so this had no consequence to the drivers. In sharper curves, however, the followers routinely experienced the preceding truck leaving the field-of-view of the ADAS sensors for a few seconds, causing intense acceleration. No longer detecting a vehicle before it, the truck assumed a clear path, accelerating to comply with predefined settings which were often higher than the current speed.

Tunnels and narrow sections

The platoon traversed 23 tunnels. Difficult situations arose when the platoon encountered oncoming trucks in narrow tunnels with low overhead clearances, see Figure 18. Both the oncoming and the lead truck would slow down to ensure safe passage. Hence, speeds for the platoon were reduced, often significantly, and the trucks frequently had to have their outer wheels on the outside of the edge marking to leave enough room for the opposing truck. Simultaneously, the drivers had to make sure that their cab or trailers did not touch the curving tunnel roof. In such situations, the followers usually had their foot over the pedals, ready to intervene. Such situations occasionally made the platoon speed drop below the 15 km/h ACC disengagement threshold.

Road widths were mostly discussed when passing through tunnels. Even before encountering the tunnels, however, all three drivers ended up disabling their LKA systems. The LKA would warn drivers that they were approaching or slightly exceeding the road markings when negotiating curves.

Figure 18. Tight passage when encountering oncoming truck.

Intersections and urbanized areas

The platoon traversed five small, urbanized areas. Roundabouts were the main intersection type, and 11 were traversed. Straight movements through roundabouts tended to work fairly well. Speeds usually exceeded the 15 km/h lower threshold, so the ACC system mostly remained active. In the tightest roundabouts, where field-of-view was most likely to be lost, the followers would pre-emptively disengage the system and traverse them manually.

2.1.17.4 Conclusions and recommendations

The field trial showed that the truck platooning system was feasible on high-speed rural roads with forgiving alignment. There, the platoon remained connected, driving in a coordinated manner with consistent speeds and separation distances, but this was mostly expected. Roads with subpar geometry, on the other hand, were more difficult. While the trucks mostly remained connected also on such roads, sharp curves, narrow tunnels and alternating inclinations caused the platoon to contract and expand as the trucks successively traversed different road features. On average, the trucks maintained quite low driving speeds. In sum, the roads lent themselves poorly to obtaining fuel savings from platooning.

It is unclear whether the system behaved any differently than what a conventional ACC system would on the same stretch. The issue of lost connection in curves presumably also depended on the prescribed ACC gaps. The longer distance settings would better accommodate acceleration following connection losses, while acceleration at short following distance would result in dangerous situations with the potential for rear-end collisions.

Drivers also wished the system reacted faster when the preceding truck changed its speed. One participant suggested that Vehicle-to-Vehicle (V2V) communication would have resulted in smoother operation, due to its ability to instantaneously transmit driving commands between the vehicles.

To do future tests more like real automated platooning driving one has to include V2V technology. There are also need for some regulation exemptions, allowing for smaller following distances.

While many of the issues faced by the platoon can be solved by infrastructure adaptations, technology developments, or combinations thereof, the latter is presumably more realistic from a cost-benefit standpoint. However, physical infrastructure improvements are still key to eliminate the worst bottlenecks.

Lateral automation has only briefly been discussed herein, through the faults of the LKA system in being useful for the drivers on the winding roads. This suggests that safe lateral automation will be challenging to accomplish, as error margins are small. It is also unclear how platoons would operate in tunnels, having limited GNSS and cellular connectivity. The same goes for speed bumps, intersections, roundabouts and sharp curves, neither of which are ideal for platooning operations.

Hence, the operational readiness of semi-automated truck platoons on Norwegian rural roads is questionable, and more testing and development is needed.

2.2 MaaS and services for public transport

2.2.1 National access point development for MaaS services

2.2.1.1 Background and aim

The aim of this study was to develop services related to MaaS and public transport including data from cities and public transport operators and making relevant data publicly available through the Finnish National Access Point and NordicWay interchange nodes. This enables better MaaS services but also forms a basis for optimising public transport for example by implementing bus priority and last mile services.

One use case was opening the real-time or dynamic transportation data feeds for NordicWay3 use case and concept development. Standardize data feeds and open APIs make it possible to develop services which makes changing the data between road traffic and public transport vehicles possible. Public transport vehicles are constantly sending data packages like speed, heading, estimate time between stops, calculated time between stops and alert messages. As a use case real-time data availability and functionalities of over 4000 public transport vehicles were developed and listed as data sets to NAP

2.2.1.2 Methods and equipment

Work was done in two phases:

- Traffic data ecosystem actors created a concept plan on how data is shared, validated and aggregated in order it to have meaningful role in MaaS and situational awareness (like road traffic conditions) business cases. Data ecosystem generated use cases for improved data sources which could benefit either directly or indirectly development of more sustainable and comprehensive mobility service. Exchange of information related on network conditions, estimated stop times, real-time feeds and POI information and analytics information was considered to be vital place of improvement. At the moment traffic management and road data sources and mobility services are two separate entities (not including rail transport) where is plenty of need for improvements. Additionally, it was evident that due to the operational volumes the need for sharing data is more vital on city areas and thus on street, not national road network.
- Functionalities and improvements for data availability and security were added on Finnish MMTIS NAP. This was done as a concrete development work and better mapping of real-time services listed in the data catalogue. Service now shares through two MQTTs the positions, estimated stop times, alerts and messages of over 4000 public transport vehicles. Data is now available for developing improved services in the field of MaaS and also for adapting interchange nodes for receiving real-time public transport data.

The participants in this development were:

- Traffic Management Company Fintraffic Ltd. as the NAP operator
- Solita Ltd. as the subcontractor for Fintraffic responsible for concept design and technical development
- Members of the task group on transport information within the Finnish Traffic Data Ecosystem

2.2.1.3 Results

Development of the data models and exchange protocols for mobility and/or MaaS services and C-ITS within the traffic data ecosystem was started. This enables the relevant data from cities and public transport operators to be publicly available through interchange nodes. The data catalogue (NAP) and data security and access management modules were improved.

A plan for the next generation of the Finnish NAP for traffic data and services, based the overall concept for transport data related services in Finland was conducted. The focus was on data availability, data accessibility, metadata and discovery services. Within the work, mobility data related real-time services which could share the data for real-time traffic conditions in Finland was defined. The needs of end users, transport service providers and MaaS operators were analysed. This concept was defined and agreed on together with the relevant stakeholders in the traffic data ecosystem.

The overall concept for transport data related services in Finland is defined and in use. Real-time data from over 4000 vehicles is now available for developing existing and new use cases and relevant initiatives and business cases

2.2.1.4 Conclusions and recommendations

The main lesson learned in this development was that it is possible to develop a sustainable business model and ecosystem for the data value chain in collaboration with the public and private stakeholders involved in transport services (public sector – road authorities, C-ITS operators, content and service providers).

The development of centralized data platforms and data delivery services such as NAPs and Interchange Nodes as well as common master data management architecture is a key element when building a data ecosystem.

It is recommended that the development of NAP and Interchange operations is continued to support the development and implementation of C-ITS services, adapted to the conditions, urban and interurban environments in Finland. Additionally, the connection of C-ITS services and MaaS should be studied in city transport as well as on the main corridor, and the data shared through the Finnish Interchange Node once it is operational.

Participants needed in further implementation are:

- Traffic Management Company Fintraffic Ltd. as the NAP and interchange operator
- Fintraffic Road Ltd. as road operator and C-ITS data provider
- Finnish municipalities as data providers
- Transport or MaaS operators as service providers.

2.2.2 Development of data models and exchange protocols for MaaS services and C-ITS

2.2.2.1 Background and aim

Constantly updated real-time data available from mobility services should be securely shared through MMTIS NAP to the interchange node. At the time of the pilot, MMTIS NAP data including real-time data was not shared in the interchange node nor between NAPs with neighboring countries.

To access all the available data, it was evident that the findability of the data sets needs to be improved and also methods how to exchange standardized data between different systems. Also, it is important to have minimum lag in data transfers and trusted source for data generating. These were major background known-knowns which were addresses at the work.

The aim of this study was to study are real-time data models and exchange protocols for mobility and MaaS services as well as for C-ITS possible to integrate into an interchange node. In this use case this means data collected by the public transportation and communication between other vehicles and possibility also with roadside infrastructure.

It was also the aim to study how, in certain scenarios, for example, SIRI messages relied between public transport systems, like passenger information systems, can be reused and repurposed also in road transportation and how they could improve traffic management and coordination.

SIRI is a CEN Technical Standard that specifies a European interface standard for exchanging information about the planned, current or projected performance of real-time public transport operations between different computer systems. SIRI is a Transmodel real-time standard and stands for Standard Interface for Real-Time Information. Market coverage of SIRI is still quite low in Finland, but availability is regulated in MMTIS delegated regulation as a standard to share real-time information from all modes of mobility services.

2.2.2.2 Methods and equipment

The topic was approached through the open and common European IT standards for public transport favoured by ITxPT (https://itxpt.org/specifications/). The goal was that the data exchange protocols are based on solutions already in regulation and on the market. A good starting point for this is the specifications listed by ITxPT, whose documentation is also available on the organization's website. Further if implemented in full scale (national, regional) open solutions like MQTT would be considered as a service backbone.

The used methods enabled more flexible ways of sharing real-time data in Finnish MMTIS NAP but also in operative, open APIs, like listed in Digitransit MQTTs https://digitransit.fi/en/developers/.

Base source for tested real-time vehicle data was Finap.fi, which is Finnish MMTIS NAP. Finap includes data sources from all roughly 30 public transport authorities (PTAs) currently offering their services in Finland. Main data feeds in the interest were Transmodel/CEN standardized SIRI data (Now real-time data is provided roughly from 4000 vehicles and data standard is global GTFS RT, not SIRI which is required in MMTIS delegated regulation.

Project participants and their roles were:

- Traffic Management Company Fintraffic Ltd – project lead
- Solita Inc. – sourced developer team for public transport data and MMTIS NAP
- NAP data providers like public transport authorities in Finland

2.2.2.3 Results

SIRI standardized data was successfully shared from transport operators and public transport authorities. Operational API is now available through Finap and also directly from Digitransit API management. In its current form, the interchange node needs further development and improved utilization of public transport and other mobility data feeds.

Main driver for interchange nodes, like used in NW3, are in road transportation and gathering and sharing data between vehicles and or road infrastructure. Using SIRI data as an additional data for vehicle messages in interchange nodes could have an impact both in private car users, traffic management centres and also improve reliability in scheduled travel times in public transport. Real-time public transport systems are equipped with communication devices and systems that support the SIRI and international GTFS RT standard. SIRI and GTFS RT messages could be handled in a similar way than other traffic messages in the message broker.

SIRI offers following messages to add value for traffic management and issue handling

- Service monitoring data
- Vehicle monitoring data
- Facility monitoring
- Connection monitoring
- Situation exchange
- General messages
- Stop events.

Interchange node database could include messages generated by large scale public transport operations. Data is also usually shared without any relations with personal or otherwise protected data. Service, vehicle, and situation messages can be used to improve live events happening in the street and road network.

2.2.2.4 Conclusions and recommendations

The current practices do not support the use of SIRI messages as one base data element in the interchange node. Also, there is currently only a few providers for standard SIRI data in Finland. Most of the transport service providers and public transport authorities are providing similar data which however is not CEN standardized data GTFS RT. In order to have more scalable and standardized data, public transport organizations should provide more real-time data on MMTIS required data formats like NeTEx and SIRI. When data is more available from both street and road networks, further adaptations should be considered to develop new functionalities for interchange nodes.

Using for example SIRI standardized real-time data, as an additional message relied between vehicles and between vehicles and infrastructure, there is a possibility to get improvements in quantity and quality for data.

It would be beneficial to study the possibility to connect the messages from public transport to the interchange node through conversion on message types. In addition, it would be beneficial to study the real benefits for having thousands of prescheduled vehicles on the street and road network for sharing scheduled and data on estimated arrival times.

2.2.3 Needs, capabilities and willingness of municipalities to provide and use traffic information

2.2.3.1 Background and aim

Automated vehicles will benefit from digital traffic data. The availability of such data from street networks is still quite low as ITS regulation has been concentrating on main road networks. However, the need for traffic data also from street networks is clear. Service providers, OEMs and governmental authorities would benefit from this data. Unfortunately, the capabilities of municipalities to provide such data have been quite low.

In order to clarify the current situation and to activate municipalities in data production and ecosystem cooperation, the needs, capabilities and willingness of Finnish municipalities to provide and use traffic information were studied. In the study, focus was given to the datasets listed in the revised RTTI regulation (2022/670). The study also aimed to activate municipalities in the traffic data ecosystem by sharing information about the use cases for RTTI and C-ITS data. The municipalities were also able to specify future support needs for the provision of traffic / C-ITS data.

2.2.3.2 Methods and equipment

Several cities were interviewed. The interviews were semi-structured thematic interviews. The following topics were discussed:

- the production of traffic data
- the use of traffic data within the organization
- the resources allocated for traffic data production
- the organizations' needs for support for data production.

After the interviews a workshop was organized with the aim of defining the necessary actions to be taken to facilitate traffic data production from street networks.

Project participants and their roles were:

- Traffic Management Company Fintraffic Ltd – project lead
- Sitowise Ltd – project consult conducting the study
- The cities of Helsinki, Kuopio, Vaasa, Tampere, Turku, Lappeenranta, Oulu, Lohja and the Kaustinen district, consisting of 6 municipalities - interviewees

2.2.3.3 Results

The interviews clearly showed that the maturity for production and collection of traffic data varies greatly even among the bigger cities. Traffic related issues are often divided into different organizational silos and there are no common platforms for data collection and delivery. Many municipalities have developed and piloted different solutions in projects, but these have run into problems when the project funding has stopped.

In general, there is a will to make more traffic data available. At the moment, most of the traffic information the municipalities are delivering is delivered via websites and social media. These channels will not reach the service providers, OEM etc. Therefore, there is a need for national level guidelines and recommendations for data collection and delivery that the municipalities can utilize. The role of the national access point (NAP) was highlighted here to work as a common platform not only for data delivery but for national guidance too.

Based on the study, Fintraffic as the national access point operator and traffic data ecosystem lead defined actions to be taken to facilitate traffic data production from street networks.

2.2.3.4 Conclusions and recommendations

Based on the interviews and the workshop, four recommended actions were identified:

1) Define the most important datasets that the municipalities efforts and national coordination should address (Data top 15).
2) Create material to motivate the municipalities, not only from the regulatory aspect but also from the benefits of producing and delivering traffic data.
3) Establish a (meta)data catalogue to facilitate data discovery and to function as the source for national level recommendations.
4) Identify and develop service model options for the municipalities for data production and delivery, three possible models were identified for further development:
    - The municipality itself produces the data in the recommended format and APIs
    - The municipality has the data, but not in a useful format. The national access point can convert and deliver the data in the recommended format and APIs
    - The municipality utilizes third party services that are compatible with the national guidelines and recommendations

3 Discussion

NordicWay 3 project listed several key innovations to be achieved. Activity 6, Coordinated pilot on Cooperative, Connected and Automated Mobility, fulfilled the key innovations related to connected and automated mobility (CCAM) as well as to the pre-requisites of CCAM.

The Activity included CCAM piloting in cities as well as on the main road networks within NordicWay 3. Services were implemented within urban areas, on the interfaces between urban and interurban areas, and on specific motorway sections. The pilots involved the traffic management operations and focused on the build-up and operation of a CCAM ecosystem including authentic organization and architecture. For this reason, the NordicWay 3 pilot involved all relevant stakeholders, including national and city road authorities and operators, telecom providers, vehicle OEM's and ITS OEM's. The pilots were based on the use of a set of state-of-the-art passenger cars, heavy goods vehicles, buses, and users of nomadic devices. These were connected via clouds by cellular and to some extent ITS G5 communications and equipped with appropriate driver interfaces. Piloted CCAM services and studies in this activity were new and innovative in Nordic countries and thus explorative in their nature.

All in all, this activity included 19 projects which focused on demonstrations of proof of concept on technology, architecture and business models of CCAM services, and piloted these services in real traffic under naturalistic conditions. To ensure interoperability, safety and reliability of the implemented services as well as avoiding technology lock-in, the viability of both cellular and short-range communication was also covered. The pilots further elaborated and expanded the business models and eco-systems required for large scale implementation of services as well as sharing of the required data. Harmonization of data and message exchange was a cornerstone.

The focus of the pilots lied in both services related to services for automated driving and Mobility as a Service (MaaS) and public transport. The pilots were conducted both on urban and non-urban areas as well as on different road types to get experiences and evidence from various environments in Finland and Sweden. Pilots involved all relevant stakeholders, including national and city road authorities and operators, research institutes, consulting companies, telecom providers, vehicle OEM's and ITS OEM's.

Services for automated driving CCAM

Most of the pilots implemented CCAM services and developed automated digital and physical infrastructure requirements of driving (see Chapters 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.1.9 - 2.1.14 and 2.1.16 -2.1.17). The pilots increased knowledge about the ODD requirements in Northern conditions.

In the services, the data was transmitted in machine readable format which will be an important part of the future of automated driving. All services were fully aligned with C-Roads specifications. Several pilots implemented several CCAM related services in which demonstration vehicles were applied.

Demonstration and test vehicles were operated in numerous pilots under naturalistic driving conditions to generate significant results (see Chapters 2.1.3 and 2.1.10 - 2.1.14). Some trials were conducted even in winter conditions. Several automotive OEMs provided their vehicles for the use of NordicWay3. In addition, Finnish Transport and Communications Agency Traficom developed a test plate certification process for automated vehicle trials in real traffic and issued 23 test plate certificates during NordicWay3 (Chapter 2.1.2).

In the pilots, new, automated methods for data collection on road network, pavement condition and maintenance vehicle fleet were developed. The developed methods make data collection faster, more cost efficient and user-friendly (See Chapters 2.1.6 - 2.1.8). These services provide additional information for future automated vehicles beyond their sensor horizon. Regarding user-interaction, consumer awareness of automated driving assistance systems and understanding of their responsibility as a driver was increased (see Chapter 2.1.3)

Piloted services for CCAM elaborated several key innovations set for NordicWay3:

- The feasibility of Day 1 and Day 1.5 services using hybrid communication solutions was demonstrated.
- Services were fully based on European standards and contributed to the harmonisation and interoperability of the C-ITS services in Europe.
- The pilots and studies supported the development and implementation of C-ITS services, adapted to the conditions, urban and interurban environments in the Nordic countries by developing and implementing services supporting highly automated vehicles
- The pilots further elaborated and expanded the business models and eco-systems required for large scale implementation of services as well as sharing of the required data. This includes both private and public actors and their data.
- The viability of cellular 5G for use also for time critical C-ITS applications was assessed.
- A sustainable C-ITS business model and ecosystem for the data value chain in collaboration with the public and private stakeholders involved in NordicWay 3 was developed.
- A border-independent platform for geo-localized message exchange allowing for negotiated conditions between connected stakeholders through the federated NordicWay Interchange network was developed.
- The capacity of future connected and automated vehicles to monitor road infrastructure and its status in Nordic weather conditions was supported.
- A foundation for deployment of future connected and automated driving also in challenging road and weather conditions by solving major deployment issues in such conditions was supported.

Each CCAM pilot and study reported their own conclusions and recommendations which are presented in Chapters 2.1.x.4. Some main findings were:

- The accomplished service level framework for automated road transport gives national authorities and operators increased understanding of the most critical parts of the infrastructure regarding conditional or highly automated and connected driving. (See Chapter 2.1.1)
- A better understanding of the roles and responsibilities in the automated driving value chain is needed. Actors have differing views of e.g. who gains from automation and therefore they also have differing views of who should be funding possible pilot activities. (See Chapter 2.1.2)

- ADAS systems are developing fast and it is very important to make consumers understand the limitations and safe use of these system. It will be extremely important to keep consumers aware of the newest systems on the market and how they effect their role as a driver and make sure that new systems will be used in a safe manner, especially in challenging road and weather conditions prevailing in Nordic countries. (See Chapter 2.1.3)
- Digitalisation of traffic rules is recommended to be started on those rules that are included in the delegated regulation on RTTI. (See Chapter 2.1.4)
- Intersection topology data (MAPEM data) is a necessary component in all C-ITS solutions, including traffic signals. Cities need a centralized platform where they can upload MAPEM data. For that, MAPEM processes were defined. (See Chapter 2.1.5)
- Traditional road pavement condition surveys are mostly performed manually, subjecting the process to human errors and delays, and further draining limited resources. Using automated survey methods, pavement condition data collection is four times faster and at half the cost compared to conventional visually inspected methods. (See Chapter 2.1.6)
- Digital operating models for automated vehicle fleet management enable transparent and cost-effective work and the comprehensive department-level utilization of resources. In the system, it is possible to compare the utilization rate and current demand for vehicle resources, allowing an impact on identified needs and work situations, as well as future recruitments. (See Chapter 2.1.8)
- The future development needs of data connections in road traffic are mainly related to the increased communication by vehicles and the development of autonomous traffic. The current understanding is that the communication between future vehicles will not occur via mobile networks alone; rather, some of the applications that require delay-critical or large-scale data transfer rely on direct communication between vehicles. (See Chapter 2.1.9)
- C-ITS messages need to be signed to ensure security. To roll out the service, a generic and easy to use process to produce MAP data is needed. When a small change is done in an intersection, the MAP data must be updated to be accurate. (See Chapter 2.1.10)
- A C-Roads specified C-ITS service using LTE-V2X Direct technology and 4G/5G networks was successfully tested and deployed. Also, the onboard unit and roadside unit were both successfully registered to EU CCMS and security of the system was tested. The used LTE-V2X technology proved to be a well working option for implementing C-ITS services. (See Chapter 2.1.11)
- The mobile networks of today are well suited to carry the average expected C-ITS messaging traffic levels. Considering all the digital mobile network technology generations, even 4G network technologies can provide the connectivity and capacity needed, and future developments for 5G technologies can potentially even improve the ability to serve high-device-density and high-message-frequency services such as in the C-ITS framework. (See Chapter 2.1.12)
- The services require an interchange node for exchange of transport related data. (See Chapters 2.1.10, 2.1.13, 2.1.14)
- Road operators can contribute to the favourable development and deployment of road transport automation, but their influence is limited; some of the actions are still waiting for technologically evolving automated driving systems' requirements for the infrastructure and road operator processes. Actions and investments that are beneficial for both conventional and automated vehicles

will be needed in any case independent of the timing of the roll-out of automated driving (See Chapter 2.1.16)
- A field trial in Norway showed that the truck platooning system was feasible on high-speed rural roads with forgiving alignment. However, roads with subpar geometry, on the other hand, were more difficult. While the trucks mostly remained connected also on such roads, sharp curves, narrow tunnels and alternating inclinations caused the platoon to contract and expand as the trucks successively traversed different road features. Hence, the operational readiness of semi-automated truck platoons on Norwegian rural roads is questionable, and more testing and development is needed. (See Chapter 2.1.17)

MaaS and services for public transport

The pilots and studies on services related to MaaS and public transport focused on data from cities and public transport operators and making relevant data publicly available through the NordicWay interchange node and NAP (see Chapters 2.2.1-2.2.3). Additionally, possibilities to integrate real-time data models and exchange protocols for mobility and MaaS services as well as for C-ITS into an interchange node were investigated.

Piloted services elaborated several key innovations set for NordicWay3:
- Development and implementation of C-ITS services, adapted to the conditions, urban and interurban environments in the Nordic countries, was supported by developing Mobility as a Service, automated processing of “Big data”.
- The business models and eco-systems required for large scale implementation of services as well as sharing of the required data was elaborated. This included both private and public actors and their data. The city-perspective was emphasized.
- The provision of EU-wide real-time traffic information and multimodal services were developed.

Each pilot and study reported their own conclusions and recommendations which are presented in Chapters 2.2.x.4. Some main findings were:
- The development of centralized data platforms and data delivery services such as NAPs and Interchange Nodes as well as a common master data management architecture are a key element when building a data ecosystem. (See Chapter 2.2.1)
- In order to have more scalable and standardized data, public transport organizations should provide more real-time data on MMTIS required data formats like NeTEx and SIRI according to the specifications listed by ITxPT. (See Chapter 2.2.2)
- Main driver for interchange nodes, like the ones used in NW3, is in road transportation and gathering and sharing data between vehicles and or road infrastructure. Using SIRI data as additional data for vehicle messages in interchange nodes could have an impact both on private car users, traffic management centres and also improve reliability in scheduled travel times in public transport. (See Chapter 2.2.2)
- The maturity for production and collection of traffic data varies greatly even among the bigger cities. Traffic related issues are often divided into different organizational silos and there are no common platforms for data collection and delivery. (See Chapter 2.2.3.)

- Information about road transport routes, traffic management information and the traffic situation should be published via the national access point (NAP) or similar, alternatively using other approved information sharing methods. (See Chapter 2.2.1)

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