Final report – Activity 9 Swedish Pilot

NordicWay 2

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Nordic WAY 2

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All Swedish partners in the project have contributed to this report through the individual task reports that are provided in the appendix of this document.

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2020-09-01	0.1	Internal review
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Executive Summary

The Swedish pilots in NordicWay 2 were based around four service clusters: Emergency vehicles warning, Traffic signals, Access control and Road Work Warnings. For each of these clusters one or several services were developed, implemented, piloted and evaluated. The pilots took place in real traffic in the cities of Stockholm, Uppsala and Gothenburg. Vehicles for the pilots are provided by industry partners.

A hybrid communication was used with cellular as the primary means of communication, supplemented by ITS-G5 for road works warnings with an Interchange node developed to support the transfer of messages across vehicles, OEMs, infrastructure and service providers.

In Sweden, the quality-of-service (Technical) evaluation focused on latencies. For the various pilots, a couple of different setups were used for transmission of messages from one end to the other through the common interchange node. The latency measurements were done separately for different C-ITS services. As could be seen from the results in Sweden, variations in latency over time show how different factors and conditions in IT infrastructure can impact latency both short and long term. This highlights the need for designing solutions that are robust and scalable. It also shows the importance of constant monitoring of the KPIs of the complete system to make sure that data is usable for end-consumers. For the purpose of the pilots, the latencies did not hinder the piloted services

The ecosystem evaluation concludes that more research needs to be carried out in how to create viable business models and what the roles and responsibilities are for the actors in a large-scale implementation. Currently the revenue streams are unclear in the service ecosystem networks. The corresponding values are mainly linked to socioeconomic benefits which indicate that the public road authorities need to support development and implementation. Further, harmonisation and standardisation of data and protocols are highlighted as an important building ground for future implementation. For most of the services the potential benefits increase when it is provided in a group of other services. Additionally, a large user base will increase the expected benefits since more people receive the information and will be able to act on it. For further development the user base therefore needs to expand.

The user acceptance of C-ITS services was evaluated via a common survey across the Nordic countries. The survey was designed for the general public, targeting 1 000 driver's licence holders per country. The questions addressed the relevance and acceptance of the services and willingness to use of the services. C-ITS services were seen most often as improving fluency or safety. In all, 44% of the drivers stated that they would be willing to use C-ITS services always or on most of their trips, especially on longer trips and on unfamiliar routes. The possibility to use the same C-ITS on other Nordic countries and in Central Europe was considered important by those who drive abroad.

The socioeconomic evaluation concluded that C-ITS provide positive effects in safety (however hard to estimate its magnitude) and a reduction of crash-related congestion due to fewer road crashes. The comparison of costs and benefits indicates that from the road operator perspective, in 2030 the benefits even in the low effectiveness scenario will exceed the sum of annual operating and maintenance costs that year and the investment costs up to that year in all countries. Worth to mention is that the sensitivity analysis of the socioeconomic assessment highly depends on made assumptions on the coverage, use and effectiveness of the services.

In the Swedish pilots of NordicWay 2 several dissemination activities have been performed during the project period. The various pilots have participated and presented on conferences, published reports, and pilot specific films have been created to showcase the services provided. A final showcase event where the Swedish pilot results were presented took place in the autumn of 2020 with over 300 participants.

Abbreviations

Term	Definition
AMQP	Advanced Message Queuing Protocol
API	Application Programming Interface
ASN.1	Abstract Syntax Notation One
CEF	Connecting Europe Facility programme
CIP	City Innovation Platform
C-ITS	Cooperative Intelligent Transport Systems
DENM	Decentralized Environmental Notification Message
ETC	European Transport Conference
EV	Emergency Vehicle
EVA	Emergency Vehicle Approaching
GLOSA	Green Light Optimal Speed Advisory
GUI	Graphic User Interface
HLN	Hazardous Location Notifications
HMI	Human Machine Interface
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MAP	MapData (geographical data)
MAPEM	MAP (topology) Extended Message
NW1	NordicWay 1
NW2	NordicWay 2
OEM	Original Equipment Manufacturer
PHEV	Plug in Hybrid Electric Vehicle
REST API	Representational State Transfer Application Programming Interface
RWW	Road Works Warning
SI	Signalized Intersections
SPAT	Signal Phase And Timing
SPATEM	Signal Phase And Timing Extended Message
STA	Swedish Transport Administration
STC	The Swedish Traffic Cloud
TMA	Truck Mounted Attenuator
TMC	Traffic Management Centre
TSP	Traffic Signal Priority request by designated vehicles
TTG	Time To Green
TTR	Time To Red
XML	Extensible Markup Language

Content

1 Introduction

In recent years the technical development in the transport sector has developed rapidly with Connected Intelligent Transport Systems as one area of major development. C-ITS focuses on the communication between a vehicle and another vehicle (V2V), vehicles to road infrastructure (V2I) or communication between other C-ITS related systems. When vehicles and road infrastructure is connected different stakeholders using the road or managing the traffic can share information between each other which contribute to better coordination of actions in the traffic. C-ITS is expected to contribute to a safer and a more efficient transport system and the development of C-ITS is also constitute an important foundation for future automated driving systems. Hence, The European Commission has adopted a plan for the coordinated deployment of C-ITS in Europe "A European strategy on Cooperative Intelligent Transport Systems" (European Comission, 2020). The project NordicWay 2 is one part of that work.

NordicWay 2 has been a four years long project, started in 2017 and ended in December 2020, with the main objective to deploy pilot studies in order to further develop interoperable Day-1 and Day 1,5 C-ITS services and support infrastructure readiness for connected and automated driving in the Nordic countries. This in order to contribute to the harmonization of C-ITS services by using mainly cellular networks for connections between vehicles (but also WLAN based communication (ITS-G5)) and a cloud-based information exchange between actors. Furthermore, the project aims to contribute to the development of digital infrastructure that prepare our transport system for connected and autonomous driving. NordicWay 2 is a C-ITS collaboration project between Norway, Finland, Denmark and Sweden. The project is partly funded by the EU via the Connecting Europe Facility programme (CEF).

Within Sweden a couple of different C-ITS services or use cases have been tested and evaluated in a set of pilots. The following report is a description of the main Swedish activities within the NordicWay 2 project, all managed within Activity 9 – Swedish pilot. The aim of the Activity 9 - Swedish pilot was to demonstrate the possibility to communicate between vehicles, infrastructure and clouds and to show the interoperability, scalability and flexibility of the NordicWay interchange network. This was shown by testing Day-1 and Day-1,5 services in real conditions. The pilots were conducted in Stockholm, cities of greater Stockholm such as Uppsala, and Gothenburg and their access routes. The pilots included a range of operating environments, from city streets to inter-urban motorways, the pilots had the possibility to assess the viability of different applications on different types of road network using different technologies for connection. All pilots were connected to a common interchange node. All actors within the pilots either received or provided information to the interchange node for other actors to consume and create services. The concept of data exchange via an interchange node was developed in NordicWay 1 and further developed in NordicWay 2.

In chapter 2 a description of the set up and functionality of the Swedish interchange node is provided. Chapter 3 provides an overview of each C-ITS service piloted followed by chapter 4 where evaluation results of these pilots are presented. Chapter 5 describes the main Swedish dissemination activities and chapter 6 provides with final remarks and conclusions of the project. In the appendix a more technical description of the Swedish interchange node is provided, as well as all individual C-ITS service pilot reports. In those reports you can read in more detail about each service piloted.

Other supporting documents and reports for deeper understanding are mentioned below and can be found on www.nordicway.net.

- NordicWay 2 Evaluation Results report
- Final report on NordicWay architecture and service definitions/ Activity 2: Interoperability and Technical Coordination, including:
    - NordicWay Service Definitions: Services and Use cases

1.1 Services and use cases piloted in Sweden

In Sweden eight different C-ITS service pilots have been executed. Each pilot was set up between a number of partners (Implementing Bodies). In Activity 9 sub-activities and pilots was divided into tasks. Task 1 was Pilot coordination and Task 10 Final reporting and evaluation. The pilots were part of Task 2 to task 9, see Table 1. For a formal definition of the services listed see the report *NordicWay Service Definitions: Services and Use cases* (NordicWay 2, 2020).

Table 1. Services and use cases piloted in Sweden.

Task	Service	NordicWay use cases
2	Hazardous location notifications (HLN)	Emergency vehicle approaching (EVA)
3		Emergency vehicle simulator studies and demonstrations
4	Signalized intersections (SI)	Time to green (TTG)
5	Signalized intersections (SI)	Traffic signal priority request (TSP)
6	Signalized intersections (SI)	Green light optimal speed advisory (GLOSA)
7	Connected and cooperative navigation in and out of the city	Dynamic access control of designated Infrastructure
8	Dynamically controlled zones	Dynamic environmental zones
9	Road works warning (RWW)	Road works warning (RWW)

1.2 Partners and implementing bodies

Activity 9 Swedish pilot was coordinated by the Swedish Transport Administration (STA), acting as a beneficiary in the project among the other Nordic national road authorities. Except from managing the Swedish pilot STA was involved in some of the tasks acting as a partner. The other partners participating in the Swedish pilot are formally called implementing bodies and are managed under the Swedish Ministry of Infrastructure.

Table 2 lists the project partners and in which tasks they were involved in.

Table 2. Implementing bodies and their task involvement.

Partner	Task involvement
Carmenta	Task 2: Emergency vehicle approaching (Lead of this task)
	Task 3: Emergency vehicle simulator studies and demonstrations
City of Gothenburg	Task 4: Time to green (TTG)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 8: Dynamic environmental zone
City of Uppsala	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
City of Stockholm	Task 4: Time to green (TTG)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 7: Dynamic access control of designated Infrastructure
Ericsson	Task 2: Emergency vehicle approaching (Lead of this task)
	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 7: Dynamic access control of designated Infrastructure

	Task 8: Dynamic environmental zone
	Task 9: Road works warning (RWW)
Kapsch TrafficCom AB	Task 9: Road works warning (RWW) (Co lead of this task)
Scania	Task 2: Emergency vehicle approaching
	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 7: Dynamic access control of designated Infrastructure
	Task 9: Road works warning (RWW)
Springworks	No involvement due to bankruptcy.
Technolution	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 7: Dynamic access control of designated Infrastructure
	Task 8: Dynamic environmental zone
Volvo Cars Corporation (VCC)	Task 2: Emergency vehicle approaching (Lead of this task)
	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 8: Dynamic environmental zone
	Task 9: Road works warning (RWW)
Volvo Technology AB	Task 2: Emergency vehicle approaching (Lead of this task)
	Task 4: Time to green (TTG)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 9: Road works warning (RWW)
VTI (Statens väg- och trans-portforskningsinstitut)	Task 2: Emergency vehicle approaching
	Task 3: Emergency vehicle simulator studies and demonstrations (Lead of this task)
Zenseact (previously Zenuity)	Task 4: Time to green (TTG)
	Task 5: Traffic signal priority request (TSP)
	Task 6: Green light optimal speed advisory (GLOSA)
	Task 9: Road works warning (RWW)

2 Overview of NordicWay 2 Interchange Node Architecture

The NordicWay 2 Interchange is an AMQP (Advanced Message Queuing Protocol) publish – subscribe message broker. The Swedish NW2 interchange is based on the NW1 interchange developed by Ericsson. It is not the same code that has been developed as open source for the interchange nodes in Norway and Finland as it was developed earlier but has the same functions and interfaces. For support of some of the unique Swedish use cases in NW2 a set of translators, databases and protection functions have been developed and grouped in what is named NW2 Swedish Traffic cloud. In appendix 1 a more technical description of the Swedish interchange node is available. Additionally, the *Final report on NordicWay architecture and service definitions/ Activity 2: Interoperability and Technical Coordination* also provide more information on this topic. Figure 1**Error! Reference source not found.** illustrates a simplified scheme on how the data is transmitted between different actors via the interchange.

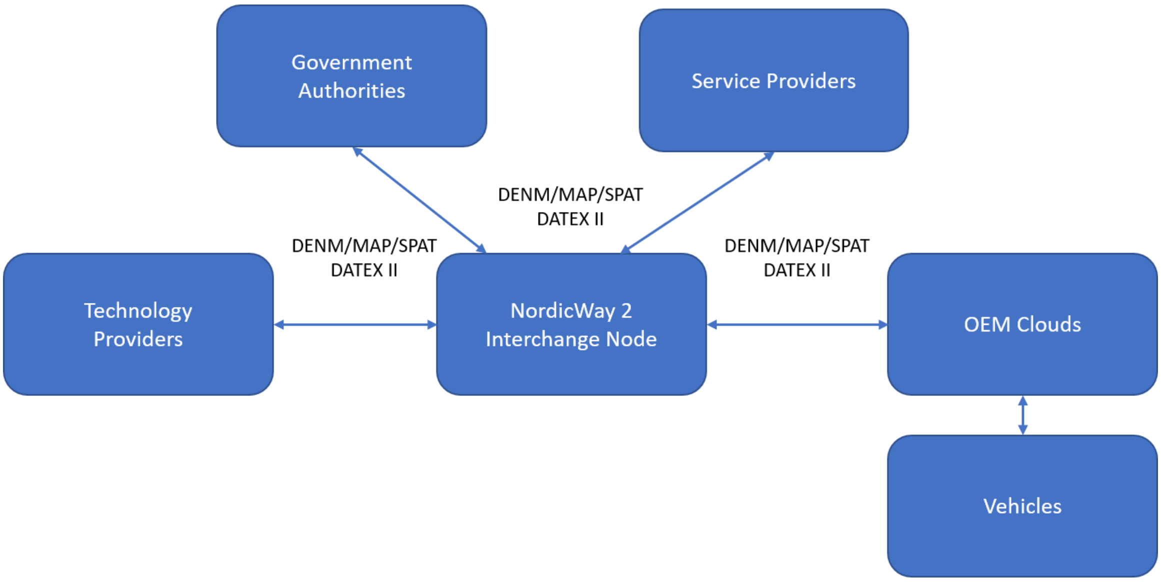

Figure 1. A simplified scheme of data flow via the interchange node.

2.1 Transmission of messages via interchange node in the pilots

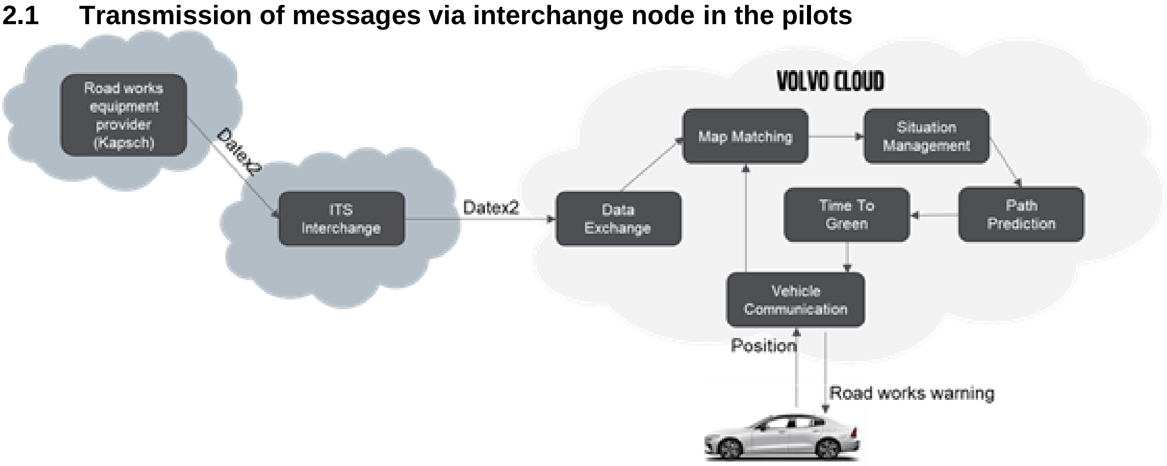

Figure 2. Schematic description of VCC's cloud application in Task 9.

Transmission of messages amongst various components in NordicWay 2 pilots happens via the interchange node. For example, the cloud application responsibility is to receive the RWW message (task 9) messages from the Interchange node, determine which vehicles are concerned and convey the relevant information to them (Figure 2). The test vehicles in the pilot was connected to the OEM clouds using the cellular network: reporting its position and receiving information back.

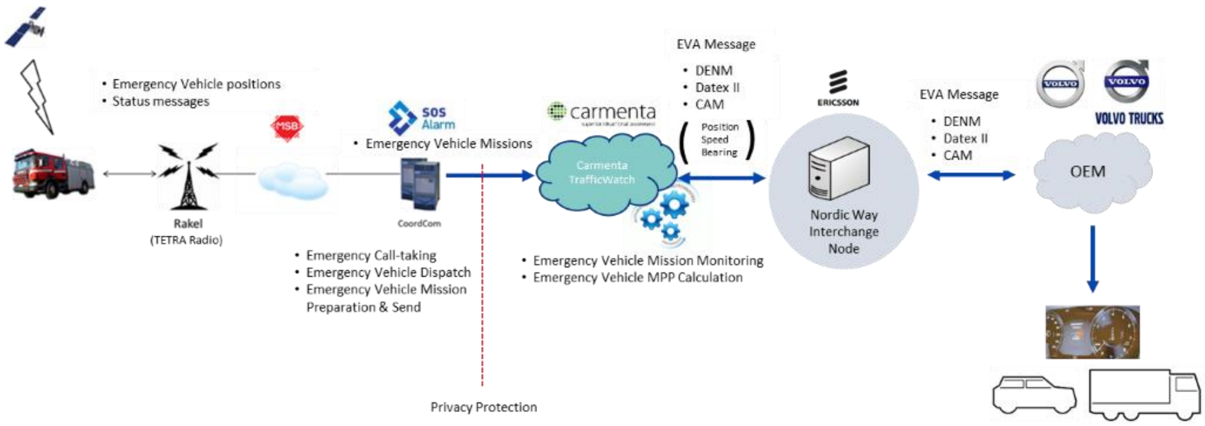

Figure 3. Description of the components used for the Emergency vehicle approaching warning messages in NW 2.

The Emergency Vehicle Approaching messages includes the parts from the integration and connection with SOS Alarm until the EVA warning messages finally are received in the vehicles and a message is displayed in the vehicle HMI (Figure 3).

2.2 Federation Interface to other interchanges

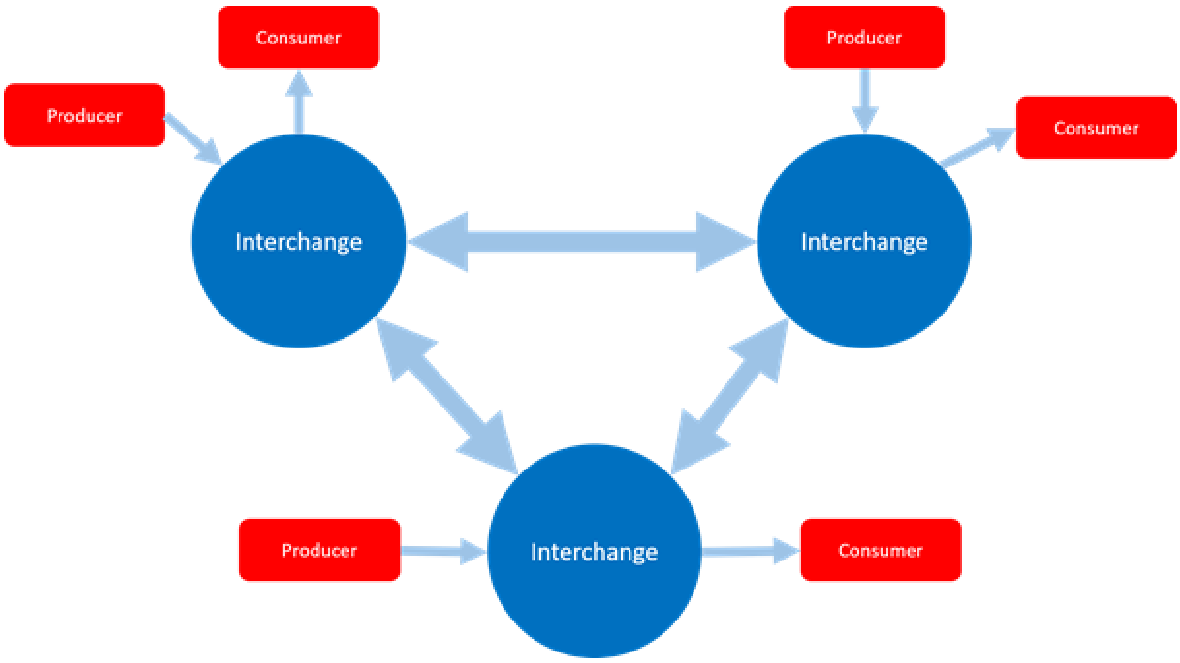

Figure 4. Federated Interchanges.

Interchange Federation makes it possible for a consumer connected to its home interchange to consume data produced by producers connected to other interchanges. The exchange of data streams between the federated interchanges is controlled by inter-interchange subscriptions that can be changed over time to match the demand from the local consumers and the available capabilities of the federated interchanges (See Figure 4).

During the NordicWay 2 project, the Swedish NW2 Interchange federation implementation was fully and successfully tested with the NPRA interchange. The tests covered security, capabilities ex-change, sub-scription exchange and update, and data exchange. The successful tests prove that it is easy to federate interchanges with different implementations using the federated interfaces. (See Appendix 1.3 for more information)

3 Overview of Pilots

This chapter is an overview of the pilots executed in Sweden. For more detailed information of a specific pilot the full pilot reports are available in Appendix 2-7.

3.1 Emergency Vehicle Approaching

The main working packages have been focused on producing and consuming the EVA services that alerts vehicles of emergency vehicles approaching before the driver can perceive the Emergency Vehicle through siren sound or visually. To be able to create the EVA warnings, emergency vehicle positions and information about their missions have been provided by an integration with an Emergency Response system.

The work with the Emergency Vehicle Approaching service have been done in close cooperation with VTI in the task Emergency Vehicle Simulator Studies and Demonstrations. The responsibility of leading this pilot was Carmenta with Ericsson, VCC, Volvo Technology AB and Scania, as other partners.

The Emergency Vehicle Approaching Pilot have been set up in the Gothenburg area since this was convenient for the participating companies and to perform the tests. Test vehicles from VCC and Volvo Trucks have been used, in total 2 test vehicles consuming the EVA warning messages (See Figure 5 and Figure 6 to see the HMI prototype). An ambulance has been used during the tests and demo opportunities and tests have also been performed in driving simulators at VTI.

Work and solutions developed within this NordicWay 2 task have been synchronized with other Drive Sweden activities in order to assure that results from other Swedish project in the same field of work are reused. An important objective of NordicWay is that activities shall be able to lead to commercial solutions that can be utilized and operated in other countries, within the Nordic region and in Europe. Therefore, there has been a focus for services developed in the Emergency Vehicle task that they are standardized and are applicable also to other areas than the Gothenburg pilot site.

The main objective of the service is to provide an Emergency Vehicle Approaching (EVA) warning message to vehicles before a driver can detect the emergency vehicle, visually or upon hearing the siren.

The effect desired by offering the service to road users are twofold;

- A better experience for road users and drivers, by not being surprised by the sudden appearance of emergency vehicles.
- Shortened response times for emergency vehicles and a smoother and safer traffic flow when an emergency vehicle approaches.

Figure 5. Test vehicles used for demonstration and filming in Gothenburg.

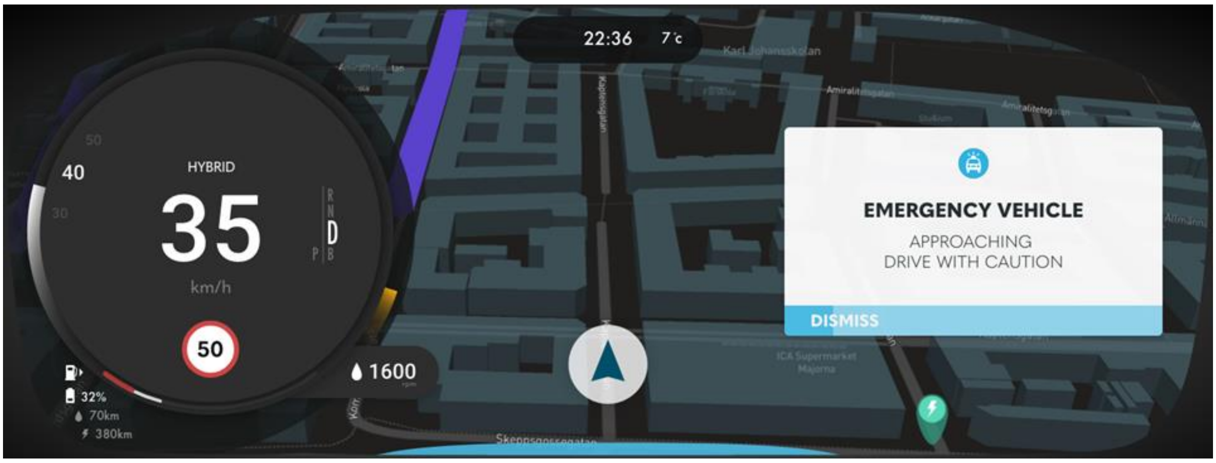

Figure 6. Prototype HMI displaying EVA warning message.

3.2 Emergency Vehicle simulator studies and demonstrations

In the task Emergency Vehicle simulator studies and demonstrations led by VTI, studies have been made regarding the effects of introducing EVA warnings in traffic, with Carmenta as a partner.

The objective was to explore the possibilities to simulate and investigate entire scenarios and add new perspectives to the emergency vehicle service cluster, through simulation activities.

The purpose of the simulations was to design services, and their human-machine interaction, in such a way that safety is guaranteed and efficiency and effectiveness of the ITS solutions becomes as large as possible and to establish a demonstration, visualisation, and integration platform.

The pilot started with an existing simulator rig developed for another project (See Figure 7). With the information collected from users, a second rig was then developed. During fall 2018 and winter 2019, a data collection with professional participants recruited by convenience from different “blue light” actors was performed at several different locations in Sweden.

Figure 7. The scaled-down simulator rig.

3.3 Signalized intersections

The objective of the service signalized intersection is to provide information to road users to support safe and efficient crossing of signalized intersections. The use cases which have been tested and demonstrated within the project are Time to Green and Time to Red (Task 4), Traffic Signal Priority Request (Task 5) and Green Light Optimal Speed Advisory (Task 6). The implementation of the use cases is believed to increase traffic safety, traffic flow efficiency and reduce adverse environmental effects following from erratic and stop-and-go driving (NordicWay 2, 2020). The partners that have been involved in piloting these use case are City of Gothenburg, City of Stockholm, City of Uppsala, VCC, Volvo Technology, Scania, Zenuity, Swarco, Technolution, Ericsson, and Swedish Transport Administration. The physical test sites where located in Gothenburg and Uppsala (Figure 8).

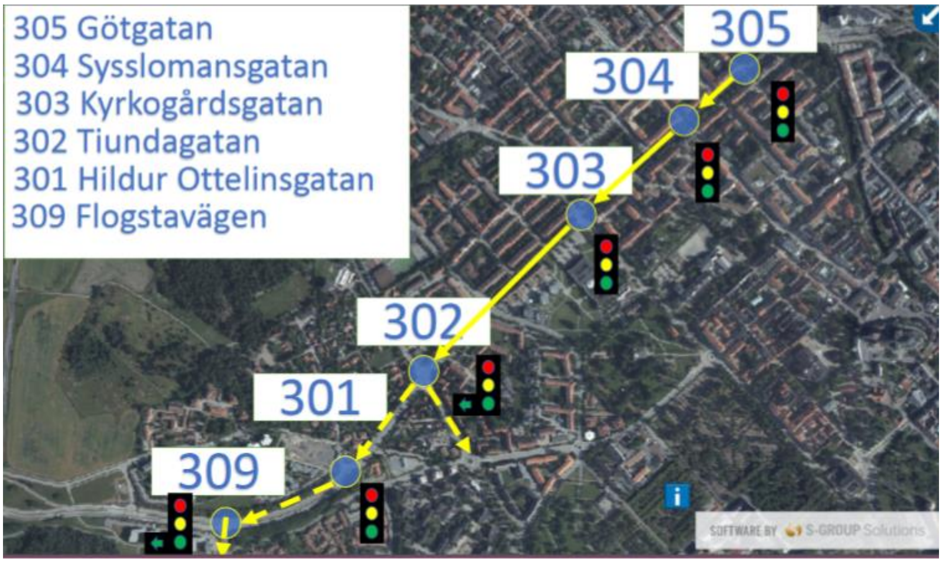

Figure 8. Example of intersections in Uppsala where tests were performed.

3.3.1 Time to Green (TTG) and Green Light Optimal Speed Advisory (GLOSA)

The overall purpose of TTG and GLOSA for traffic signals is to provide solutions prepared for implementations/roll out in near future.

The general technical set up was that SPAT- and MAP-data from Traffic Light Controller is generated and passes through the interchange node to the OEMs´ different clouds. The TTG and GLOSA messages are generated at the OEM side.

In the TTG pilot, information was received through the OEM's cloud, and an approximate position of a traffic light group was shown with a traffic light symbol in the driver information module in the car. Also, the position of the vehicle was shown on the same map. TTG was illustrated by showing the countdown to green light in seconds when the vehicle was getting closer to the traffic light. See Figure 9 and Figure 10.

Figure 9. Example of HMI used in test of TTG.

Figure 10. Example of HMI used in the tests.

3.3.2 Traffic Signal Priority Request

The aim was to demonstrate in practice, the technical dataflow from a public transport vehicle, e.g. a bus, to the traffic light in an intersection. Focus was to explore how to use the standard format "message" from J2735 specification, the Signal Request Message, SRM and the sub-sequent Signal Status Message SSM.

The TSP service is initiated from the vehicle side. A request comes from public transport vehicles that asks for priority at the Traffic Light Controller, which executes it and sends a message back to the vehicle. A Public Transport actor is part of the data flow and decide if and how the public transport-vehicle will be prioritised compared to other vehicles and as well other public transport vehicles.

3.4 Dynamic Access Control of Designated Infrastructure

The purpose of this pilot was to test dynamic access control to enable future optimization of existing road capacity in accordance with the so-called "four-step principle". This pilot saw cooperation between City of Stockholm, Ericsson, Scania, Technolution and STA. The practical demonstration was conducted in March 2020 just south of Stockholm where a Scania vehicle was allowed to drive on public transport lanes (see Figure 11). The demonstration focused on the decision about if the truck may utilize public transport lanes were made based on predefined requirements of the vehicle and on the basis of current traffic conditions. Under the right conditions, the truck will be given access, otherwise the truck will be denied access to use the public transport lane.

The test vehicle sends a request to a simulated traffic control centre to use the bus lane. Under the right pre-conditions, the test vehicle was granted access, otherwise denied. The practical demonstration always granted access when safe to do so which was determined by the truck driver.

Permission was required by the County Administrative Board to carry out the test. The project submitted an exemption that was granted (decision JT35 142/19 in December 2019) a permit to use the bus lane during low traffic (09.00-15.00) for the period 9 March 2020 - 13 March 2020.

Figure 11. Picture of demonstration truck from Scania.

3.5 Dynamic Environmental Zones

The overall objective of this service is to enable cities to create and distribute dynamic environmental zone descriptions to road users. The purpose is to reduce local emissions (air pollutants and noise) in urban dense are-as to improve environment and air quality. The pilot aimed to do this by enable cities to create and distribute virtual, dynamic environmental zone descriptions where the characteristics of the vehicles can be adapted.

The goal of this pilot was to develop a city, interchange and OEM cloud and a vehicle software to enable a demonstration and a proof of concept of dynamic environmental zones in the city of Gothenburg. This concept enables road authorities to create and distribute zone description of an environmental zone in an urban area to vehicles which can adjust vehicle characteristics, accordingly, e.g. shift from hybrid mode to pure electric mode when accessing a designated environmental zone. See Figure 12 and Fig-ure 13 to see the test zones.

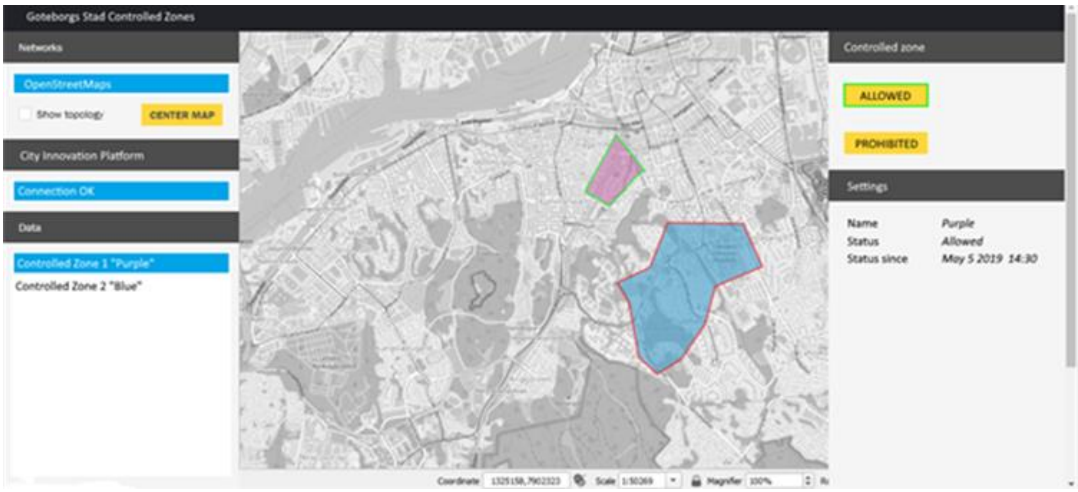

Figure 12. Screen shot from the interface of the municipality operator desktop.

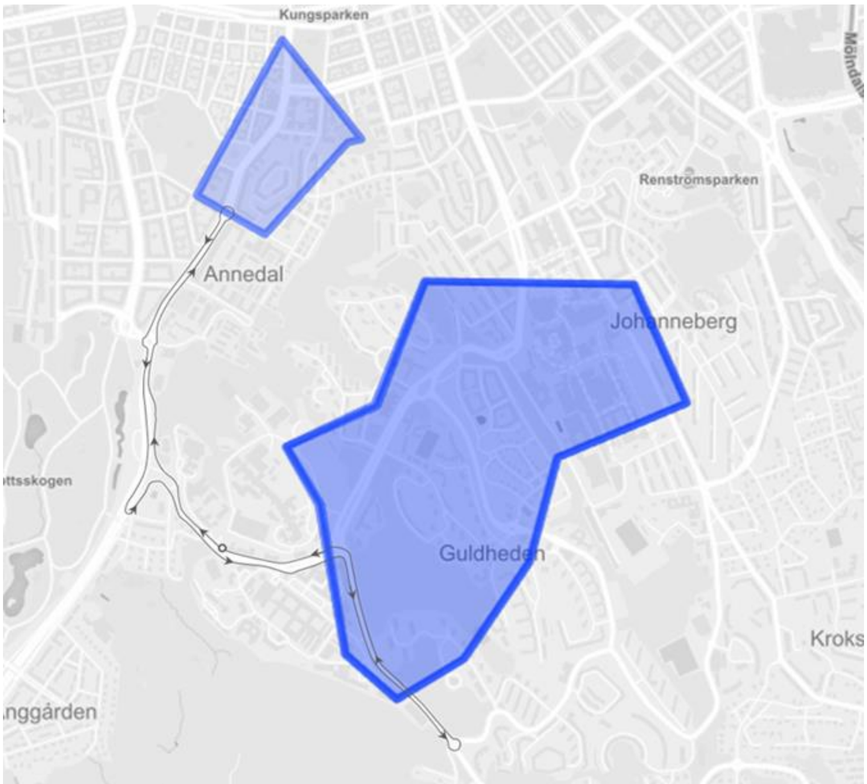

Figure 13. The two environmental zones and the driving route during the test drives.

This pilot saw cooperation between City of Gothenburg, Ericsson, Technolution and VCC. The idea was simple: if environmental emissions are too high in a city area, it is possible for a Plug in Hybrid Electric Vehicle, PHEV, to automatically shift from hybrid mode to pure electric mode, reducing emissions in desired zone. See Figure 14 and Figure 15 to see the HMI prototype developed for the pilot. Together the project developed a pilot consisting of a graphical user interface (GUI) for the operational management tool, the exchange format with VCC, the connection to Gothenburg's City Innovation Platform (based on FIWARE) and the NordicWay (Ericsson's) Interchange Node. VCC's PHEV demonstrated the ability to automatically switch to run in pure electrical mode, when the cars enter the geofenced area controlled by the city's traffic operator via the interface.

This would be a service which drivers of plug in hybrid electric vehicles can activate if they are willing to take actions on their awareness of environment and particularly city centres' air quality. The interest would most likely increase with incentives like lower toll, free charging or free parking, but it was difficult to define suitable incentives in the pilot.

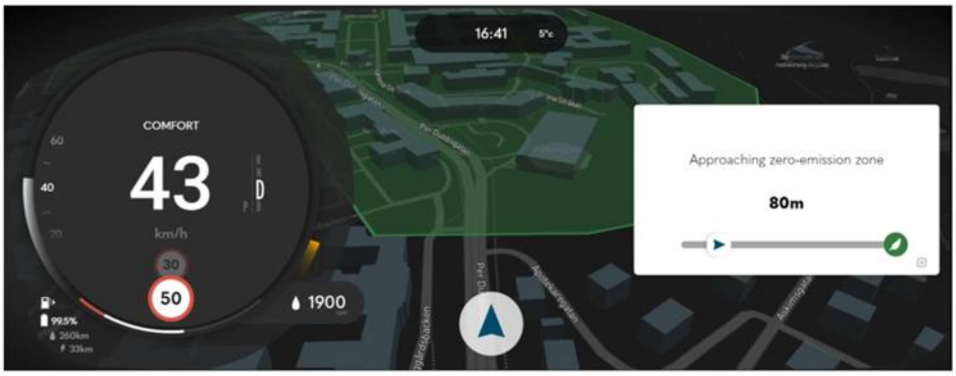

Figure 14. Driver information shown in the HMI when the vehicle approaches the zone. This is an HMI prototype for research projects, not intended for production.

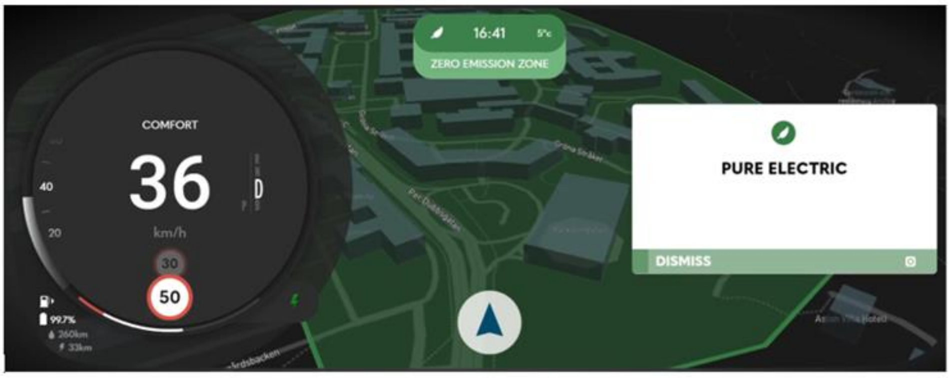

Figure 15. Driver information shown in the HMI when the vehicle enters the zone. This is an HMI prototype for re-search projects, not intended for production.

The target group for this pilot are therefore drivers with an interest to support environmental cause. No information from the vehicle or driver is needed by the city. Therefore, the area of integrity and GDPR is not in focus in this pilot.

3.6 Road Works Warning (RWW)

The purpose of the HLN – RWW (Hazardous Location Notification – Road Works Warning) task has been to specify, implement, integrate, test, and provide a possible solution for RWW with different partners in the NordicWay cluster.

RWW is an EU priority C-ITS service and provides the possibility to share safety related traffic information. This pilot was carried out by Kapsch TrafficCom as lead and, Ericsson, Scania, VCC, Volvo Technology and Zenseact as partners.

The service is to warn road users about nearby road works (mobile, static, short term, long-term). The objective of the service is to inform road users of road works providing for more attentive and adjusted driving when approaching and passing road works zones.

The communication of this warning was realized as true Hybrid Communication with the RWW unit mount-ed on the RW vehicle delivers information to the interchange node, in order to warn the vehicles via cellular communication AND delivering directly information from the RWW unit to the vehicles via V2X WLAN communication (ITS-G5).

Two road work vehicles that are in operation in the vicinity of Gothenburg have been equipped with RWW units from Kapsch TrafficCom (see Figure 16). Figure 17 shows the HMI prototype developed for the pilot.

Figure 16. RWW unit mounted on test vehicle - overall view.

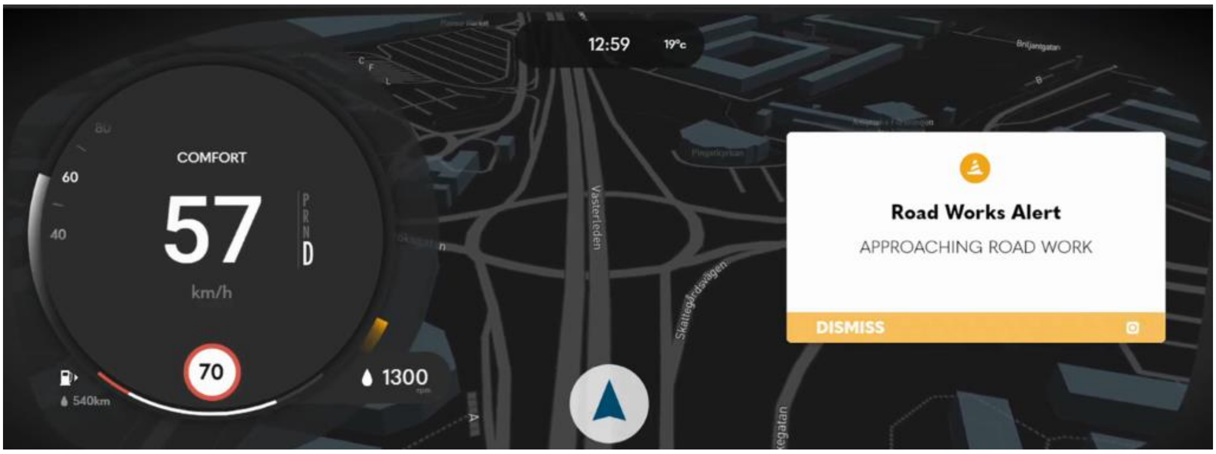

Figure 17. Prototype HMI from VCC displaying RWW warning message. This HMI prototype is for research projects, not intended for production.

4 Summary of evaluation results

Within the NordicWay 2 project a set of evaluation activities were coordinated on a Nordic level, with Finland as lead, in order to harmonize the project results and collaboration. The main topics of this evaluation were technical, service ecosystem, user acceptance and socio-economic evaluation. In this chapter a summary of the Swedish contribution and results is provided. For evaluation results for all Nordic countries see the *NordicWay 2 Evaluation Results report*.

4.1 Technical evaluation

4.1.1 Latency (KPI_Q08, KPI_Q08b)

For the various pilots in Sweden a couple of different setups were used for transmission of messages from one end to the other through the common interchange node. The latency measurements were done separately in the following tasks in Sweden.

Emergency Vehicles Approaching (EVA) warning (Task 2 and 3)

In case of Emergency Vehicle Approaching (Task 2 and 3), the messages include the parts from the integration and connection with SOS Alarm until the EVA warning messages finally are received in the vehicles and a message is displayed in the vehicle HMI (Figure 18).

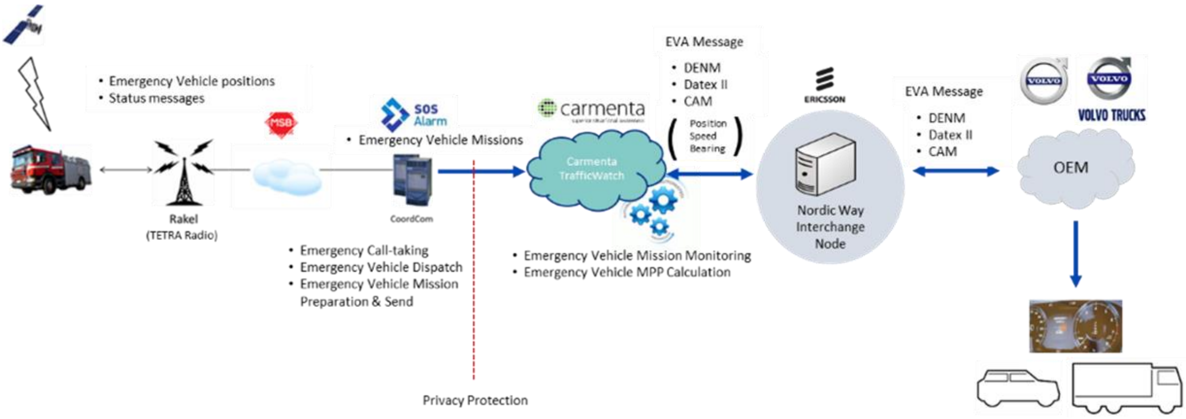

Figure 18. Description of the components used for the Emergency Vehicle Approaching warning messages.

For Task 2 and 3 (EVA), end-to-end measurements have been performed for the Emergency Vehicle Warnings from the Emergency Response system at SOS Alarm, through Carmenta TrafficWatch and the Interchange Node to the VCC backend cloud that the sends the messages to the cars. In total, there were 31400 records of messages at Carmenta TrafficWatch from 251 different emergency missions.

The average latency round trip time between Carmenta TrafficWatch and VCC' cloud was 203 ms.

	rttCtc2Vcc (in ms)
count	1813.000000
mean	202.570916
std	70.777248
min	31.252861
25%	156.244755
50%	187.510252
75%	234.375238
max	1031.264067

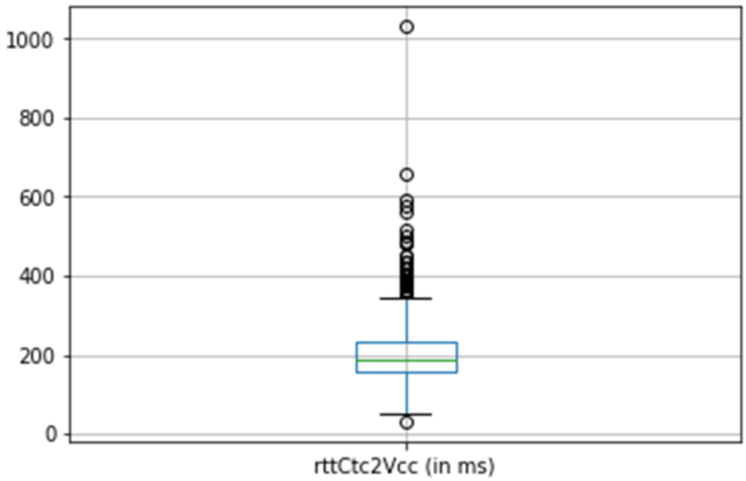

Figure 19. Results from measurements of messages sent between Carmenta TrafficWatch and VCC's cloud.

Table 3. Latency results for Task 2 and 3.

Quality KPI	KPI	Description	Unit	Results	Comment
KPI_Q08b	Latency (between Federated inter-change nodes)	Delay between the first (validated if necessary) detection of the event and the moment the in-formation is provided by the content access point	ms	203 (average) (N=1813)	Round trip time be-tween Carmenta TrafficWatch and VCC's cloud

Other results: A simulator study performed in VTIs driving simulator showed that there was an effect of EVA message on distance to the ambulance when giving way, such that two different versions of EVA messages (EVA 1 and EVA 2) caused the driver to give way earlier (i.e., at a greater distance before the ambulance caught up). In EVA 1, only the instrument cluster was used. The EVA message was presented as a yellow triangle with a blue warning light and a text message stating "Utryckningsfordon på ingång! Var uppmärksam!" [Emergency vehicle approaching! Pay attention!]. As the ambulance closed in, further instructions were displayed regarding yielding and slowing down. In EVA 2, the EVA message was additionally presented on the infotainment display in the center console. There was also an interaction effect between EVA Message and Baseline Order, such that when EVA 0 (no EVA mes-sage) was the first condition (and EVA 1 and EVA 2 followed) drivers did not give way as early when there was no EVA message, but then gave way much earlier. However, when EVA 1 and EVA 2 initial-ized the test and EVA 0 finished it, the drivers gave way about as early even when there was no EVA message, which implies a learning effect induced by previous EVA messages.

Signalized intersections (Tasks 4, 5, and 6)

In Figure 20. Architecture for TTG/TTR and GLOSA (one-way communication) in Task 4, 5 and 6., the architecture for Task 4, 5 and 6 shows how timings (SPAT and MAP data), from Traffic Light Controller are generated and passes the Interchange Node for the goal, the OEMs´ different clouds. The ser-vices Time-To-Green and Green-Light-Optimal-Speed-Advisory etc. are generated at the OEM side.

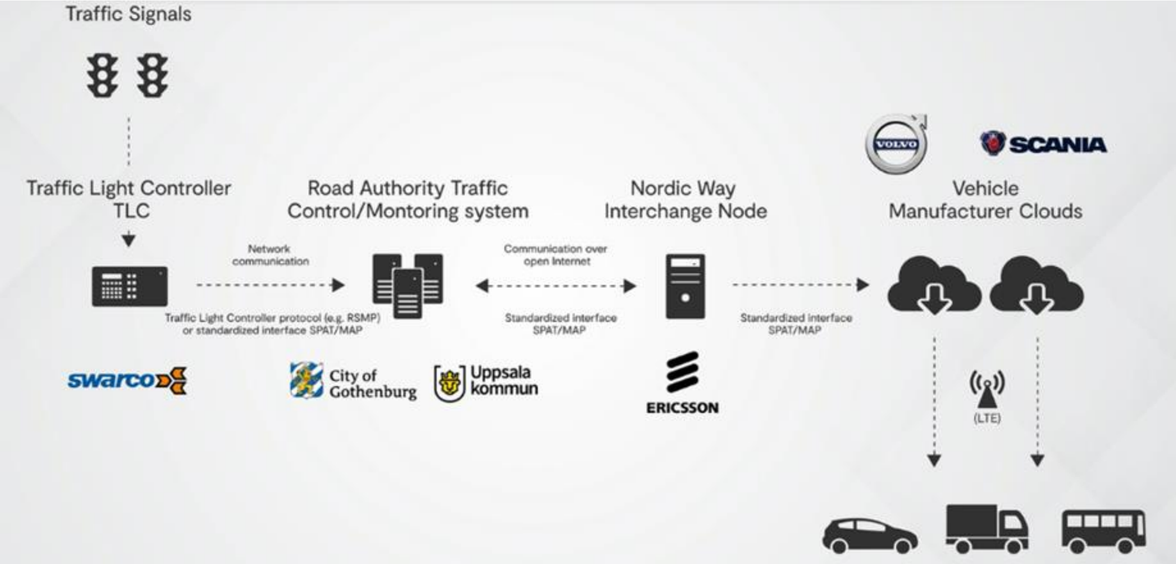

Figure 20. Architecture for TTG/TTR and GLOSA (one-way communication) in Task 4, 5 and 6.

For Task 4, 5 and 6 (*Signalized intersections*) the time between the change in the traffic signal aspect (green, yellow or red) and what you see/sense in the vehicle was measured as latency. For this task the time from the switch of signal at the infrastructure to the OEM Cloud was measured (Figure 21). The HMI has not been involved in the process.

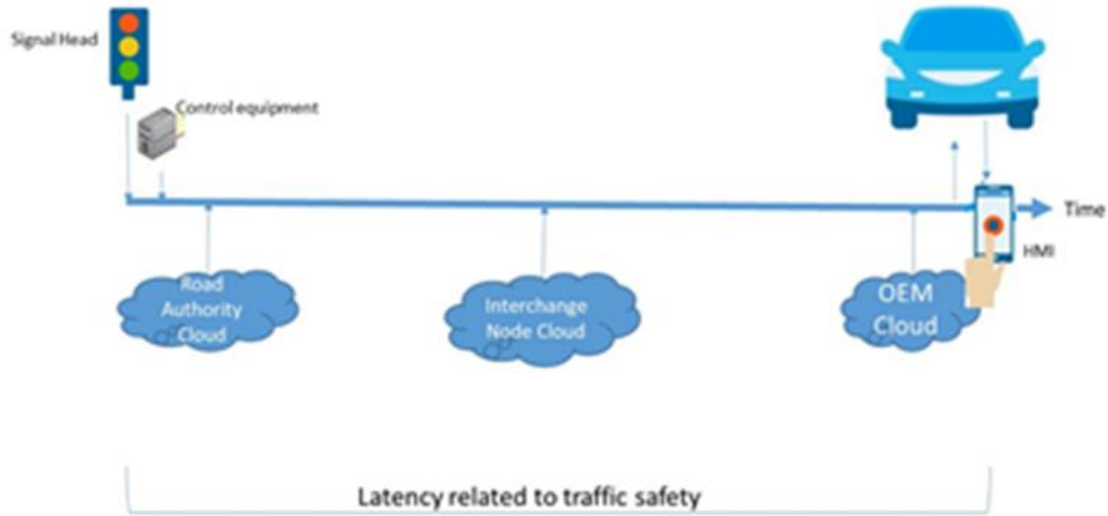

Figure 21. Latency measurement in Tasks 4, 5 and 6.

For Task 4, 5 and 6 (Signalized intersections), There have been some tests executed within the project on some different locations. See
Table 4 for summary of latency results.

- City of Gothenburg:
  Results from May 2018 shows the latency mainly being less than 200ms and results from June 2020 shows the latency being between 200-500 ms.

- City of Uppsala:
  Results from May 2020 show latency in intersection 304 and 305 was 800-1000 ms. Latency in intersection 303 was roughly 1600 ms.
  Results from June 2020 shows latency in intersection 303 and 304 was 700-900 ms. Latency in intersection 305 was mainly 400 – 500 ms. Average latency at intersection 303 being 1200ms, at intersection 304 being 850ms and at intersection 305 being 675ms.

- Swedish Transport Administration:
  In one of the Swedish Transport Administration's intersections in Gothenburg area where traffic signal "6830" is the starting point and the VCC-cloud is the end/receiver point. The latency was found to be mainly less than 50 ms for SPATEM-messages.

The variations in latency over time shows how different factors and conditions in IT infrastructure can impact latency both short- and long- term. This highlights the need for designing solutions that are robust and scalable over time. It also shows the importance of constant monitoring of the key performance indicators of the complete system to make sure data is usable for end consumers.

Table 4. Latency results for Task 4, 5 and 6.

Quality KPI	KPI	Description	Unit	Results	Comment
KPI_Q08b	Latency (between Federated interchange nodes)	Delay between the first (validated if necessary) detection of the event and the moment the information is provided by the content access point	ms	1. City of Gothenburg: < 500ms (max) 2. City of Uppsala (average): intersection 303 = 1200ms, intersection 304 = 850ms, intersection 305 = 675ms. 3. Traffic signal 6830 in Gothenburg: < 50ms (max)	The variations in latency over time shows how different factors and conditions in IT infrastructure can impact latency both short- and long- term.

__Dynamic access control of designated Infrastructure (Task 7)__

For Task 7, the architecture contains of three main sub-systems (Figure 22). Traffic Management Center (TMC), Interchange Node and the OEM digital environment. The messages initiate at TMC which contains systems from Technolution for the exchange with the interchange node, the interaction with the traffic operator and the central databus for traffic data. The message then passes through the interchange node to the OEM's digital environment. Scania develop an interface making it possible to send request for access and receive message for approved or denied access provided through the Interchange Node.

The architecture includes a set of future extensions where the dynamic access control can be connected to C-ITS solutions, traffic network management systems and weather systems for additional information from external sources.

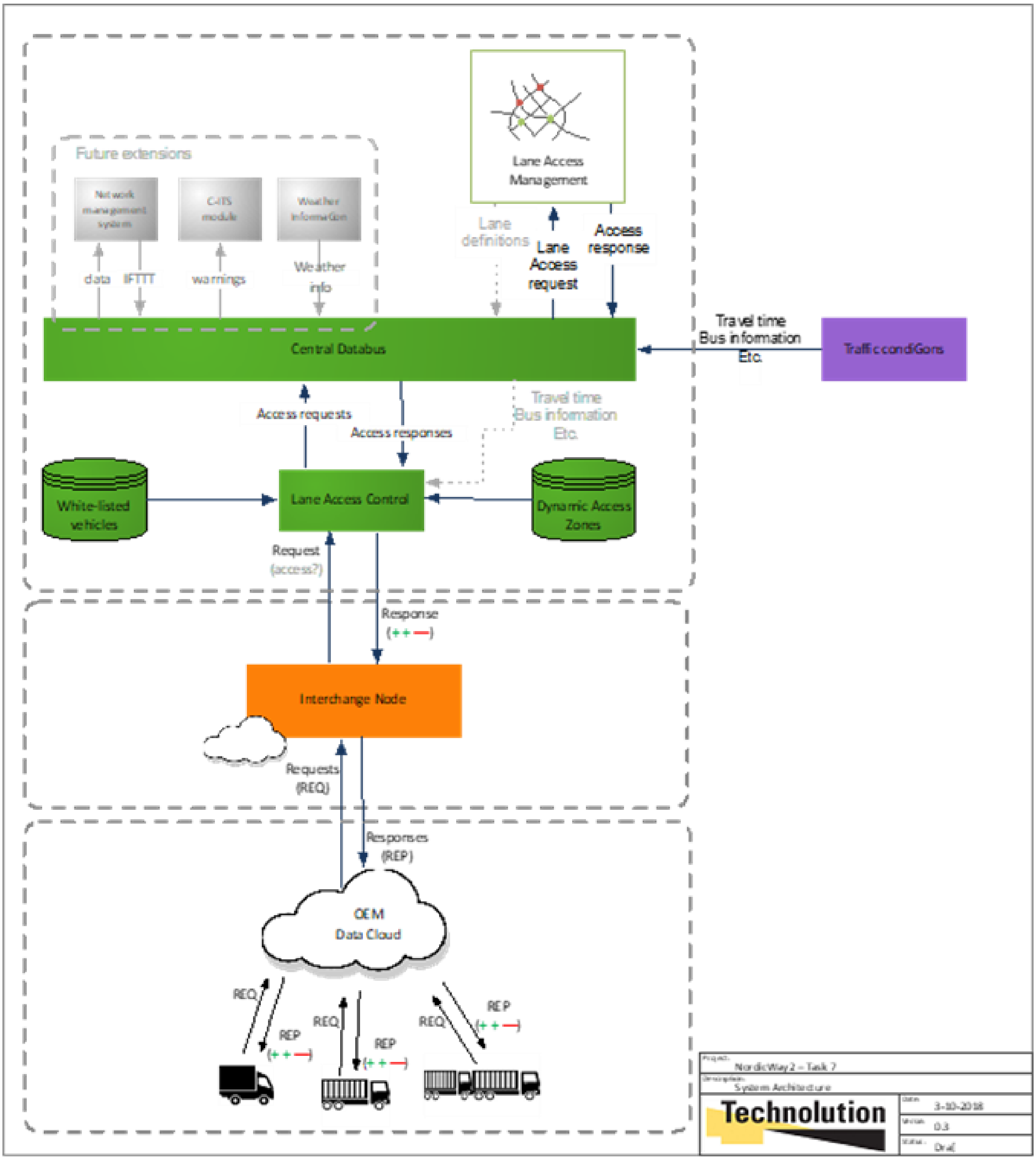

Figure 22. System architecture for Dynamic access control (Task 7).

For Task 7 (Dynamic access control), the latency was measured by the 'Stopwatch' method. Two different latencies were measured. First, the latency between access request from within the truck to the operator and back again to the truck and second, latency between transmission and reception in the application.

Using the stopwatch method, a latency of 20 seconds between the driver's request and response from the traffic operator was measured. The largest part of this delay was due to human interaction from the traffic control centre and driver response. An average latency of 300 ms between transmission and reception in the application was also measured (Table 5).

Table 5. Latency results for Task 7.

Quality KPI	KPI	Description	Unit	Results	Comment
KPI_Q08	Latency (end-to-end)	Send/receive latency – time from timestamp sent to timestamp received of message	s	20	The largest part of this delay was due to human interaction from the traffic control centre and driver response
KPI_Q08b	Latency (between Federated interchange nodes)	Delay between the first (validated if necessary) detection of the event and the moment the information is provided by the content access point	ms	300 (average) (N=299)	Latency between transmission and reception in the application

Other results: The demo in Dynamic Access Control of Designated infrastructure pilot has shown that it is technically possible to implement dynamic access to designated road infrastructure, but more challenging is probably to comply with current regulations and to get social/political acceptance for this use-case. As for now dynamic traffic regulations need to be available in the actual road infrastructure, only digital availability is not accepted. Even more challenging might be to get acceptance to use a bus lane for other purposes than for public transport as promoting public transport is key for the politicians. It can also be challenging to get acceptance from drivers of ordinary vehicles that trucks drive in the bus lane.

Dynamic environmental zones (Task 8)

In Task 8, The City of Gothenburg offered a test version of a City Innovation Platform (CIP) which is in development currently as part of the EU project IRIS. This CIP delivers a common means for data exchange and storage from a smart city perspective (Figure 23). Exchange of controlled zone information, restrictions, status etc. is most suitable through this platform. The central data exchange is based on the Ericsson NordicWay 2 Interchange Node that offers a common platform for information exchange between business and governmental systems. Technolution deploys an installation of their traffic management suite MobiMaestro, for this purpose, the existing central data-bus is extended with support for controlled zone information. MobiMaestro exchanges the controlled zone information with CIP through a standardized REST API. Finally, VCC extends the cloud enabling the controlled zone information to be received and pushed to vehicles in the area. Test software in the vehicle ensures that vehicle automatically runs on pure electric within the zone.

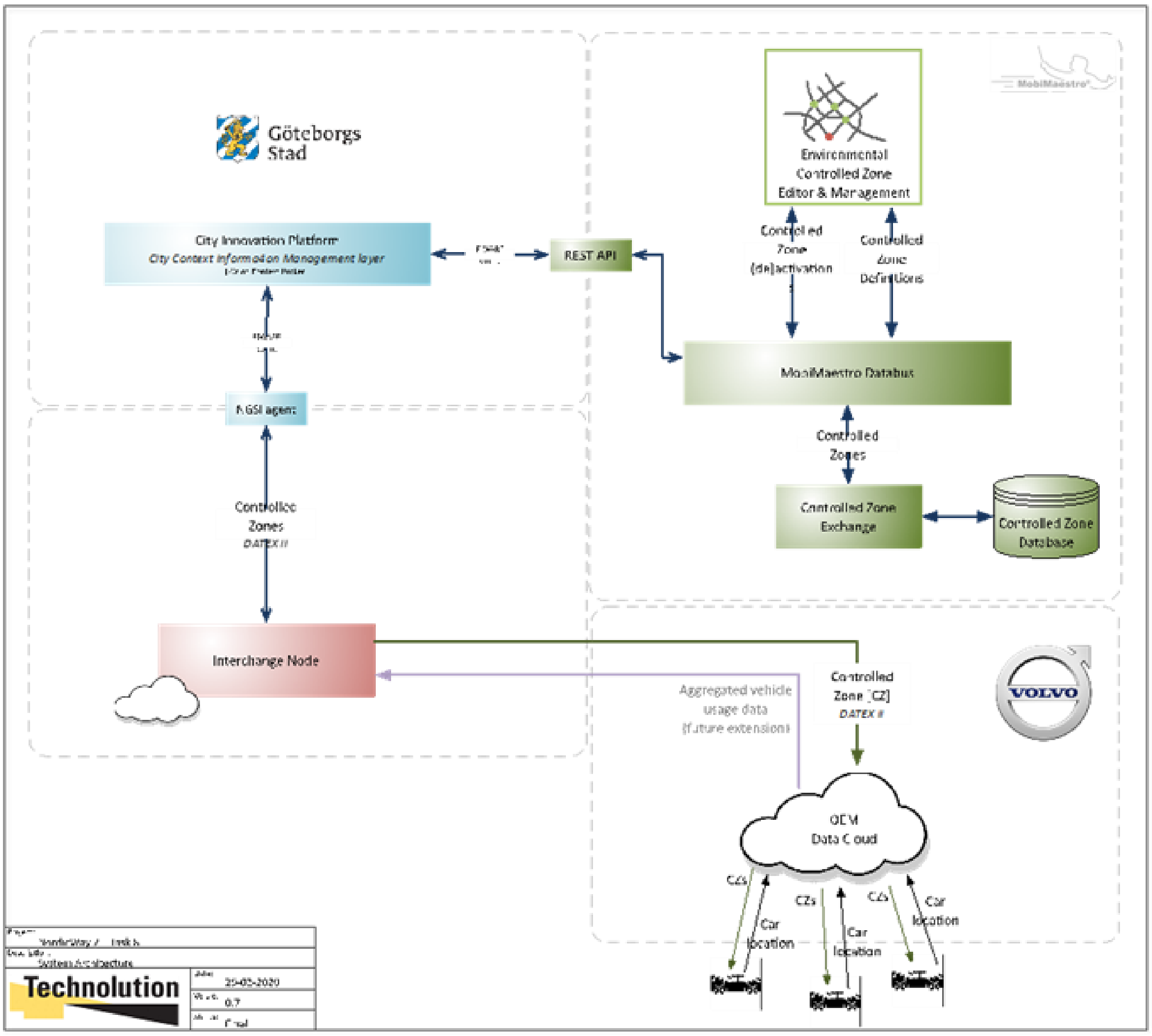

Figure 23. Dynamic controlled zone (Task 8) architecture.

For Task 8 (Geofencing), the latency was measured by the ‘Stopwatch’ method. The measurement corresponds to the measure of latency between changing a geofence state in the GUI and the actual response in the vehicle.

Using the stopwatch method, a maximum latency of 10 seconds between the GUI change and the actual response in the car was measured (See Table 6).

Table 6. Latency results for Task 8.

Quality KPI	KPI	Description	Unit	Results	Comment
KPI_Q08	Latency (end-to-end)	Send/receive latency – time from timestamp sent to timestamp received of message	s	10 (average)	Latency between GUI change and actual response in the car

Road Works Warning (Task 9)

In Task 9, as can be seen in Figure 24, the service and warning message for Road Works Warning (RWW) is generated at the RWW unit mounted on the TMA vehicle. The message is sent to the Kapsch node, which transfers the RWW message in DENM and DATEXII format through the interchange node to OEM cloud and then finally to the vehicle. The OEM cloud also receives Road work information messages from Swedish Transport Administration in DATEXII. Additionally, the message is directly sent from the RWW unit to the vehicle as DENM via ITS-G5, which results in true Hybrid Communication. Latency wasn't measured in Task 9.

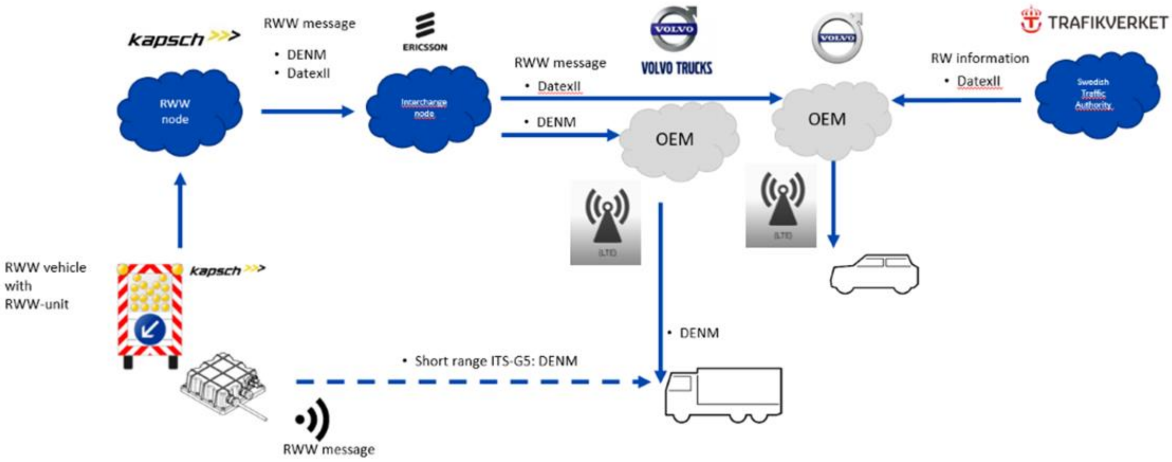

Figure 24. Flow of messages in Task 9.

4.2 Service ecosystem

The development of C-ITS services has to a large extent been technology driven with focus on testing new technology solutions as proof of concepts. Less focus has been put on the values and business viability of the C-ITS services. In order to provide and implement these services to the end users on a wider scale it is crucial that there are viable business models that create values for all stakeholders involved. As the partner set up of the pilots indicate, several different actors, both private and public, is needed to create these services which add some complexity to the creation of viable set up for large scale implementation.

To discuss these issues all the tasks within the project participated in ecosystem workshops. The objective of the workshops was to describe the current ecosystem of the C-ITS service, its actors and their roles, and to better understand the business potential and what is needed for implementation of the service. In total five workshops were conducted:

- 29th of October 2019: Emergency Vehicle Approaching (Task 2 and 3)
- 21st of January 2020: Road Works Warning (Task 9)
- 22nd of January 2020: Dynamic Environmental Zones (Task 8)
- 27th of January 2020: Signalized intersections (Task 4-6, with focus TTG and GLOSA)
- 4th of February 2020: Dynamic access control of designated infrastructure (Task 7)

4.2.1 Workshop set up

The workshop was divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilot. Thereafter a description of the current ecosystem, i.e. how the pilot is set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem (a network diagram) on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the workshop a scaled-up version of the ecosystem was constructed (an extended network diagram). This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

4.2.2 Results

Below follows a summary of the main takeaways and results from each workshop. In the individual task reports a more detailed description is available including illustrations on the ecosystem network for each service. See Appendix 2-7.

Emergency Vehicle Approaching (Task 2 and 3)

The current ecosystem of partners active in the EVA pilot are private actors, i.e. service providers and OEMs. The producers of data are not active participants in the pilot but contribute with data such as the position of emergency vehicles. The main pain the partners experience being a part of the project is the amount of resources put into development and adjustments in current technology. The gains pinpointed are the creation of new knowledge and new business partnerships.

For the full potential of the EVA service a large majority of the vehicles on the roads needs to be able to receive an EVA warning. Therefore, some new actors (other OEMs, app providers and fleet operators) need to be a part of a future ecosystem. The pilot does not investigate the revenue streams of the EVA service, and how this service is going to be financed is one crucial question to solve if the service is to be implemented. The main reason and benefit of the EVA service is to increase accessibility for emergency vehicles on the road and therefore a public actor would probably be the one responsible for the service. However, who among public actors that should be the paying body needs to be further elaborated. It is also unclear who the owner of the EV data is and how the data is allowed to be used for service providers to create the EVA service in future.

Signalized intersections (Task 4-6, with focus TTG and GLOSA)

In the traffic signal pilot both public (cities and STA) and private (software and hardware service providers, OEMs etc) actors participated. The pains to be involved in the pilot are the lack of certain quality standard of data, development and training. For the cities a pain was that developing this service is not the city core business. The gain highlighted was collaboration between public bodies and industry and with this pilot gaining knowledge and also the opportunity to influence the data protocols for traffic signals. Further, gains in terms of socioeconomic values were highlighted such as smother traffic flow that can decrease air pollution, emissions and accidents. Most of the actors described themselves as committed to these services. However, from a public/city perspective the socioeconomic benefits need to be proved in order to fully commit on further development.

The implementation of these services will probably happen stepwise with certain intersections and road stretches, and from there be scaled up. Both OEMs and local road authorities stressed that harmonisation of data protocols etc. on European level is needed for large scale implementation. It will be much easier for OEMs and local road authorities to have clear instructions than investigate every and develop own solutions. At this moment there is no routine for generating MAP messages and keeping them updated and the road authorities need to find a way to achieve this. Cities/municipalities need support in this work by STA, otherwise different systems and set ups in different cities/municipalities.

Further, new investments to handle and process the big amount of data are also needed. Perhaps there will be new service providers that provides a new service/connection layer, doing the MAP data work, and selling this data to subscribers such as OEMs.

Dynamic access control of designated infrastructure (Task 7)

The dynamic access pilot was a small group of participants trying out the concept for giving access to a bus lane. The pains highlighted was the novelty of this concept, totally new software and a fragmented actor ecosystem. In terms of actors one crucial actor is the involvement of a traffic management centre which was not participating in this pilot. The gains were described as learning and discovering new concepts. Also, the future potential benefits, when there is a fully developed concept, was highlighted such as more effective use of current infrastructure.

If this service is to be feasible it needs to be implemented over a bigger geographical area. Exchange of information and data between the road operators and road authorities/cities is important. As well, a collaboration with law enforcement to make sure the traffic rules are being followed is essential. It is still not clear who makes the investment and who gets the revenue. This needs to be further discovered. The service also needs to be bundled to sell better and can possible be joined with other services in order to make the whole set of services profitable.

Dynamic Environmental Zones (Task 8)

The ecosystem of this pilot involved both private and public actors exploring the potential of dynamic environmental zones and also geofence issues in general. The conflict between regulation and voluntary involvement from end users was one pain indicated by most of the actors. Creating knowledge and confronting questions such as the regulation issues for geofence services considered as the main gain.

In the future there will probably be a lot of different set ups and scenarios for geofence. In near future (five years) the service will be incentive based but in 10 – 20 years it might be regulatory driven. A start is to use the service as an incentive and in parallel start the process with the regulatory work. It is important to see this service as a step in gradually introducing new automatic systems. If the system should be efficient in the future it needs to be coordinated with other services as well. The ecosystem could also be described in the terms of different roles:

- Definer: e.g. cities and road authorities
- Service enabler: e.g. software developers
- Data broker: e.g. Interchange node
- Retriever: e.g. OEMs
- End-users: Action by the end-user (whether it is forced or not forced upon the driver)

One problem with this ecosystem is probably for the retriever to know what service is applicable to the driver and how to distinguish them? Therefore, it is also important to have one trusted authority that provides the true source. It should be the authorities that have the responsibility of acting as a trusted source and all intermediate systems who are trusted to forward the information.

Road Works Warning (Task 9)

The RWW pilot involved a set of actors creating the RWW service. However, no actual sub-contractors owning and managing the TMA trucks was participating which would be a mandatory actor in an implementation scenario. Experienced gains by the active partners in the pilot are the new retrieved knowledge and the creation of this ecosystem of partners. This service is seen as a new business potential for the private partners in the pilot and for the public stakeholders in a way to avoid road works related accidents and increase safety for road workers.

For future implementation more users need to have access to the service information. To increase the number of users the information also needs to be accessible in smart phones and not only integrated in the vehicles HMI. Therefore, app providers are a possible new group of actors. Further it is important for the road authorities to create general standardized requirements (e.g. required data on the RW vehicles and installation guidelines) for their subcontractors as procurement. Another important role for the public sector could be to secure the quality of the data.

The RWW service is mainly for the common good, i.e. the drivers will probably not pay for this service. In this stage it is hard to point out who should pay for the service. However, there are several actors that would benefit from it. For the whole system the main values are less accidents, less severe accidents and better traffic flow. Also saving money for TMA truck owners is an important value (road works warning decreases the risk that vehicles are crashing into the TMA trucks and destroying them).

4.2.3 Conclusions

From the ecosystem evaluation it is evident that each pilot has proven that is possible to create a C-ITS service in technical terms but more research in how to actually scale up the services is needed. The knowledge building, collaboration and partnership creation in the pilots seem to be the most agreed upon gain with the pilots. Further, the feeling of contributing to future technical enhancement, standards for data formats, protocols etc are also important gains. In order to scale these services some main conclusions can be drawn:

- Viable business models and responsibilities of different actors need to be further investigated. The created value or the goal of the services are in most cases linked to socioeconomic values such as increased safety on roads, less emissions, more efficient use of infrastructure etc. For the public sector these values are very important and therefore it is often argued that the funder and responsible actor in most cases should be a public actor, very often mentioned is a road authority such as STA.
- Harmonisation and standardization of data and protocols are important for implementation on a larger scale. This indicate that continued work within various platforms such as C-Roads and collaboration projects like NordicWay is needed.
- Another common opinion is that the service by itself is not a viable business case alone. The value increases if there are a set of services that being offered which means that it seems to be a value of some sort of common data sharing platform that lays a ground for actors to create services and subscribe to them.
- More users need to be reached to reach the full potential of the services since the value of the service increase when more people use it. Therefore, more OEMs need to implement the service and, in some cases, also app providers can implement solutions for smart phones which can increase the user base.

4.3 User acceptance

4.3.1 Survey

Sweden participated together with the other countries in developing a questionnaire to be sent out to approximately 1000 households per country. The responsibilities included tasks such as developing work procedures, survey content, partaking in discussion and commenting. Each country was responsible for translating the questionnaire into their national language before sending out the questionnaire.

Sweden conducted data analysis of the Swedish responses to the questionnaire and provided the results to the coordinators of the evaluation who are Finland.

The results where then reviewed together with the other participating countries of the project.

4.3.2 Results

In total, over 4000 drivers responded to the survey in Finland, Denmark, Norway and Sweden. The main results were analysed both for “all countries” and for each country separately. Statistical analysis per background variable (age, gender, driving experience and technology adoption) were made for the entire data (all NordicWay 2 countries together), not for each individual country.

The main results are presented in the Final report of NordicWay 2.

Findings from the survey

- Nearly all NordicWay services got high scores in relation to importance.
- Minor differences between the Nordic countries.
- Sweden a bit more positive
- More than 50% have not heard about C-ITS services at all.
- Accident ahead is the most important service on motorways. Emergency vehicle approaching is the most important on urban streets.
- Willingness to pay for the services is low
- Willingness to share data is more than 50%

4.3.3 HMI

Two different HMIs for providing warnings on emergency vehicles approaching (EVA) were studied. The effectiveness of information provision was measured as drivers' propensity do give way to an ambulance on an emergency call. The experiment was conducted with 22 car drivers as subjects.

There were three experimental conditions of EVA Message:

- EVA 0 = Baseline, no display (and no alert)
- EVA 1 = Display in one location (instrument cluster)
- EVA 2 = Display in two locations (instrument cluster + centre console).

4.3.4 Simulator study on the effects of EVA messages

The purpose was to test the effect of EVA messaging on drivers' propensity do give way to an ambulance on an emergency call.

A total of 22 car drivers in Sweden with valid driving licenses for a private car (category B in Sweden) participated. They were aged 19–57 years, M = 29.3 years, SD = 12,3 years, whereof 13 males and 9 females, and had had their driving licenses for 1–38 years, M = 10.1 years, SD = 12.3 years.

There were three experimental conditions of EVA Message: baseline with no EVA message (EVA 0), EVA message on the instrument cluster alone (EVA 1), and EVA message on the instrument cluster and on the infotainment display in the center console (EVA 2). The design was 3 Í 2 Í 2 (EVA Message Í Interface Order Í Baseline Order) split-plot factorial, with EVA Message and Interface Order within groups, and Baseline Order between groups. EVA Message refers to the three experimental conditions (i.e., EVA 0, EVA 1, and EVA 2, respectively). In Interface Order 1, EVA 1 was presented first, whereas in Interface Order 2, EVA 2 was presented first. Baseline Order 1 had the EVA 0 baseline condition first and then either of EVA 1 and EVA 2, whereas Baseline Order 2 had either EVA 1 or EVA 2 first and finished with EVA 0.

Figure 25. Simulator used in the study.

A proprietary small car simulator without motion cueing was used, see Figure 25. The EVA message was presented as a yellow triangle with a blue waring light and a text message stating "Emergency vehicle approaching! Pay attention!". As the ambulance closed in, further instructions were displayed regarding yielding and slowing down. In EVA 2, the EVA message was additionally presented on the infotainment display in the center console. See Figure 26 for the two versions of EVA message. The EVA message was received 50 seconds before the ambulance was estimated to catch up with the participant's car, based on the relative speed difference.

Figure 26. Two versions of EVA messages.

The test scenario took about 30 minutes to complete and was about 20,000 m long. An ambulance on an emergency call, with blue lights and sirens engaged, caught up with and passed the participant's car three times during the session (at about 3,000 m, 6,000 m, and 11,500 m from the start of the scenario). The scenario ended after the participant being passed by the ambulance for the third time, at about 20,000 m.

4.3.4 Results

There was a main effect of EVA message on distance to the ambulance when giving way, such that the two versions of EVA 1 and EVA 2 caused the driver to give way earlier (i.e., at a greater distance before the ambulance caught up). There was also an interaction effect between EVA Message and Baseline Order, such that when EVA 0 was the first condition (and EVA 1 and EVA 2 followed) drivers did not give way as early when there was no EVA message, but then gave way much earlier. However, when EVA 1 and EVA 2 initialized the test and EVA 0 finished it, the drivers gave way about as early even when there was no EVA message, which implies a learning effect. See Figure 27 for a summary of these results.

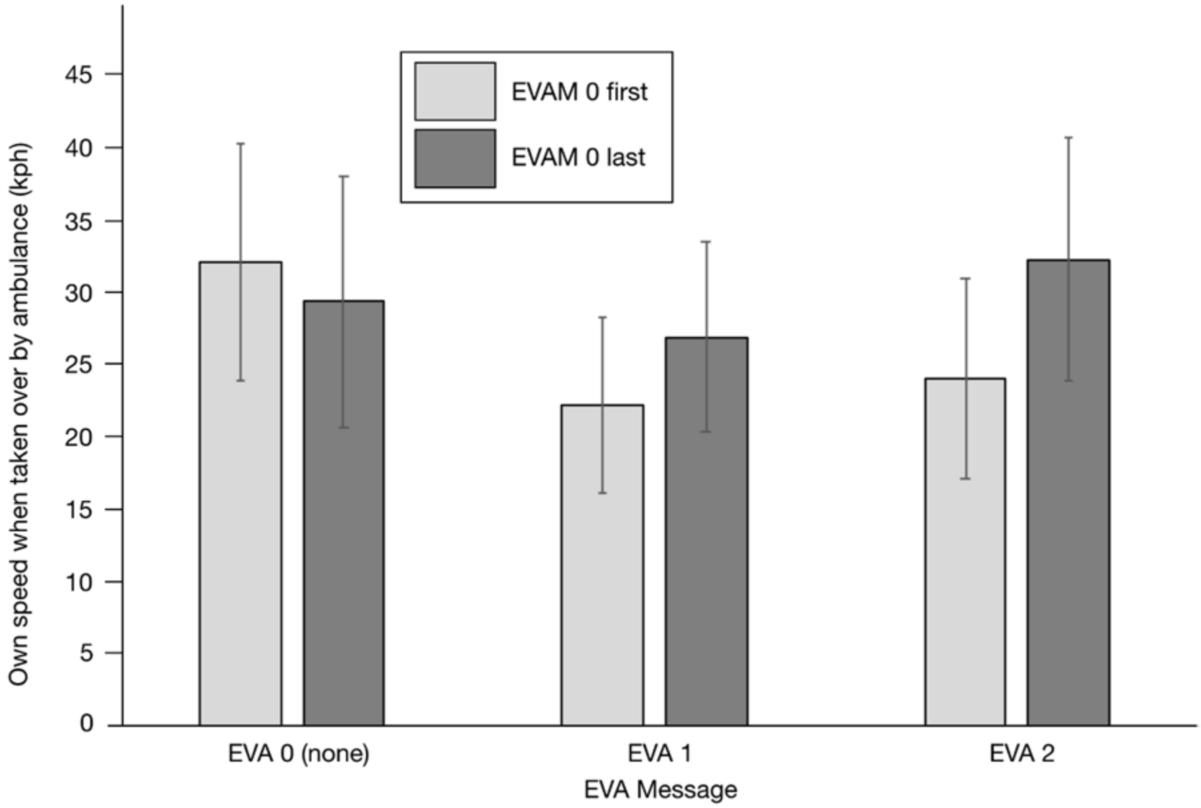

Figure 27. Distance from ambulance when giving way.

4.3.4 Conclusions

EVA message had a significant effect on how early the drivers gave way, such that the EVA message made the drivers give way at much greater distances to the ambulance than when there was no EVA message. There was also a learning effect such that after receiving the EVA message, the drivers gave way early even though there was no EVA message. The EVA message thus improved the driver's propensity to give way early.

4.4 Socio-economic

The assessment of socio-economic impacts was made as a joint effort of NordicWay 2 Evaluation Group. The impacts were assessed for the Nordic Countries participating in the pilot deployments of the project. The assessment was carried out country by country, and also for all four countries together. Finland led the analyses and reporting, while other participating countries were responsible for collecting the data needed for their respective country.

The assessment covers all services piloted in the NordicWay 2 project by at least one of the partners. As the pilot deployments does not typically represent fully the final deployment in terms of networks covered, user segments, HMI nor other service details, the analysis was carried for hypothetical expected end user service of the service type in question. This enables the utilisation of results of other studies and pilot deployments of the same service types elsewhere.

The socio-economic impact assessment included the impact areas seen relevant from the point of view of the piloted services. The areas that were considered include mobility (travel behaviour), safety (accidents), traffic efficiency (travel time and environment (emissions). (Innamaa et al. 2018). The socio-economic impact assessment made for Finland in NordicWay (Innamaa et al. 2017) was utilised as a basis.

Each country then provided the basic data for their road networks, containing the following data for their networks in years 2020 and 2030:

- Length (km)
- Vehicle kilometres driven (million/year)
- Share of heavy vehicles (%)

- Average speed (km/h)
- Vehicle hours driven (million/year)
- Vehicle hours spend in congestion (M/year)
- Fatal accidents (number/year)
- Non-fatal injury accidents (number/year)
- Property damage only accidents (number/year)
- CO_2 emissions (million tonnes/year)

The evaluation further assessed impacts such as Mobility impacts, Safety impacts, Efficiency impacts and Environmental impacts where assessment was carried out for a smaller area where the services were applied before scaling them for the whole coverage.

4.4.1 Results

Sweden has participated in all the stages of the socio-economic assessment work as listed in the above summary of work progress. The results of this evaluation can be viewed in detailed in the *NordicWay 2 Evaluation results* report.

In summary, the socioeconomic impact assessment indicated that as a specific response to the service, the amount of travel is likely affected by the route guidance type of services on unfamiliar routes. Public transport priorities have an impact on mobility by making the use of public transport more attractive via improved punctuality and reduced travel time. C-ITS services for car drivers in general may also influence mobility by making one's own car a more attractive travel option due to increased awareness and a feeling of being better informed. The estimates of direct safety effects were largest for in-vehicle speed limits, emergency brake lights, and slow/stationary vehicle and traffic ahead warnings. Indirect safety impacts were also expected, but in many cases their magnitude was hard to estimate. Important efficiency effects were expected to result from a reduction of crash-related congestion due to fewer road crashes.

In addition, positive efficiency effects arise from the decreased distance driven due to the above mobility effects. In the environmental impact assessment, we focused on CO2 emissions. The largest speed-related effects are due to the decrease in congestion described in the efficiency impacts, as fewer vehicles will use low-congested flow speeds with the highest CO2 emissions. The comparison of costs and benefits indicates that from the road operator perspective, in 2030 the benefits even in the low effectiveness scenario will exceed the sum of annual operating and maintenance costs that year and the investment costs up to that year in all countries. Yet, sensitivity analysis showed that the outcome of socioeconomic impact assessment depended highly on the made assumptions on the coverage, use and effectiveness of the services.

5 Dissemination

During the project phase several dissemination activities such as presentations, films, reports and workshops have been performed. This chapter summarizes the main dissemination activities for the Swedish part in NordicWay 2.

5.1 Launch of Swedish pilots

The 1st of May 2019 in Uppsala and 16th of May 2019 in Gothenburg the Swedish pilot in the NordicWay 2 project was officially launched. This was one of the milestones in the project.

The launch in Uppsala was focusing on TTG and Scania was responsible for the presentation and demonstration together with Uppsala municipality. The main purpose of the launch was to show that it is possible to access the traffic signals in six intersections that are available from Uppsala municipality via the Swedish interchange node. The launch and general information about the NordicWay 2 project were presented for the Uppsala municipality the 2nd of May 2019.

In Gothenburg the launch was focusing on TTG and dynamic environmental zone. The purpose of the launch was twofold; 1) to show that it is possible to access the traffic signals in six intersections that are available from the Gothenburg City via the Swedish interchange node, and 2) access the different environmental zones that also are available from the City of Gothenburg via the Swedish interchange node. Representatives from Scania, Volvo AB, VCC, Swarco, Ericsson, STA, Uppsala municipality, City of Gothenburg, City of Stockholm, CLOSER and RISE was attending the event. During the day presentations were held regarding the pilots and a film from the Uppsala launch was shown. The participants also got the opportunity to drive the cars and experience the services and at this time a film was also made.

Figure 28. Participants of demonstration in Gothenburg.

5.2 Project films

Film as a format is an informative and efficient way of capturing the core of each pilot and to reach out to a wider audience. In the project each task created a film about their service that describes the pilot and the functionality of the service. All films are available on https://www.nordicway.net/ and on Youtube.

Table 7. Links to the pilot videos.

Task	Service	Link
2	Emergency vehicle approaching (EVA)	https://www.youtube.com/watch?v=gqN2aABeOPs
4, 5, 6	Signalized intersections (SI)	https://www.youtube.com/watch?v=qj77VTs8KpM&t=3s
7	Dynamic access control of designated Infrastructure	https://www.youtube.com/watch?v=nXuf_RAVtVg&t=8s

8	Dynamic environmental zone	https://www.youtube.com/watch?v=IRNbpBbyYXY&t=9s
9	Road works warning (RWW)	https://www.youtube.com/watch?v=s_MRUKw7D54&t=9s

5.3 NordicWay 2 Swedish pilot showcase

During the 23rd of October 2020 the final event for the Swedish part of the NordicWay 2 project was held as a digital showcase. During the first part of the showcase all films were shown followed by presentations from each task. The second part of the showcase was more focused on what will happen after NordicWay 2 is finalised and included panel discussions about the usefulness and further development if these services from an industry and public perspective, further development for data exchange platform and EU cooperation.

The showcase was initially planned as a physical showcase in spring 2020 but had to be postponed and turned into a digital showcase due to Covid-19 situation. However, during the event there was around 300 participants at its most and people from a wide variety of countries. This would probably not been achievable with a physical event.

The showcase was hosted in collaboration with Drive Sweden which is one of 17 of the Swedish Strategic Innovation Programs. Drive Sweden assisted with studio and the technical solutions for the event and. The monitors of the event were Sofie Vennersten, Drive Sweden and Magnus Hjälmdahl, Sweco (supporting STA with NordicWay 2 project management).

The showcase was recorded and available on the NordicWay Youtube channel, link:

https://www.youtube.com/watch?v=K7T7Gz-rVHI&feature=youtu.be

Figure 29. A picture from the studio at Lindholmen Science Park.

5.4 Conferences and other events

During the project period partners and tasks have been participating and presented NordicWay 2 in various conferences and other events. Some of these were:

- Launch of the Swedish pilot May 2019, Uppsala and Gothenburg, Sweden
- Transportforum, January 2018, Linköping, Sweden
- ITS EU Seminar Swedish Transport Administration, 31 May 2018, Stockholm, Sweden
- ITS World Congress Copenhagen, September 19th 2018: several partners presented and demonstrated the ongoing work in NW 2.
- Transportforum, January 2019, Linköping, Sweden

- European Transport Conference (ETC) in Dublin, 2019: presentation of results from GLOSA study.
- NordicWay 2 PMB in Gothenburg May 12th 2019: Evening event for Nordic partners and potential new NordicWay 3 partners
- NordicWay 2 Swedish pilot showcase, October 23rd 2020, Digital

6 Final remarks

The NordicWay 2 pilots in Sweden demonstrated the provision of C-ITS Day 1 and Day1.5 services successfully. NordicWay 2 with its interchange node tested and achieved a seamless connection between service providers, government authorities, technology providers and OEMs. Hybrid communications with low latencies were also successfully demonstrated. The pilots also proved that an ecosystem supporting the OEMs and service providers' customers relationships is achievable to provide innovative services. With the success of Swedish pilots, the system is a step closer to large-scale deployment.

Concluding words from the Swedish Transport Administration:

By enabling communication between vehicles, infrastructure and other road users, Cooperative Intelligent Transport Systems (C-ITS) has the potential to greatly improve safety and efficiency in road transport system. The CEF-funded NordicWay 2 project has successfully contributed greatly with knowledge and practical experience to early C-ITS deployment in Sweden as well as in Scandinavia. Based on the project results it has also constructively contributed to the European roadmap for these services.

NordicWay 1 demonstrated that the cellular communication network in place is sufficient, both when it comes to latency and coverage for the piloted C-ITS services. NordicWay 2 continued where NordicWay 1 left off and enhanced the cooperation between relevant stakeholders in order to build a common understanding of what is needed in the area of data communication from future digital and physical infrastructure.

Apart from proving the technical concept of C-ITS-services, the project focused on the organisational, legal and social aspects of a future connected road transport system. NordicWay 2 provided a valuable platform for such discussions on roles and responsibilities between public and private stakeholders.

Even though the implementation of C-ITS services in Europe has started, further cooperation is still needed. To achieve a harmonized and interoperable eco-system, areas like the procurement process and operational aspects will have to be addressed. This is part of the goal of the NordicWay 3 project.

7 References

European Comission. (2020, November 11). *European Comission Mobility and Transport*. Retrieved from Intelligent transport systems - Cooperative, connected and automated mobility (CCAM): https://ec.europa.eu/transport/themes/its/c-its_en

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NordicWay 2. (2020). *NordicWay Service Definitions: Services and Use cases.*

NordicWay 2 EG. (2020). *NordicWay 2 Evaluation Results.*

8 Appendices

Appendix 1: NordicWay 2 Data Interchange Node Architecture

The NordicWay Interchange is an AMQP (Advanced Message Queuing Protocol) publish – subscribe message broker. The Swedish NW2 interchange is based on the NW1 interchange developed by Ericsson. It is not the same code that has been developed as open source for the interchange nodes in Norway and Finland as it was developed earlier but has the "same" functions and interfaces. For support of some of the unique Swedish use cases in NW2 a set of translators, data bases and protection functions have been developed and grouped in what is named NW2 Swedish Traffic cloud.

Reference documents for a deeper understanding are:

- NordicWay Service Definitions Services and Use Cases Deliverable D22 (Part 1)
- NordicWay Service Definitions Messages Deliverable D22:2 (Part 2)
- NordicWay Client Specification AMQP Client Specification

1.1 Interchange Component Overview

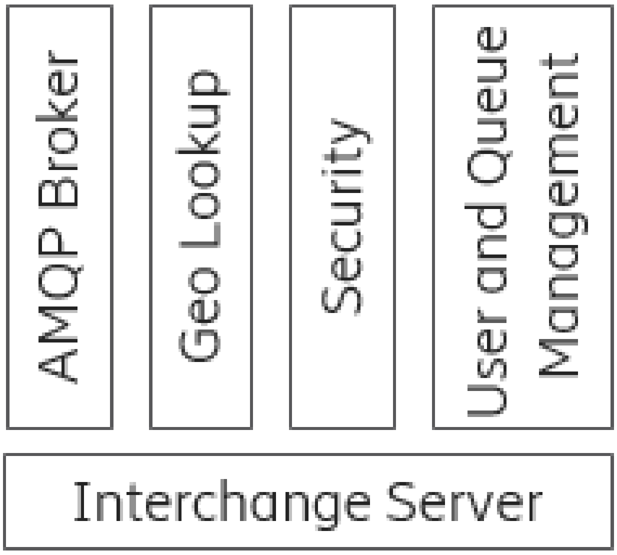

Figure 1. Interchange Component Overview.

The software components, as illustrated in Figure 1, providing the building blocks of the interchange are

- AMQP broker: Implemented using Apache QPID server and running in a docker container
- Geo Lookup: Implemented using PostGis and running in a docker container
- Security: Implemented using TLS, Ericsson provides the certificates to the onboarded partners on the Interchange.
- User and Queue Management: Ericsson provides this.
- Interchange application: Is the Interchange logic and is implemented using Node JS. This application is running in a docker container. For logging purposes MySQL is used and is running in a docker container.

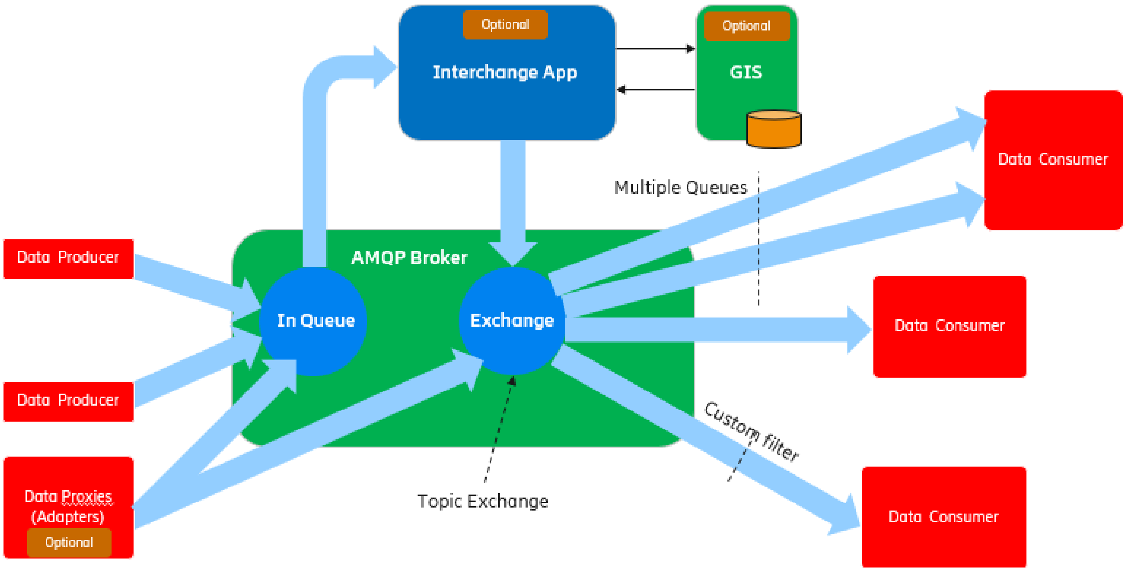

Figure 2. Generic Deployment Architecture.

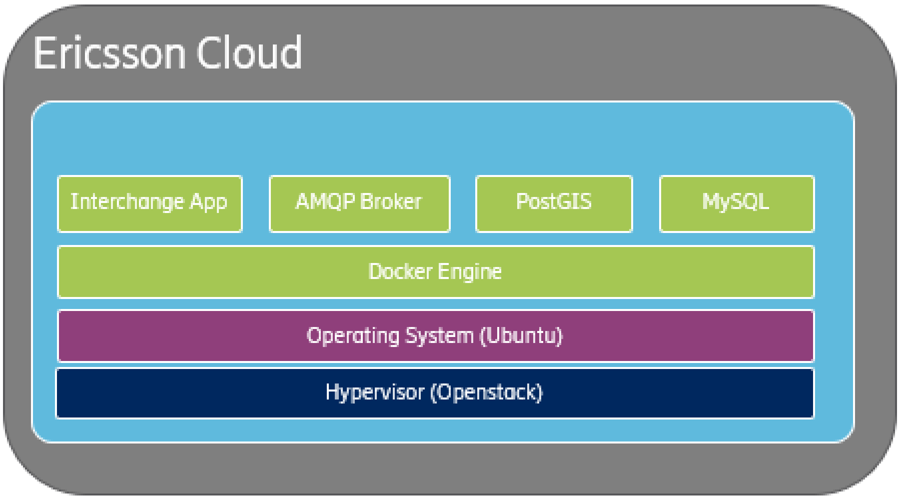

Figure 3. NordicWay Interchange Components.

The Swedish NW2-Interchange is installed in the xerces.ericsson.net environment with two (2) instances, production instance and staging instance. The xerces.ericsson.net environment is operated by Ericsson Research and located in Lund, Sweden.

1.2 Messages transiting the interchange

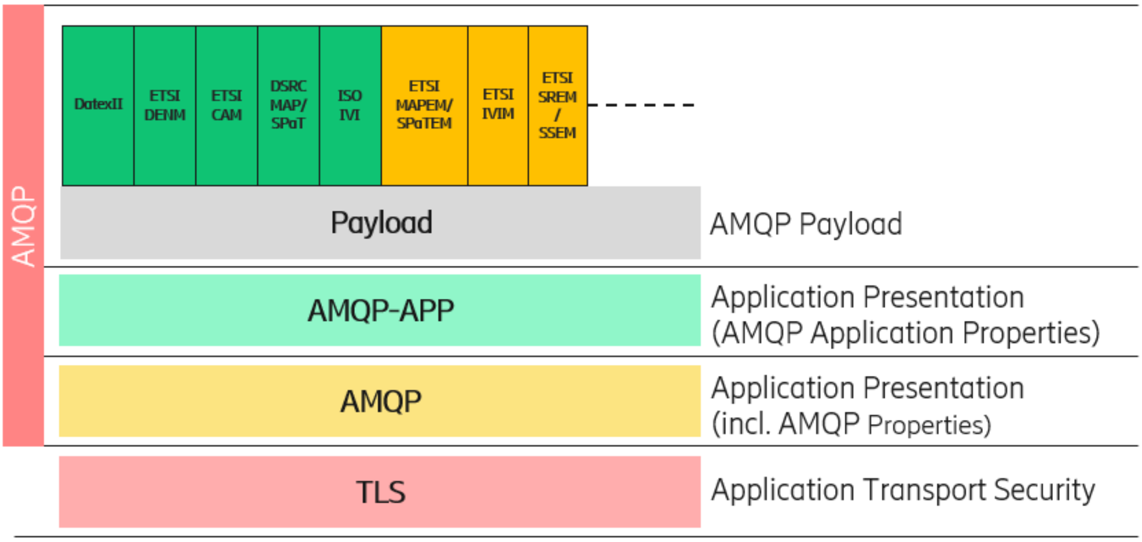

Figure 4. Message Stack.

The AMQP application properties are used to identify the payload, the format of the payload, any related mime types and versions of the payload.

1.2.1 STC

The Swedish Traffic Cloud (STC) is a collection of cooperating components facilitating data exchange with Swedish authorities and partners. The SOAP/AMQP gateway of STC has been in operation since NW1.

The STC is installed in xerces.ericsson.net environment with two instances, the SOAP/AMQP gateway and a combined instance for the other components of the STC, named “spatmapbroker”.

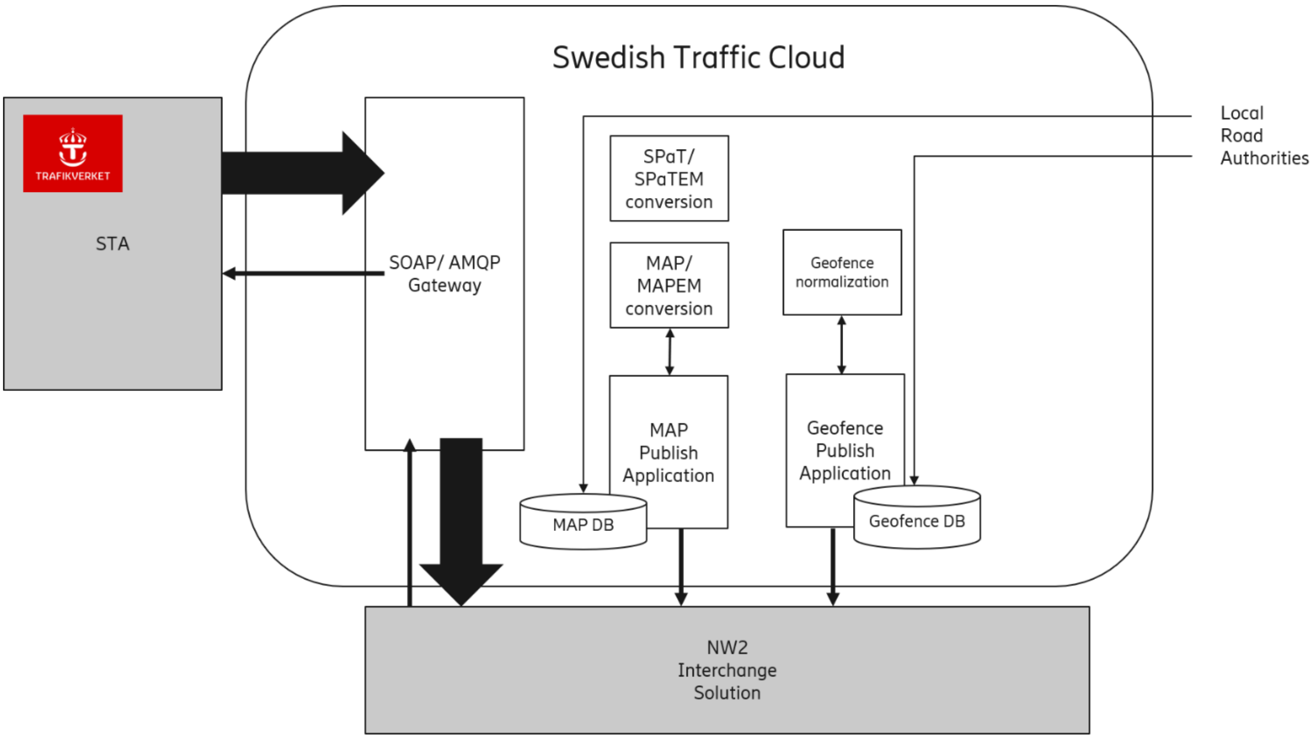

Figure 5. Swedish traffic cloud.

The SOAP/AMQP Gateway, implemented as a NodeJS application, converts data from STA towards the NW2 Interchange, and vice versa. On a typical day, there are approximately 10 000 messages sent from STA via the SOAP/AMQP Gateway to the NW2-IC. The SOAP/AMQP Gateway was developed as part of the first NordicWay project and has been in uninterrupted operation since then, until it was intentionally turned off and put into stand-by sometime during 2019.

The MAP Publish Application automatically converts MAP data from MAP to MAPEM format, and from any encoding (ASN.1 binary, ASN.1 base64, XML, JSON). The MAP Publish Application distributes all MAP data stored in its MAP Database to the NW2-Interchange:

- Immediately upon update of the MAP data
- Periodically, every 4 hours
- Upon restart of the MAP Publish Application

The Geofence Publish Application automatically normalizes the Geofence data based on configuration, with help of the Geofence normalization component. The Geofence Publish Application distributes all Geofence data stored in its Geofence Database to the NW2-Interchange:

- Immediately upon update of the Geofence data
- Periodically
- Upon restart of the Geofence Publish Application

1.2.2 Private Exchange

A “private channel” is setup for exclusive data exchange between VCC and City of Gothenburg for Activity 9 Task 8 – Dynamic Environmental Zones.

For Task 7 - Dynamic access control of designated Infrastructure a private channel is implemented as a private exchange between the two partners, Scania & Technolution.

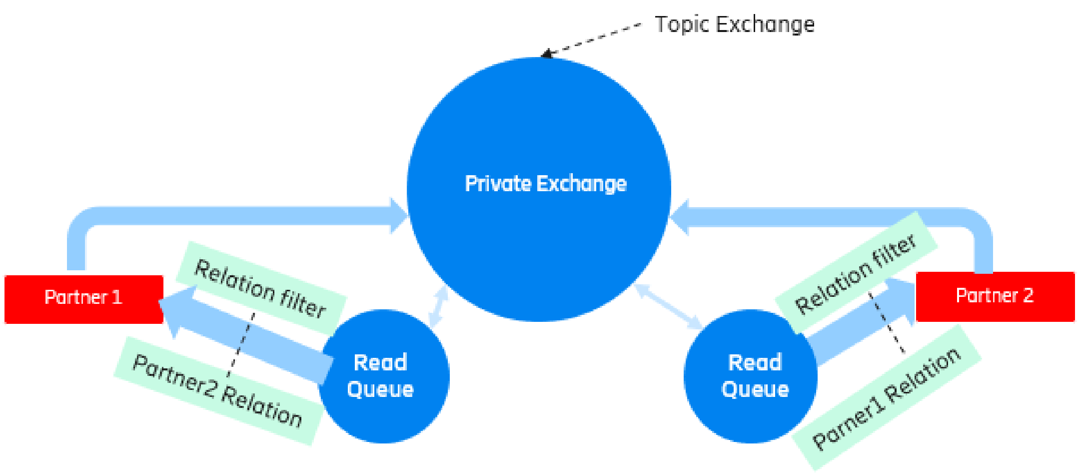

Figure 6. Interchange Setup - Private Exchange.

Both partners can write to the topic exchange. They consume data based on relation application property filter.

1.2.3 MAP Implementation

MAP implementation involves

1. An application to convert XML files to ASN.1 format and publish these payloads on the Topic Exchange.
2. Queues are aligned with other queues of the interchange.

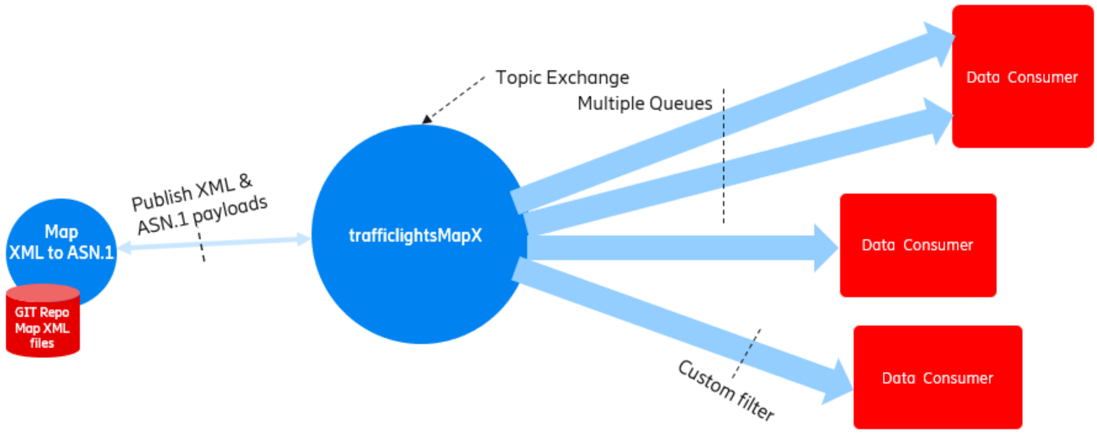

Figure 7. Interchange Setup – MAP Implementation.

1.2.4 SPaT Implementation

SPaT implementation involves

1. Receiving data from producers
   a. JSON data from Göteborg TK, Uppsala and Swarco Mizar (Trondheim, Oslo) are published through HTTP POST messages on to different listeners.
   b. ASN.1 data from Trafikverket for Göteborg is published to a queue.
2. An application to convert JSON payload in HTTP to ASN.1 format and publish these payloads on the Topic Exchange.
   a. This conversion is only available for Göteborg TK and Uppsala data.
   b. For Norway data, the data is published as JSON
3. An application is used to validate messages published to the producer queue and the published to the Topic Exchange.
3. The Queues are aligned with other queues of the interchange.

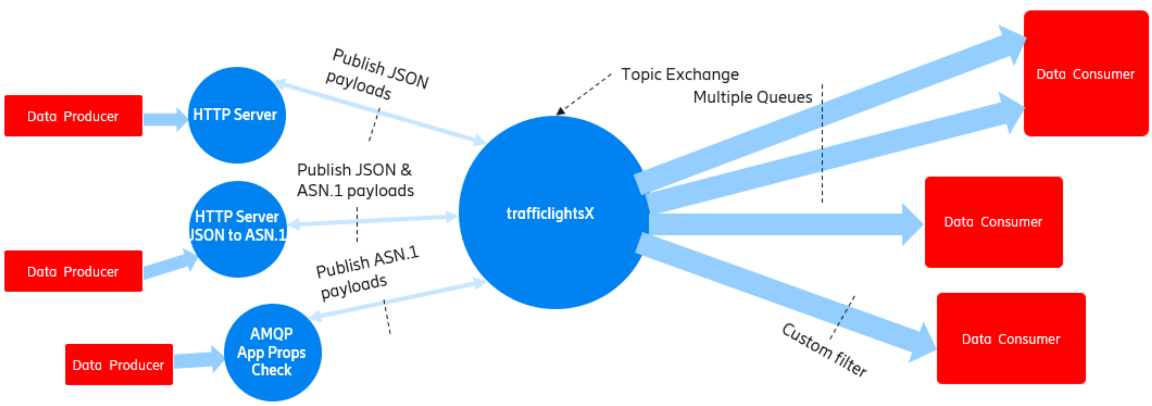

Figure 8. Interchange Setup – SPaT implementation.

1.3 Federation Interface to other interchanges

Interchange Federation makes it possible for a Consumer connected to its home interchange to consume data produced by Producers connected to other interchanges. The exchange of data streams between the federated interchanges is controlled by inter-interchange subscriptions that can be changed over time to match the demand from the local consumers and the available capabilities of the federated interchanges.

The Swedish NW2 Interchange implementation comprise:

- Basic Interface over AMQPS for data exchange with other federated interchanges, payload agnostic.
- Control interface over HTTPS for exchange of capabilities and subscriptions between the federated interchanges.
- Support for federation with an arbitrary number of other federated interchanges.

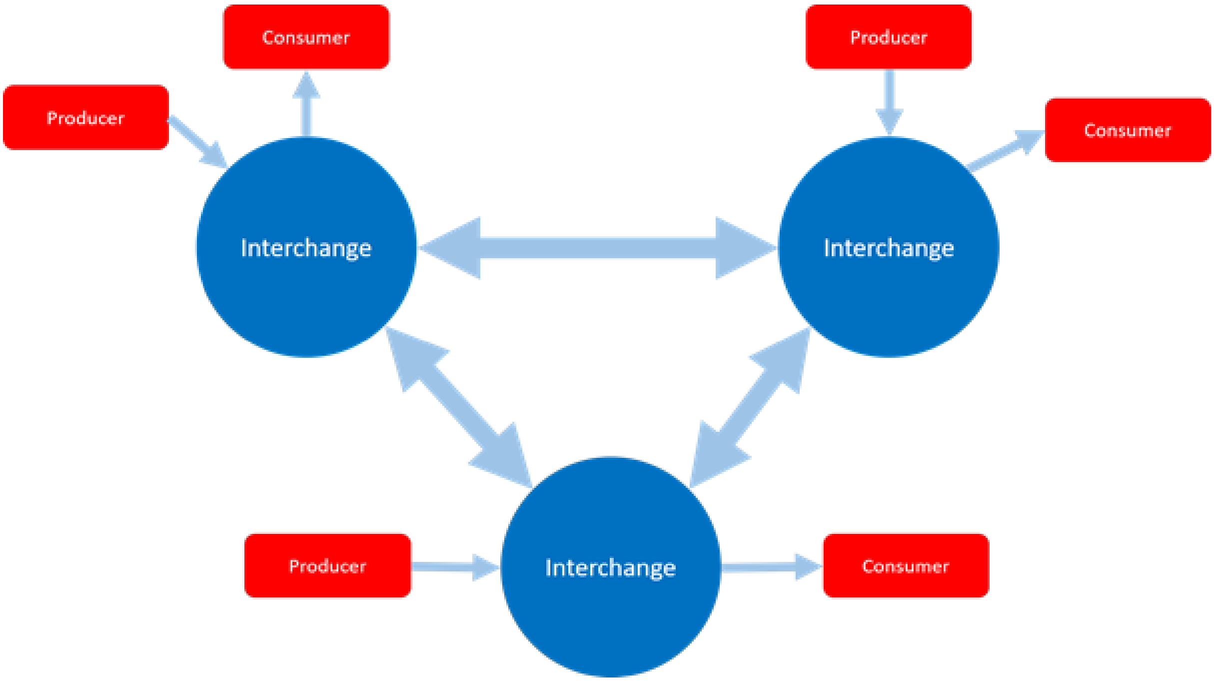

Figure 9. Federated Interchanges.

During the NordicWay 2 project, the Swedish NW2 Interchange federation implementation was fully and successfully tested with the NPRA interchange. The tests covered security, capabilities exchange, subscription exchange and update, and data exchange. The successful tests prove that it is easy to federate interchanges with different implementations using the federated interfaces; the NPRA interchange is implemented using Java, while the Swedish NW2 interchange is implemented using NodeJS and an Apache Qpid server, see 8.1. Round-trip latency was measured as part of the federated interchange test together with NPRA.

Measured round-trip per message (producer - NPRA interchange - Swedish NW2 interchange - consumer/producer ("bouncer") - Swedish NW2 Interchange - NPRA Interchange - consumer): mean value 118 ms, average 114 ms.

If we assume the time in the "bouncer" is negligible, then the latency of a federated message from producer to consumer can be estimated to be less than 60 ms on average.

The transport time in the fibreoptic network is 200 km/ms for the optical signal but conversion to electrical signals in routers and back to optical signal will add delays. For very long distances some care must be taken to choose the optimal network and routing when setting up the physical connection.

Appendix 2: Emergency Vehicle Approaching report

Final report – Emergency Vehicle Approaching



NordicWay 2, Activity 9, Task 2

Version 1.1

Date: 23. October 2020

Document Information

Authors

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Distribution

DATE	VERSION	DISSEMINATION
2020-04-27	0.1	Work group task 2
2020-05-29	0.2	Work group task 2
2020-06-03	0.3	Work group task 2 & 3
2020-06-10	0.4	Work group task 2 & 3
2020-06-11	0.5	Work group task 2 & 3
2020-06-18	0.6	Work group task 2 & 3
2020-07-01	0.7	NW2
2020-08-21	0.8	NW2
2020-09-02	0.9	NW2
2020-10-02	1.0	NW2
2020-10-23	1.1	NW2

List of Abbreviations

AMQP	Advanced Message Queueing Protocol
C-ITS	Cooperative Intelligent Transport Systems
CAM	Cooperative Awareness Message
C-ROADS	The C-Roads Platform is a joint initiative of European Member States and road operators for testing and implementing C-ITS services in light of cross-border harmonization and interoperability.

DATEXII	A data exchange standard for exchanging traffic information between traffic management centres, traffic service providers, traffic operators and media partners.
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standards Institute
GIS	Geographical Information System: is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
HLN-EVA	Hazardous Location Notification – Emergency Vehicle Approaching
HMI	Human Machine Interface
ISO	International Organisation for Standardization
IVI	Infrastructure to Vehicle Information
OEM	Original Equipment Manufacturer
RTA	Road Traffic Authority
V2I	Vehicle-to-Infrastructure Communication; Information exchange between vehicles and infrastructure.
V2V	Vehicle to Vehicle Communication; information exchange between vehicles.
V2X	Vehicle-to-any communication; X is either infrastructure or car; Including communication between vehicles as well as between vehicles and infrastructure.

Nordic WAY 2

Content

1 Introduction

The purpose of the Emergency Vehicle Approaching Task has been to provide a solution for the C-ITS Day 1 Service EVA (Emergency Vehicle Approaching).

During the NordicWay 2 project an EVA service that create warnings has been implemented, where the drivers receive warnings integrated in the vehicle HMI about approaching emergency vehicles.

The main working packages have been focused on producing and consuming the EVA services that alerts vehicles of emergency vehicles approaching before the driver can perceive the Emergency Vehicle through siren sound or visually. To be able to create the EVA warnings, emergency vehicle positions and information about their missions have been provided by an integration with an Emergency Response system.

The work with the Emergency Vehicle Approaching service have been done in close co-operation with VTI in the task *Emergency Vehicle Simulator Studies and Demonstrations* (reported separately).

2 Service definition

The EVA service (HLN-EVA) developed in the project is described in the NordicWay Service Definitions and Use Cases document, in the Hazardous Location Notifications (HLN) section.

The demonstrated solution also aligns with the HLN-EVA Use Case description in C_Roads_WG2_TF2_Service and Use Case Definitions_R1.7.0 and complies with relevant message format standards.

3 Description of the pilot

3.1 Pilot set up

Lead:	Carmenta			
Participants:	Ericsson, Volvo AB, Volvo Car Corporation, VTI, Trafikverket, SOS Alarm			
Timeframe:	Start:	January 2018	End:	December 2020

The Emergency Vehicle Approaching Pilot have been set up in the Gothenburg area since this was convenient for the participating companies and to perform the tests. Test vehicles from Volvo Cars and Volvo Trucks have been used, in total 2 test vehicles consuming the EVA warning messages. An ambulance have been used during the tests and demo opportunities and tests have also been performed in driving simulators at VTI.

Work and solutions developed within this NordicWay 2 task have been synchronized with other Drive Sweden activities in order to assure that results from other Swedish project in the same field of work are reused. An important objective of NordicWay is that activities shall be able to lead to commercial solutions that can be utilized and operated in other countries, within the Nordic region and in Europe. Therefore, there has been a focus for services developed in the Emergency Vehicle task that they are standardized and are applicable also to other areas than the Gothenburg pilot site.

Results and developments from previous projects, *NordicWay 1* and the Drive Sweden/Vinnova project *AD Aware Traffic Control - Emergency Vehicle Information*, have been reused where applicable.

3.2 Objectives

The main objective of the service is to provide an Emergency Vehicle Approaching (EVA) warning message to vehicles before a driver can detect the emergency vehicle, visually or upon hearing the siren.

The effect desired by offering the service to road users are twofold;

- A better experience for road users and drivers, by not being surprised by the sudden appearance of emergency vehicles.
- Shortened response times for emergency vehicles and a smoother and safer traffic flow when an emergency vehicle approaches.

In the task *Emergency Vehicle simulator studies and demonstrations* led by VTI, studies have been made regarding the effects of introducing EVA warnings in traffic.

3.3 Activities

After the initial specification phase of the overall NordicWay 2 project, the EVA Task 2 project group was established, with representatives from Carmenta (lead), Volvo Cars, Volvo AB, Ericsson and VTI. The ways of working were decided upon and resulted in a time plan and a series of meetings and activities. The EVA working group have had bi-weekly online status meeting, monthly face-to-face work meetings and several focus workshops and demonstrations (Figure 1).

Figure 1. The EVA Task 2 project group at a project meeting at VTI.

Below the main activities which were performed during the project are described in a timeline.

2018

During spring 2018 the technical integration between Carmenta TrafficWatch and the Zenit system at SOS Alarm was established for the project. The work included security audit and an established support organization for handling the connection and securing the emergency vehicle data provision during the extent of the project.

In May, the EVA Task 2 working group had a kickoff meeting at Carmenta in Gothenburg.

The main focus areas during the summer and autumn were

- During a series of working meetings and workshops the design, content and standards of the Emergency Vehicle Approaching warnings where agreed on in the working group.
- Latency end-to-end measurements of Emergency Vehicles warning messages in the AD Aware Traffic Control project that supported autonomous driving cars with information on emergency vehicles.

The working group also decided that there will be a combined demonstration and filming event, which was planned for the following year.

2019

January

Carmenta showcased the data flow of Emergency Vehicle Approaching messages through the Nordic-Way 2 Interchange node (**Error! Reference source not found.**).

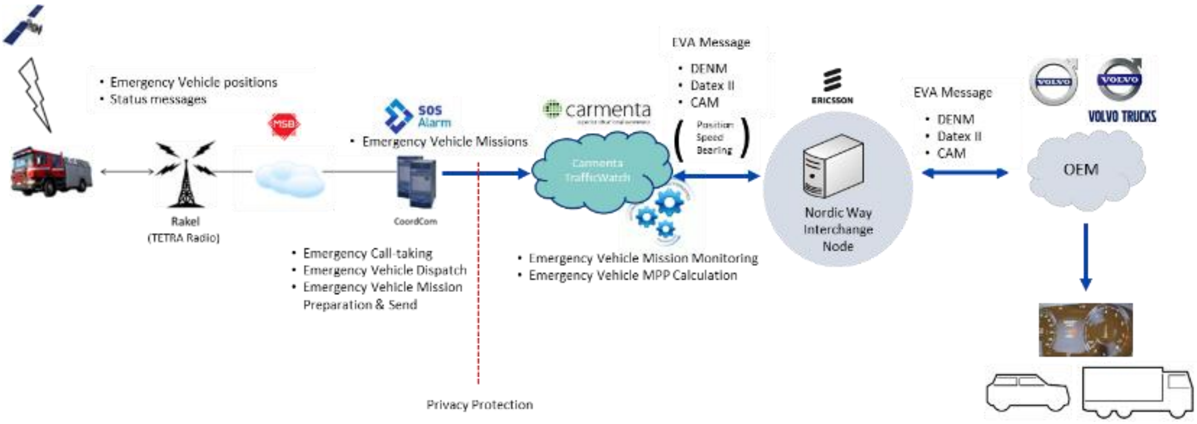

Figure 2. Illustration of Data flow for Emergency Vehicle Approaching warning messages.

Volvo Cars submitted a proposal for an extension to DATEXII with Emergency Vehicle Assignment Information. The extension was later approved and is available at the DATEXII official webpage in the extension directory (http://datex2.eu/implementations/extension_directory/emergency-vehicle-assignment-information-extension)

February

Volvo Cars demonstrated receiving EVA warning messages in the Volvo Cars Cloud from the NordicWay 2 Interchange node through the DATEXII channel (Figure 3).

Figure 3. Screenshot from Volvo Cars showing the cloud processing of EVA warnings displayed on a laptop.

Volvo Cars also showed a first version of the car prototype HMI.

Carmenta demonstrated the first EVA DENM messages sent through the Interchanged node and displayed in a map client (Figure 4.).

Figure 4. The first EVA DENM message sent from Carmenta TrafficWatch through the Interchange node.

March

Volvo Trucks demonstrated receiving EVA messages in their cloud from the NW2 Interchange node through the DENM channel and visualized the messages in the truck HMI prototype implementation.

A workshop was held at VTI in Linköping with around 60 delegates from various blue light organizations and authorities, including emergency vehicle drivers (Figure 5.).

Figure 5. Presentation of EVA for delegates at the VTI workshop in Linköping.

September - October

The Emergency Vehicle Approaching Pilot was conducted in Gothenburg with Carmenta, Volvo Cars, Volvo Trucks, Ericsson and VTI demonstrating how EVA messages are presented for drivers in the test vehicle HMI's (Figure 6).

The NordicWay 2 EVA film was recorded and produced, the videos are available on the NordicWay project website, http://www.nordicway.net/demonstrationsites/emergency-vehicle-approach.

Figure 6. Line up in front of test vehicles during demonstration and filmning in Gothenburg.

An Ecosystem Workshop for the Emergency Vehicle Approaching system was performed, led by SWECO. The results are presented in the Service Ecosystem chapter (Figure 7).

Figure 7. Ecosystem workshop with the EVA working group.

December

Evaluation work and preparations for report and continuation in NW3

2020

January – March

Preparations for presentations and demonstrations at the NordicWay 2 showcase Gothenburg in April (later postponed until October).

April – September

Writing of report and evaluation work.

October

Showcase Sweden performed as a digital event.

4 Technical description

The scope of the work done in NordicWay 2 regarding the Emergency Vehicle Approaching messages includes the parts from the integration and connection with SOS Alarm until the EVA warning messages finally are received in the vehicles and a message is displayed in the vehicle HMI (Figure 8.).

The messages created are standardized Emergency Vehicle Approaching messages aligned with C-Roads service HLN-EVA (Hazardous Location Notification – Emergency Vehicle Approaching).

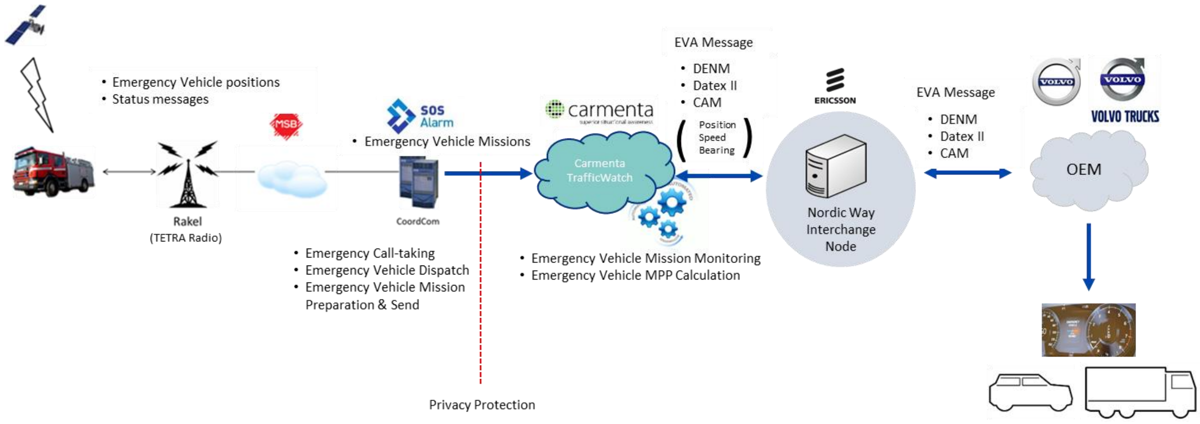

Figure 8. Description of the components used for the Emergency Vehicle Approaching warning messages in NordicWay 2.

Regarding the data chain from the emergency vehicles to SOS Alarm (including emergency vehicles, RAKEL Tetra Radio and the MSB Network), the project has used the existing solution without any changes. Those parts are very briefly described below.

Also the technical solution developed in NordicWay 2 are described in more details.

4.1 From Emergency Vehicles to SOS Alarm

4.1.1 The Emergency Vehicle

Emergency Vehicles have in-vehicle systems to receive, sign orders and calls from the SOS Alarm command central. In Sweden the rescue services use the RAKEL system for secure communication between the Emergency Vehicle and the command central. The vehicle registers and sends its positions using the GPS functionality that is part of the onboard RAKEL system. The equipment in itself can come from any certified RAKEL supplier, but it implements a common set of basic functions including the GPS positioning.
Due to limitations in the current radio-based communication solution that have been used during the execution of NordicWay 2, the GPS positions can only be updated and transmitted every 15 to 25 second.

4.1.2 The RAKEL (Tetra) Radio

RAKEL (RAdioKommunikation för Effektiv Ledning) is the system for radio communication used by Swedish security organizations and rescue services, mainly the police, the military police, Emergency Medical Services and Fire & Rescue Services and SOS Alarm.
RAKEL uses the TETRA standard (Trans-European Trunked Radio Access) which is developed by ETSI (the European Telecommunications Standards Institute) for secure radio communication.

4.1.3 The MSB Network

MSB (Myndigheten för samhällsskydd och beredskap) is the Swedish Civil Contingencies Agency responsible for operating the Swedish RAKEL network. SOS Alarm uses this network for communicating with the Emergency Vehicles, all information about positions and status are transmitted through this solution.

4.2 Integration between SOS Alarm and Carmenta

Carmenta TrafficWatch have a direct communication from CoordCom/Zenit, the command center system operated by SOS Alarm for mission handling.

As soon as a rescue mission is started in the Zenit system, the positions of the emergency vehicles assigned to that mission, together with the destination area (not the exact position to protect privacy) are sent automatically.

The data is transmitted through a secure communication solution using a standard AMQP message broker.

4.3 Carmenta TrafficWatch

Carmenta TrafficWatch™ is a powerful, cloud-based system that gives situational awareness for connected and automated vehicles.

In NordicWay 2 Carmenta TrafficWatch is used to create the standardized Emergency Vehicle Approaching messages and send them to the Interchange node.

4.3.1 Most Probable Path calculation

When a new Emergency Vehicle mission is received by Carmenta TrafficWatch a Most Probable Path (MPP) is calculated from the position of the emergency vehicle to the position of the incident.

When calculating the MPP the fact that it is an emergency vehicle that do not have to follow certain rules of traffic is taken into account. The Emergency Vehicle might take a route with the shortest total distance, even if it means driving against the traffic for a short period of time. The MPP calculation also takes into account that emergency vehicles normally exceeds the speed limit by a certain factor.

MPP calculations in Carmenta TrafficWatch are re-run each time an updated position is received from an emergency vehicle and any changes to the EVA message are dispatched as needed.

The final destination of the emergency vehicle is currently obfuscated so that no private data is possible to extract from the information sent out from Carmenta TrafficWatch.

4.3.2 Creating the EVA messages

As there is great uncertainty in knowing the exact route the driver of the emergency vehicle will take, only the part of the MPP that the vehicle by certainty will take is transmitted. Therefore the calculated path is reduced to include only the sections which have the highest probability of being used. This ensures that geometries included in the send messages are always relevant to the end user.

In order to supply sufficient information to the end user, also the heading and speed is calculated by interpolating this information from previous points. This information is added to the messages sent on to the vehicles.

The EVA system supports three different standardized formats for communication of EVA messages; DENM, CAM and DATEXII. Each contains all relevant information that is needed to display messages in the receiving vehicles.

4.3.3 Sending the EVA messages

The EVA messages are dispatched via the Interchange Node to the relevant OEM clouds, from where EVA warning messages are sent to the relevant vehicles.

Using the Interchange node, each message is sent as a payload and the parameters are set to reflect the information within the payload, to make the filtration easier when consuming the data.

4.4 The NordicWay Interchange Node

The Interchange node was developed by Ericsson in NordicWay 1 and developed further in Nordicway 2. Interchange nodes has also been developed in Norway and Finland. It is an AMQP (Advanced Messaging Queening Protocol) publish-subscribe message broker and it is further described in appendix 1; *NordicWay 2 Data Interchange Node Architecture*.

4.5 From Interchange Node to Vehicles

Two different OEMs participated in this pilot, both connected via their backend to the Interchange node. An intuitive HMI is a good support for the driver so development HMIs for both cars and trucks were used to visualize the EVA message were also included in the pilot.

4.5.1 Volvo Car Corporation

The test vehicle in the pilot was connected to the Volvo Cars cloud using the cellular network to report its position and receive information back.

4.5.1.1 Cloud application

The cloud application's (Figure 9) responsibility is to receive the EVA message from the Interchange node, determine which vehicles are concerned and convey the EVA message to them.

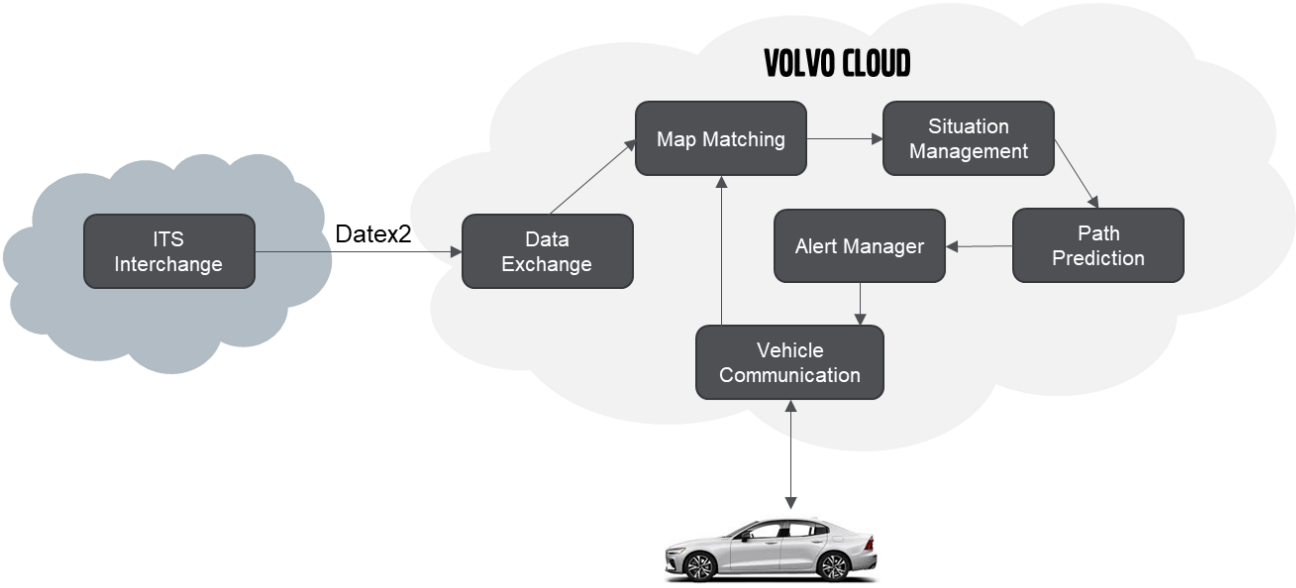

Figure 9. Schematic description of Volvo Cars' cloud application.

4.5.1.2 DATEXII extension

Volvo Cars cloud is using DATEXII to communicate with the Interchange node and as part of the project an extension for Emergency Vehicle information using existing DATEXII elements was developed (Figure 10) The DATEXII extension was later approved and is available at the DATEXII official webpage in the extension directory.

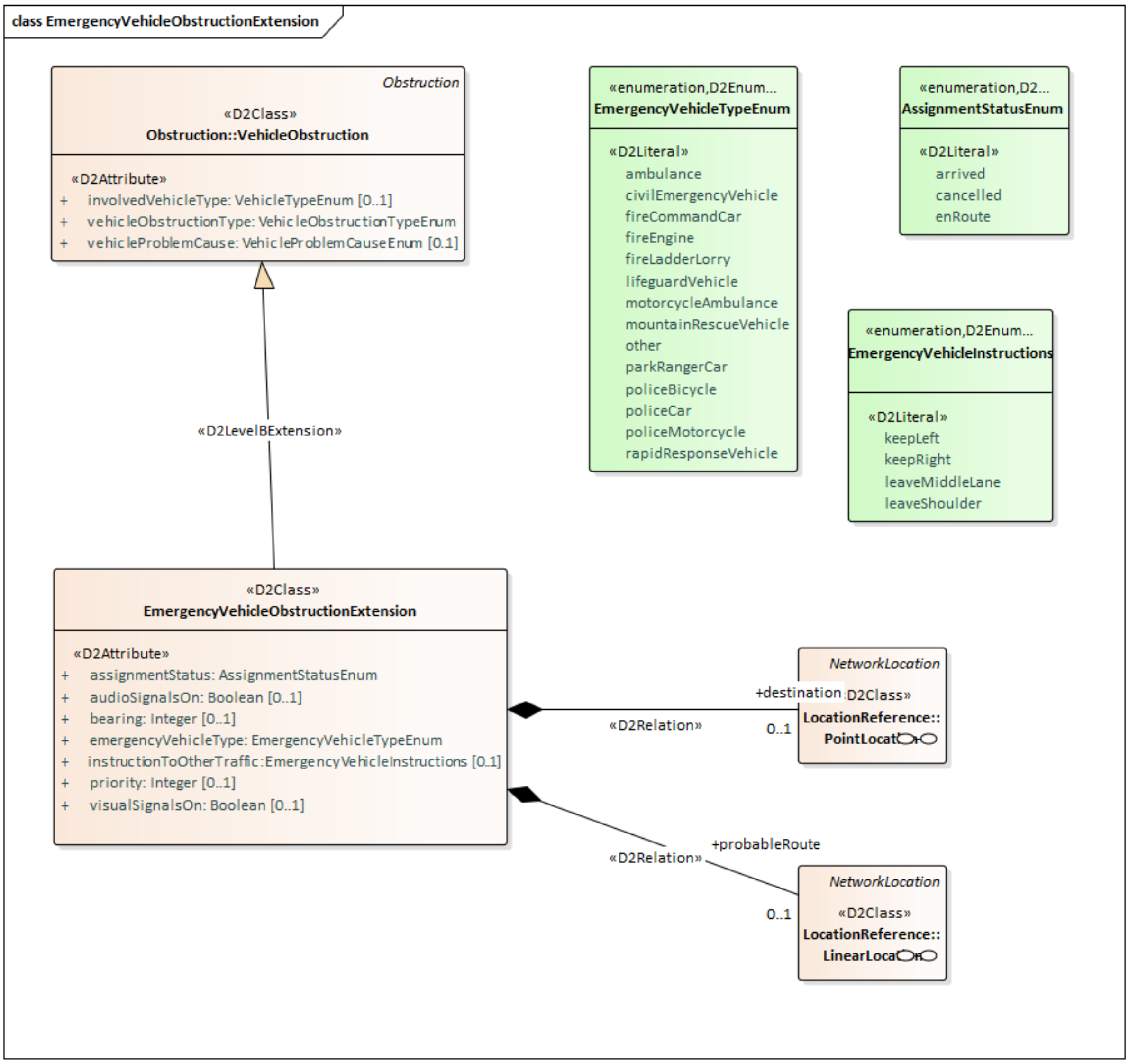

Figure 10. The DATEXII Emergency Vehicle extension.

4.5.1.3 In-vehicle HMI

An HMI concept was developed for the NordicWay 2 project (Figure 11.).

The position of the ego vehicle (ego vehicle refers to the vehicle that contains the sensors that perceive the environment around the vehicle) was shown on a map in the driver information module. Information was received through the cloud, and when an ambulance was getting closer to the ego vehicle, the driver was notified by a message indicating that it was time to give free passage for the ambulance.

The idea was to notify the driver before the siren of the ambulance could be heard, both to make it faster for the ambulance to reach the destination and also to make the driver of the ego vehicle less nervous about the situation.

The solution for Volvo Cars' test vehicle was to install a screen that replaced the driver information module, DIM, which was moved to the glove box. The computer and other needed equipment were stored in the luggage compartment in the test vehicle.

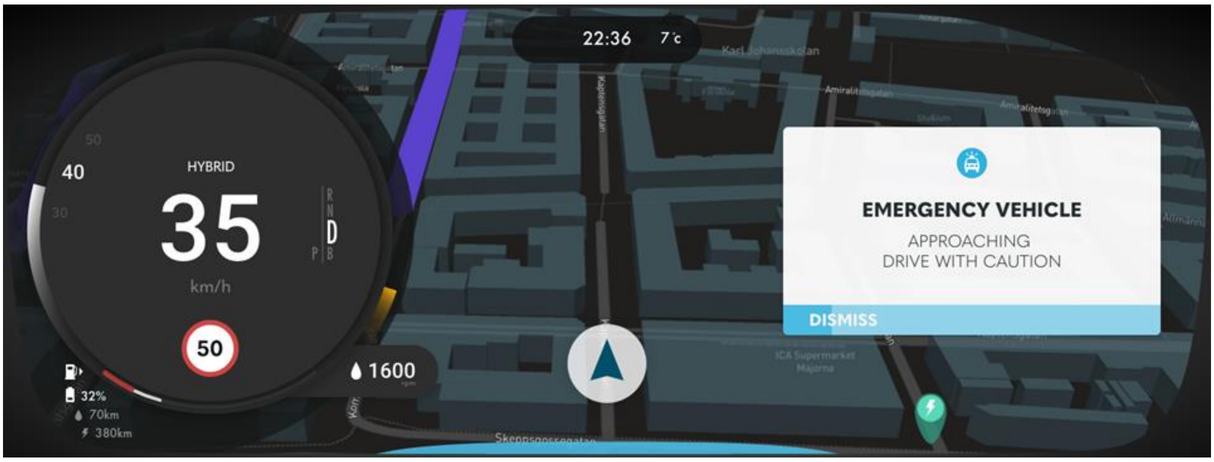

Figure 11. Protype HMI from Volvo Cars displaying EVA warning message. This HMI prototype is for research projects, not intended for production.

4.5.2 Volvo AB

The Cooperative Intelligent Transport Systems (C-ITS) implementation includes a vehicle application residing in an onboard system installed in a truck and a cloud application. The in-vehicle system is responsible for communicating with the cloud application and with the built-in instrument of the truck while the cloud application connects to the NordicWay 2 interchange node.

4.5.2.1 Cloud application

As depicted in (Figure 12) a C-ITS data service subscribes to the common distribution node. From there, warning and notification messages in CAM/DENM [ETSI reference: https://www.etsi.org/deliver/etsi_en/302600_302699/30263703/01.03.01_60/en_30263703v010301p.pdf] format are received. After that the C-ITS Filtering service will examine the content of received messages and decide which vehicles the messages should be forwarded to.

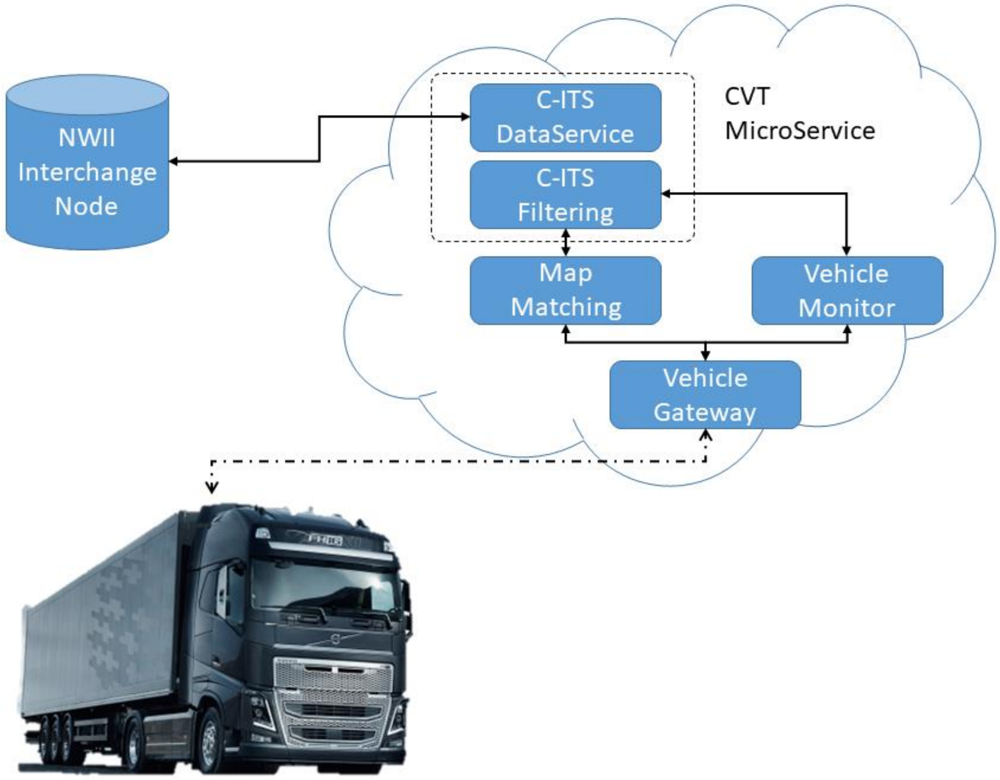

Figure 12. Schematic description of Volvo AB' cloud infrastructure.

4.5.2.2 Vehicle application

After reception of message relevant to a specific vehicle the onboard system executes a more detailed relevance check on the received messages, e.g. taking into account a set of predefined factors like speed, heading, etc. If a notification is found to be in the driver's interest it would be shown on the instrument cluster of the truck. By that the driver's awareness of the upcoming situation is raised and appropriate actions could be taken well in advance.

5 Evaluation Results

5.1 Technical Evaluation

5.1.1 Latency Measurements

End-to-end measurements have been performed for the Emergency Vehicle Warnings from the Emergency Response system at SOS Alarm, through Carmenta TrafficWatch and the Interchange Node to the Volvo Cars backend cloud that the sends the messages to the cars.

The measurements where done in an adjacent projects and is available in full in this report on page 80-86: https://www.drivesweden.net/sites/default/files/content/bilder/ad_aware_traffic_control_1_2_and_3_final_report_v1.0.pdf

Measurements where performed during a two-week period from 2018-11-13 to 2018-11-27. In total, there were 31400 records of messages at Carmenta TrafficWatch from 251 different emergency missions.

The time taken when a position is sent out from an emergency vehicle until it reaches SOS Alarm has not been measured and is out of the scoop of this project to measure. Also, the frequency of the update of positions of the emergency vehicles varies a lot and it can be up to 25 seconds between position updates due to restrictions in the current version of the RAKEL Tetra network. This is however expected to be greatly improved in the near future.

5.1.2 Latency Results

In summary the average latency (single trip) between SOS Alarm and Carmenta TrafficWatch was 253 ms (Figure 13), while round trip time between Carmenta TrafficWatch and Volvo Cars Cloud was 203 ms (Figure 14).

	latency from SoS Alarm to CTC (in ms)
count	5584.000000
mean	253.269399
std	188.749807
min	31.782866
25%	134.908557
50%	229.516029
75%	341.633737
max	3531.204700

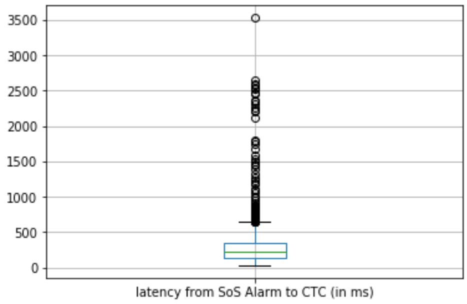

Figure 13. Results from measurements of messages sent from SOS Alarm to Carmenta TrafficWatch.

	rttCtc2Vcc (in ms)
count	1813.000000
mean	202.570916
std	70.777248
min	31.252861
25%	156.244755
50%	187.510252
75%	234.375238
max	1031.264067

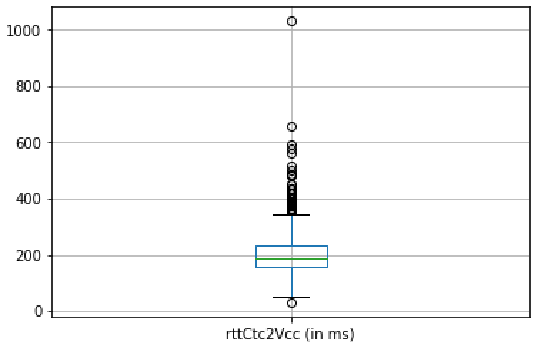

Figure 14. Results from measurements of messages sent between Carmenta TrafficWatch and Volvo Cars Cloud.

5.2 Service ecosystem

5.2.1 Method

The service ecosystem has been constructed during the Service Workshop @ October 29, 2019. The method is described in detail in the NordicWay 2 Evaluation Report.

The objective of the workshop was to describe the current ecosystem of this pilot, its actors and their roles, and to better understand the business potential and what is needed for implementation of the service. The workshop was divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilot. Thereafter a description of the current ecosystem, i.e. how the pilot is set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the work-shop a scaled-up version of the ecosystem was constructed. This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

5.2.2 Results

5.2.2.1 Current service ecosystem

Description of challenges encountered, and lessons learned in:

Forming the ecosystem (consortium, others)	• Important to explain that no cost/investment is needed in emergency vehicles • Important to explain how privacy is protected
The service formulation and provision phases	• Challenges to use existing C-ITS standards • All communication is not standardized, difference between countries • How to interpret messages for best use in vehicles • How to present to driver (in Sweden it is only allowed to inform about an approaching emergency vehicle, not allowed to order the driver to take specific measures e.g. forming an emergency corridor).
Access to data and right to use the data within the pilot (within the consortium, with public actors, with commercial actors)	• Challenge to identify owner of data – and responsible persons that have mandate to give permission to use emergency vehicle positions for the use in EVA C-ITS messages.

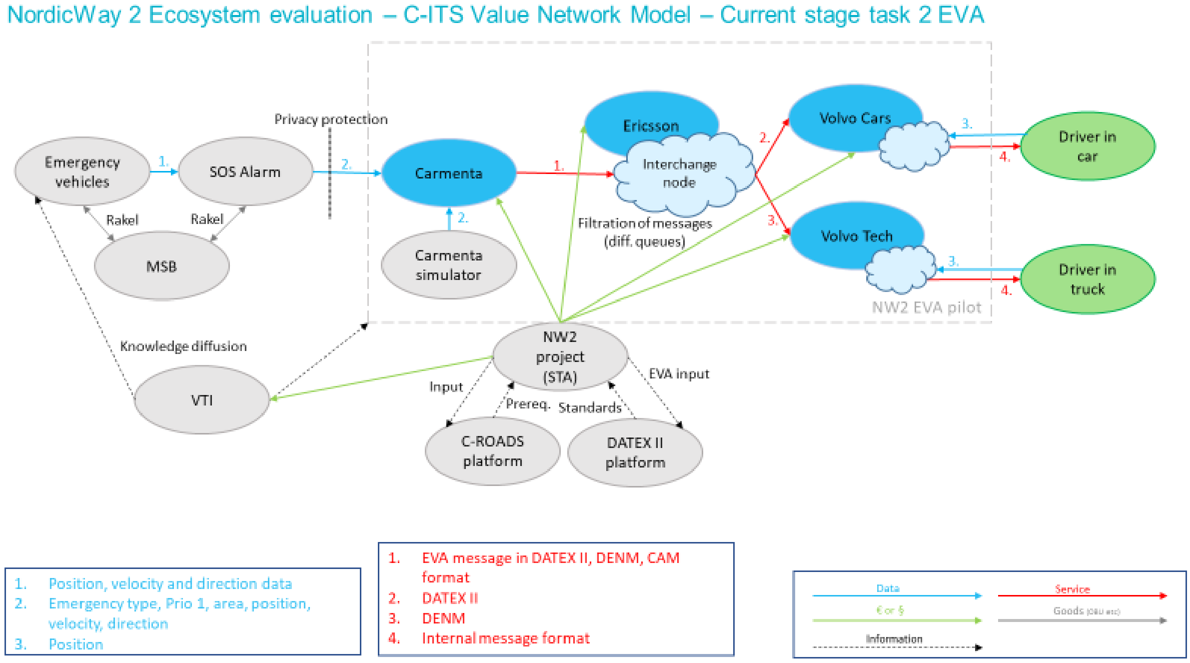

Figure 15. Current ecosystem description of EVA.

Figure 15 illustrates the current state of the EVA service. Emergency vehicles (EVs), SOS Alarm and Myndigheten för samhällsskydd och beredskap (MSB) are not included in this pilot. However, together they are the main source of data and the actors that this service is developed for, i.e. to increase the accessibility of EVs. MSB is responsible for the maintenance and development of Rakel which is a digital radio communication system for critical public safety functions. MSB works like an operator and owner of the Rakel-hardware between the EV and SOS Alarm. Carmenta has developed a simulator which can send out fake emergency alarms in order to test the system. As previously described VTI is not included in this pilot consortium but they work with the EVA service development and system evaluation and are therefore a provider of new knowledge and information for the other actors within this ecosystem. Knowledge diffusion is an important part of this ecosystem and therefore a new arrow (black dashed line) was introduced representing some kind of information exchange.

The NordicWay 2 project (via STA) funds the actors with approx. half of their costs in the project. Also, through the NW 2 project input from the ecosystem on how the service should and could be developed can be passed on to EU governed platforms such as the C-Roads and DATEX II platform. C-Roads work with harmonization of C-ITS services which is important if the service should become commercially viable in the future. The DATEX II platform provide standards on DATEX II data protocols.

It was a common agreement in the group that the users in this pilot are the drivers within the vehicles.

Pains, gains, commitment chart

Actor	Pain	Gain	Commitment
Carmenta	• Investment and resources • Data ownership uncertainty • Time consuming project administration	• Knowledge • Partnerships • Potential business • Marketing and publicity	• High commitment • Task 2 lead • R&D activity • Emergency response domain knowledge
Ericsson	• Regulation • Maybe hours worked	• Knowledge of a future role in digital eco-system	• For other applications, very out of a strategic perspective, groundwork for future more dynamic transport system
Volvo Cars	• Development, adjustment of the VCC-cloud (position, EVA, etc.)	• Cooperation partners for data from EV	• Active actor in the market/(ecosystem) • Involved in related R&D activities

		• Influence DATEXII standardization by adding EVA-messages • Influence in order to enable an implementation of an EVA service (by demonstrating the ecosystem and function of the service)	
Volvo AB	• Limited scope due to limited funding and resources	• Knowledge	• Best effort approach since limited resources and funding

5.2.2.2 Scaling up the service ecosystem

What do you expect the number of users and the turnover to be in five years from now?

It is hard to estimate a number of users. The service is limited to those who use cellular communication. In order to get more end users, more OEMs and other actors need to be involved. Maybe the service can be tested throughout all the Nordic countries in NordicWay 3.

What new actors or data sources needed in various scaling up levels? Any of the current ones becoming marginal?

Some actors might become marginal when the service is implemented such as standardization groups (C-roads, DATEX II platform). The question of who is owning the EV position data is important. Unclear now who has that mandate. The road management organisations (Cities and STA) needs to be more involved if the service is to be scaled up.

What are the implications (pros & cons) of the interchange model?

When offering several services through an interchange node at the same time, the value of the interchange node increases. A negative aspect is that it will take a long time to implement a catalogue of services and then start to offer them to the end user. Some services might be more mature than others and therefore can be implemented sooner. EVA could be such a service.

Where is investment and/or development needed?

A public body (such as MSB/STA/SOS Alarm) will have to decide that it's worth investing in this service in order for the actors to participate. In order to make this service useful, more end users need to be able to access the service. This means that more OEMs, public transport companies, fleet operators, app providers etc. need to be involved.

What should be the public sector's role?

Cities and STA need to take a more active role since they are responsible for the road management. It is important that someone takes the responsibility of running the service long term (provide support, maintenance etc.) The question of who of the public actors own the EV position data is important and will have to be investigated as a first step towards implementation.

Other issues?

The service alone will probably not be profitable in monetary terms but as a part of a whole service package with C-ITS services it could lead to a greater value.

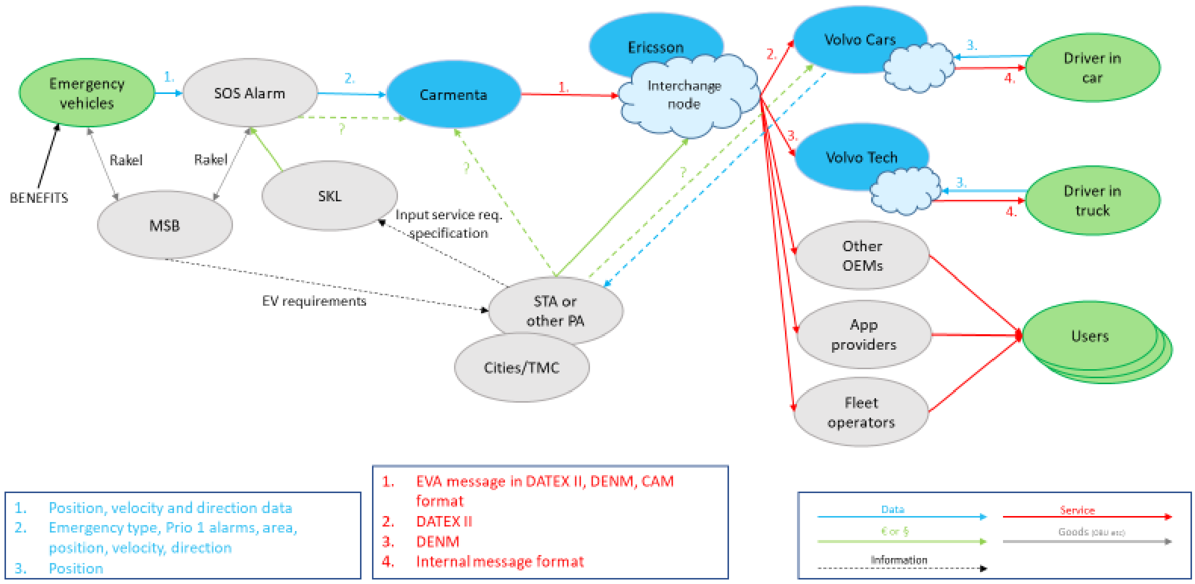

Figure 16. Scaled-up service ecosystem of EVA.

In Figure 16 a scaled-up version of the EVA service is illustrated. Some actors have been removed in this version of the ecosystem and some new actors have been introduced.

As described in the current ecosystem the main idea of the EVA service is to bring value for the EVs by increasing their accessibility on the roads. Therefore, it would seem right that the EVA service is financed by a public actor responsible for this. However, it is unclear who, among the public actors, that is responsible for providing an EVA service. It is also unclear who the owner of the EV data is and how the data is allowed to be used. These are important questions to answer in order to be able to scale up this ecosystem. In the figure two different options are illustrated where SOS Alarm and/or STA finance the operation of the EVA service, which can be procured from Carmenta or another service provider. However, other options with (partly) different actors are also possible and the way forward need to be further investigated.

Another question which needs to be addressed is who the responsible actor for operation and maintenance of the interchange node is. This needs to be in place in order to use the service as it has been developed in the pilot. In this ecosystem a suggestion is that STA or another public actor will be responsible for the interchange node and possibly outsource the maintenance to a private actor.

For the full potential of the EVA service a large majority of the vehicles on the roads needs to be able to receive an EVA warning. Therefore, some new actors (other OEMs, app providers and fleet operators) was added to this scaled up ecosystem.

6 Other results

Other results of this pilot.

6.1 Questionnaire results

6.1.1 Questionnaire 1

During conferences and events, emergency drivers performed test driving of the blue light simulator scenario. Of these participants, 41 answered the question regarding places or situations when it is not appropriate to communicate EVA-messages to other road users. Out of these 41, 10 stated that EVA is always appropriate. Of the 31 respondents suggesting inappropriate places or situations, 15 (48.4%) were paramedics, 14 (45.2%) worked with the fire brigade and 2 (6.5%) were part of the police force. Inappropriate places and situations suggested were divided into the following five categories: At limited road choices such as bridges, 2+1 roads or queues; Complex or crowded city traffic; Anonymous missions or risk for suicide; If the timing is wrong (too early or too late); It is never appropriate. The distribution of responses is displayed in Figure 17.

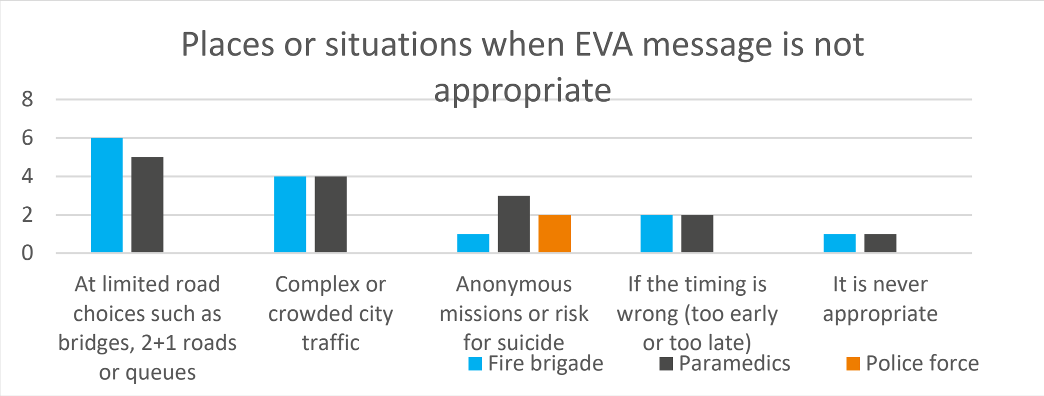

Figure 17. Answers provided by 41 participants to the questionnaire items 9 in Table 1: Places or situations when it is not appropriate to communicate EVA-messages to other road users. Divided into 5 categories and presented per profession.

6.1.2 Questionnaire 2

Another questionnaire where 28 participants from various organisations with interest and knowledge around emergency vehicle operations answered (Figure 18), gave the result that a clear majority (27 of 28) of the participants was positive to the concept of digitalized warnings to road users.

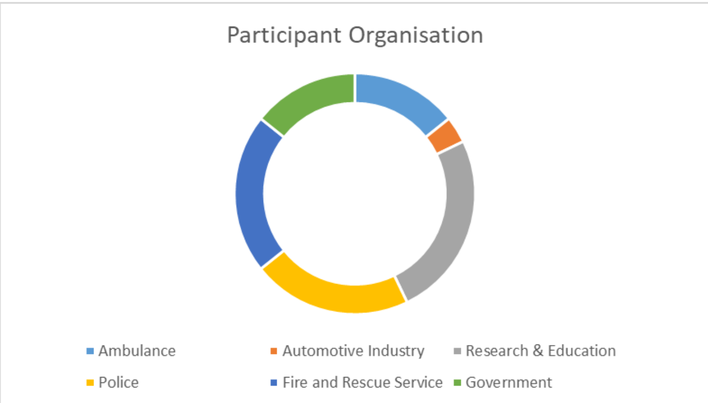

Figure 18. Organisational belonging of the 28 questionnaire participants.

The questionnaire also gave the result that the majority (64%) wanted the EVA warnings to be controlled by the driver of the emergency vehicles. Since the current NordicWay 2 solution is fully automatic where warnings are sent for high priority missions, this is something that will be addressed in future work.

6.2 Simulator study

A simulator study performed in VTIs driving simulator showed that there was an effect of EVA message on distance to the ambulance when giving way, such that two different versions of EVA messages (EVA 1 and EVA 2) caused the driver to give way earlier (i.e., at a greater distance before the ambulance caught up). In EVA 1, only the instrument cluster was used. The EVA message was presented as a yellow triangle with a blue warning light and a text message stating “Utryckningsfordon på ingång! Var uppmärksam!” [Emergency vehicle approaching! Pay attention!]. As the ambulance closed in, further instructions were displayed regarding yielding and slowing down. In EVA 2, the EVA message was additionally presented on the infotainment display in the center console. There was also an interaction effect between EVA Message and Baseline Order, such that when EVA 0 (no EVA message) was the first condition (and EVA 1 and EVA 2 followed) drivers did not give way as early when there was no EVA message, but then gave way much earlier. However, when EVA 1 and EVA 2 initialized the test and EVA 0 finished it, the drivers gave way about as early even when there was no EVA message, which implies a learning effect induced by previous EVA messages. For further reading, see Lidestam and colleagues (2020).

6.3 DATEXII extension

During the work in NordicWay 2 an extension to DATEXII regarding Emergency Vehicles has been developed. The extension with Emergency Vehicle Assignment Information has also been approved and is available at the DATEXII official webpage in the extension directory (http://datex2.eu/implementations/extension_directory/emergency-vehicle-assignment-information-extension)

7 Dissemination

Main dissemination activities performed, in order of appearance.

7.1 ITS World Congress Copenhagen September 19th, 2018

The idea and plan for the EVA task in NordicWay 2 was presented and discussed during the ITS World Congress in Copenhagen in September 2018 (Figure 19).

Figure 19. Presentation of NordicWay 2 EVA task and background at ITS World Congress 2019 by Kristian Jaldemark, Carmenta.

7.2 Workshop at VTI Linköping March 27th, 2019

A workshop was held at VTI in Linköping with around 60 delegates from various blue light organizations and authorities, including emergency vehicle drivers.

During the event NordicWay 2 was presented, a number of parallel workshops were conducted, and the participants answered two different questionnaires.

Results from the activities at the workshop have contributed to the following publications from VTI:

- Näsman, D. 2019. *Emergency Vehicle Approaching En inledande designstudie för utformning och utvärdering av användargränssnitt i en körsimulator för E.V.A-meddelande i mottagande civila fordon.* Kandidatuppsats. Linköpings universitet
- Lidestam, B., Thorslund, B., Selander, H., Näsman, D., Dahlman, J. (2020). In-Car Warnings of Emergency Vehicles Approaching: Effects on Car Drivers´ *Propensity to Give Way. Frontiers in Sustainable Cities, 2*.
- Lidestam, B., Näsman, D. (2020). Ett fordonsgränssnitt med varning för annalkande utryckningsfordon. *Transportforum 8-9 Jan, 2020, Linköping, Sweden.*

7.3 Demonstration at NordicWay 2 PMB in Gothenburg May 2019

As a part of the PMB meeting in Gothenburg in May 2019 the EVA warning messages were demonstrated in a simulated demo environment (Figure 20).

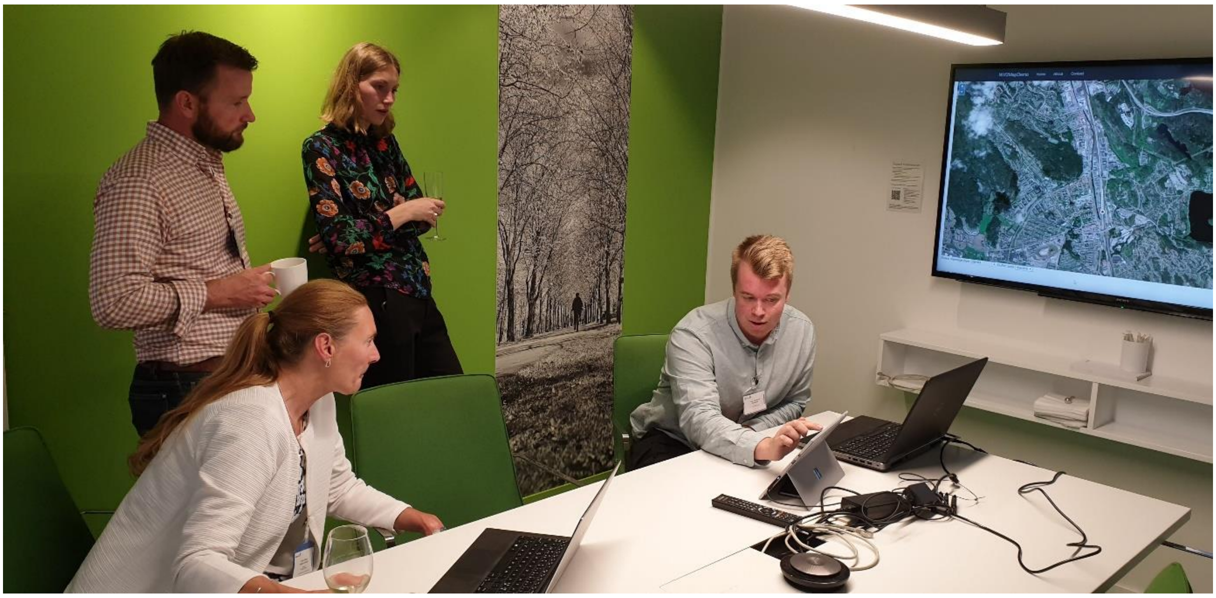

Figure 20. EVA warnings demonstrated for NordicWay 2 PMB participants in Gothenburg.

7.4 Demonstration Gothenburg October 3rd, 2019

On the 3rd of October 2019 the EVA services was demonstrated in Gothenburg, using an ambulance (contribution from VGR, Västra Götalandsregionen), a truck from Volvo AB and a Volvo Cars vehicle (Figure 21, Figure 22, Figure 23).

Figure 21. Test vehicles from Volvo Cars and Volvo AB used for demonstration and filming.

Figure 22. Ambulance used for demonstration and filming in Gothenburg.

Figure 23. Examples of how drivers are notified about approaching emergency vehicles. These are HMI prototypes for research projects, not intended for production.

7.5 Film produced from the demonstration October, 2019

The film that was produced within this task, *NordicWay Emergency Vehicle Approaching C ITS Service,* is available on the official NordicWay webpage www.nordicway.net and have been viewed more than 1000 times.

7.6 TRA 2020 Helsinki, 27-30 April 2020

A conference paper was published at Transport Research Arena TRA 2020 “User-centered development of a driving simulator for training of emergency vehicle drivers and development of Emergency Vehicle Approaching messaging: A simulator study”.

7.7 Showcase in Gothenburg

A showcase with presentations and demonstrations are planned to take place in October 2020.

8 Conclusions and recommendations

The NordicWay 2 EVA pilot, Activity 9 Task 2, has tested and demonstrated the complete ecosystem needed to provide an EVA C-ITS service on a national level in Sweden, and from a technical point of view proven that the systems works.

Results from the project together with the results from Activity 9 Task 3 indicates that a system with EVA warnings would be beneficial for the response time of emergency vehicles.

Workshops, questionnaires and dissemination activities described in this report shows that there is a positive attitude from involved actors towards pre-alerting drivers who are approaching an incident or accident scene about Emergency Vehicles and also sending out EVA messages to other road users.

From a standardization point of view it is important to make sure that the information content in HLA-EVA messages fulfill the needs in order to create a driver-centric presentation of warning messages in vehicles. There are concerns involved when displaying warning messages to drivers, for example the risk of slowing down the speed for emergency vehicles, or in the worst case creating new incident and accidents. Further work is recommended to investigate this topic.

The solution in this pilot uses the national public-safety answering point (PSAP) in Sweden to receive information about the emergency vehicles. It would be beneficial to evaluate the solution also with other integration points for emergency vehicle information.

The ecosystem workshop concludes that there are uncertainties in ownership and responsibilities regarding the emergency vehicle information and position data used, as well as the business models that can support an upscaling of an EVA service solution in Sweden. Those matters need to be more investigated.

Regarding up-scaling to a Nordic or EU level, there is a need to continue the efforts synchronizing with EU standardization.

References

Drive Sweden; www.drivesweden.net, Strategic Innovation Program launched by the Swedish government. The program is funded by the Swedish Energy Agency, the Swedish Research Council Formas and Sweden's innovation agency VINNOVA.

Final Report - AD Aware Traffic Control; Report from previous projects, AD Aware Traffic Control, where Emergency Vehicle Warnings have been demonstrated and assessed from an autonomous driving system perspective: http://www.drivesweden.net/sites/default/files/content/bilder/ad_aware_traffic_control_1_2_and_3_final_report_v1.0.pdf

DATEX II Emergency Vehicle Assignment information extension; http://datex2.eu/implementations/extension_directory/emergency-vehicle-assignment-information-extension

In-Car Warnings of Emergency Vehicles Approaching: Effects on Car Drivers' Propensity to Give Way; Report from VTI, published in Front. Sustain. Cities, 29 May 2020 (https://doi.org/10.3389/frsc.2020.00019)

User-centered development of a driving simulator for training of emergency vehicle drivers and development of Emergency Vehicle Approaching messaging: A simulator study; Lindström, A., Thorslund, B. (2020). *Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020,* Helsinki, Finland. https://www.vti.se/sv/Publikationer/Publikation/user-centered-development-of-a-driving-simulator-f_1461823

NordicWay Emergency Vehicle Approaching C ITS Service; Film published at www.nordicway.net; https://youtu.be/gqN2aABeOPs

Nordic WAY 2

Appendix 3: Emergency Vehicle simulator studies and demonstrations report

Final report –

Emergency Vehicle simulator studies and demonstrations

NordicWay 2

Version 1.0

Date: 08. December 2020

Nordic WAY 2

Document Information

Authors

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Distribution

DATE	VERSION	DISSEMINATION
2020-05-25	1	NW2 Share point
2020-06-02	2	Report meeting Task 2 and 3
2020-06-03	3	NW2 Share point
2020-06-04	4	NW2 Share point
2020-12-08	1.0	NW2 Share point

Content

1 Introduction

Emergency driving in real-life traffic is complex, often difficult, and risky. Accident involvement for emergency driving (i.e., authorized driving in response to emergencies) has been more or less proportional to the increase of traffic and traffic density (Burke, Salas, & Kincaid, 2001; Lundälv, Philipson, & Sarre, 2010; Wilbur, 1997). The emergency vehicle (i.e., the vehicle designated and authorized to respond to emergencies) often drives significantly faster than the surrounding traffic (Petzäll, Petzäll, Jansson, & Nordström, 2011; Saunders & Gough, 2003). Speed in itself, and speed differences between road users, are hazardous. Emergency vehicles on call therefore have substantially higher accident rates than when not being on call (Bockting, 2007; Custalow & Gravitz, 2004; Gormley, Walsh, & Fuller, 2008; Pieper-Nagel & Wiegand, 2011; Unterkofler & Schmiedel, 1994). The emergency driver also often has a complex task to perform during driving (e.g., Albertsson & Sundström, 2011; Hsiao, Chang, & Simeonov, 2018; Prohn & Herbig, 2020). For instance, paramedics identify lack of education and training for emergency response driving as a main risk factor (Koski & Summanen, 2019). The emergency driver may need to communicate with colleagues and the dispatch, and to navigate. The situation in itself is also by definition stressful, since getting to and from an accident or crime site is potentially a matter of life or death.

Emergency driving is further complicated by traffic intensity, which varies considerably depending on the site of the accident, where the emergency vehicle is in relation to the accident site but also because on actions taken by other road users, such as their reactions as they notice the warning lights and sirens (Vägverket, 2008). However, other road users often fail to observe the emergency vehicle although they use their blue emergency lights and sirens (Bylund, Björnstig, & Larsson, 1997). Traffic norms (i.e., how and why road users abide by laws and regulations, and interact) also may affect how inclined the road users are to identify an emergency on call and assist in providing safe passage for it (Alonso, Esteban, Montoro, & Useche, 2017).

2 Description of the pilot

2.1 Pilot set up

Lead:	VTI			
Participants:	VTI, Carmenta (primary), Ericsson, Volvo, VCC,			
Timeframe:	Start:	Q2 2018	End:	Q4 2020

The pilot started with an existing simulator rig developed for another project. With the information collected from users, a second rig was then developed. During fall 2018 and winter 2019, a data collection with professional participants recruited by convenience from different “blue light” actors was performed at several different locations in Sweden.

2.2 Objectives

The objective was to explore the possibilities to simulate and investigate entire scenarios and add new perspectives to the emergency vehicle service cluster, through simulation activities.

The purpose of the simulations was twofold:

1) To design services, and their human-machine interaction, in such a way that safety is guaranteed and efficiency and effectiveness of the ITS solutions becomes as large as possible
2) To establish a demonstration, visualisation, and integration platform.

2.3 Activities

In this work virtual roads and traffic scenarios have been developed. These scenarios correspond to typical deployment situations collected from the other emergency vehicle use cases. Prototype user interfaces have been developed for services which do not already have an established interface design. For services which were already established and developed, an integration with the virtual, simulated environment have been carried out. This has allowed for the simulator environment to serve as a demonstrator, an integration platform and tool for testing, requirements specification, and further development.

2.3.1 Research questions and simulation set-up

The objective of this work package was to prioritize research questions, specify demo scenarios, and to develop a technical simulator specification. The method was several separate workshops carried out in March 2019 at VTI in Linköping, on the topic simulator-based training of emergency driving. There were around 60 delegates from various blue light organizations and authorities. The activities included presentations about ongoing research, panel discussions about possibilities with simulator training, workshops in smaller groups, demonstration and test driving of the blue-light simulator and the systems connected to this. During the workshops and test driving the delegates were divided in 5 smaller groups, which attended the following activities.

2.3.1.1 User group workshop

In this session the benefits and possibilities of a user group were discussed. A priority list of requested development was also established. This included for example more surrounding traffic, more complex traffic situations, and scenarios adapting according to the drivers´ behavior.

2.3.1.2 EVA-messages

The concept of Emergency Vehicle Approaching warnings in NordicWay 2 was explained and demonstrated for the participants. An ambulance application connected to the emergency response system, used as navigator and emergency driver support, was used to illustrate how a future connected system could function. After the demonstration the participants answered a questionnaire about the potential benefits of having C-ITS EVA warnings sent to traffic. A majority of the participants had the opinion that it would be beneficial for the emergency vehicles if other road users could be made aware of the emergency vehicles. See Figure 1.

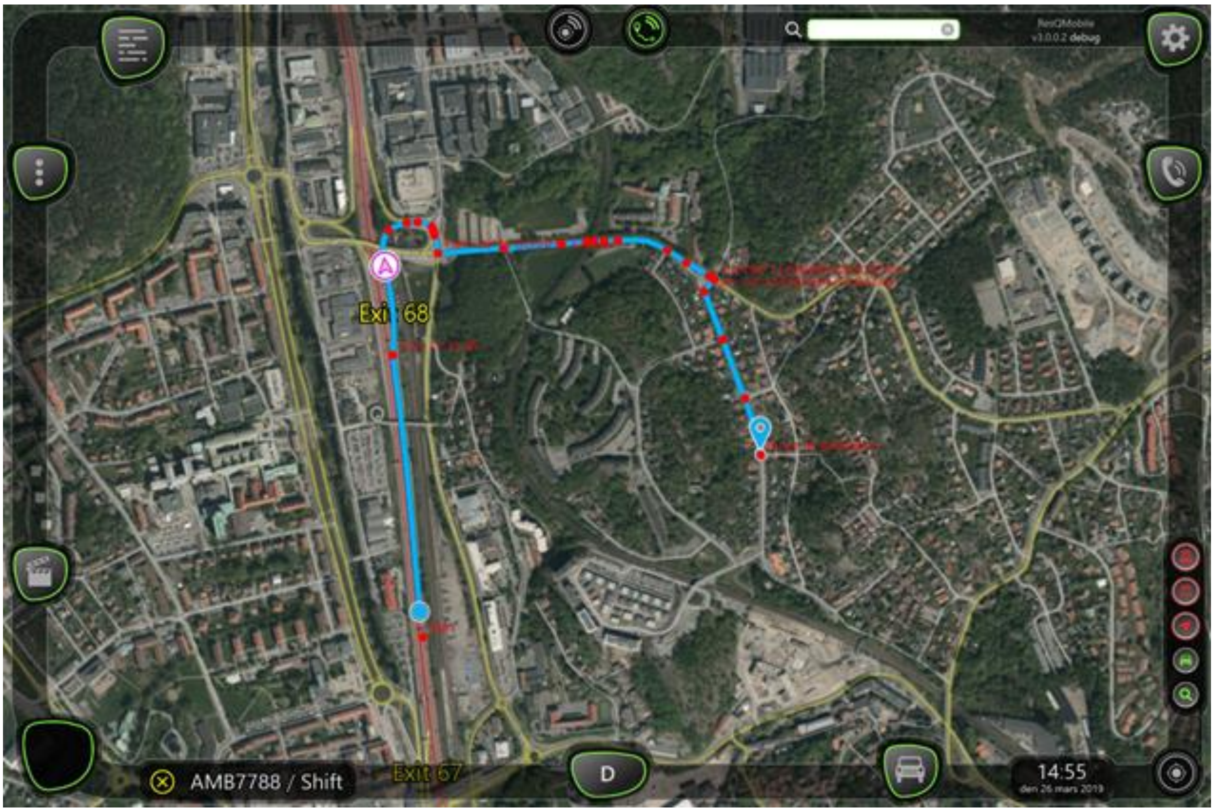

Figure 1. Carmenta ResQMobile ambulance application with demonstration of how EVA C-ITS messages can be sent to connected traffic.

2.3.1.3 Driver assistance system in blue light simulator

This session was a focus group where emergency drivers discussed EVA-messages. Representatives from the various blue light organizations all agreed that they want to be able to activate and deactivate the message. None of the groups requested a confirmation that the messages have been sent out. According to them, the EVA-massages should include information that the emergency vehicle is on its way and in which direction it is going. The message should be clear and supporting, and the timing should be 10-30 seconds before the emergency vehicle is visible. When the EVA-message is presented, other vehicle sounds should be turned off and a sound from the radio was suggested together with a symbol showing an emergency vehicle.

2.3.1.4 Emergency driving involving an AED-drone

During this simulator drive to an accident site, the participants had the possibility to send out a drone equipped with an automated external defibrillator (AED), see Figure 2. Afterwards they filled in a questionnaire with questions about the simulator and the possibility to use drones for this purpose. This was a master thesis project in collaboration with Linköping University.

Figure 2. Emergency driving with the possibility to send out a drone equipped with an AED.

2.3.1.5 Simulator study on the effects of EVA messages

The purpose of this session was to collect data to the study aiming at testing the effect of EVA messaging on drivers' propensity do give way to an ambulance on an emergency call. For this simulator Rig 2 in Figure 2 was used. This was a master thesis project in collaboration with Linköping University. The data collection was part of a student thesis and was also a contribution to a scientific paper (Näsman, 2019; Lidestam, Thorslund, Selander, Näsman, Dahlman, 2020). See further 0.

2.3.1.6 Simulator set-up

This work package aimed at defining a technical specification of how to develop simulations, driving scenarios, and how to set up simulation equipment for the research questions and use cases above.

The initial development cycle was performed using a scaled-down simulator rig (Rig 1) from a previous VTI project, which was equipped with the emergency driving scenario, see Figure 3. This rig was modified with certain add-ons, specifically designed to provide a sense of realism, and with the purpose of inducing cognitive load, similar to that under real emergency vehicle driving. To this end, the rig was equipped with communication and information devices. Some of these were mock-ups: among these was a control panel from the Rakel system provided by the Swedish Civil Contingencies Agency (MSB) and used within nearly all Swedish emergency vehicles. A fully working communication system based on walkie-talkies was also installed. A second screen was also fitted over the center console. This was implemented using an Android smartpad which alternated between showing “fake” drone photos from the accident scene, a map and (non-interactive) navigation info.

The agile method builds on close involvement with end users, who can provide valuable input and also evaluate and give feedback on the successive results from an iterative development method. It was therefore judged as important to find end users with strong engagement and professional experience, and a willingness to contribute and share knowledge. Unlike many other studies, representativeness is of less importance, why selection of subjects could take place entirely based on convenience. In this study, we included participants from both ambulance services, fire brigades, the police and sea rescue.

Therefore, subject recruitment targeted several different “blue light” actors, primarily national (Swedish) ambulance services and fire brigades, but also the police. A number of such actors, with which VTI has long-standing contacts, were invited to the VTI main office in Linköping to perform test runs in simulator Rig 1. Since both Rig 1 and the later developed Rig 2 were designed for transportability, data could also be collected in other locations, and conferences related to the subject matter were selected: Skadeplats 2018 in Helsingborg, the annual national meeting for the fire and rescue services, and Ambulans 2019 in Upplands-Väsby, a large national convent for ambulance and rescue services. A picture from the data collection set-up at Ambulans 2019 is shown in Figure 2. Rig 1 was used for data collection during fall 2018, based on which Rig 2 was developed and used for the second cycle of data collection from March 2019.

Figure 3. To the left: The scaled-down simulator rig (Rig 1) used in the first development cycle. To the right: Rig 2, at the Ambulans 2019 conference in Upplands-Väsby.

2.3.2 Simulation of Emergency vehicle warning message

This WP handles simulation activities related to the EVA message and service. A base driving scenario was developed, with the aim to demonstrate as many as possible of the emergency-related services. Concentrating on one selected road stretch and one traffic set-up was highly desirable since this allows for comparisons between different services (or designs) in identical settings. The work involved implementing a road stretch and a traffic scenario with well-defined behaviour of the actors (all other traffic) in relation to a simulator vehicle.

Deliverables from this work package are:

- A simulation scenario was created where the driver is put in the seat of the “blue light” vehicle.
- A custom-designed, small, portable simulator will be developed, to be used as a demonstrator equipment for the project.
- A recipient vehicle simulator set-up, which allows for demonstrations of the scenario to be experienced from the point of view of a driver, receiving and EVA message in her or his car.

2.3.2.1 Simulator study on the effects of EVA messages

Purpose. The purpose was to test the effect of EVA messaging on drivers' propensity do give way to an ambulance on an emergency call.

Participants. A total of 22 car drivers with valid driving licenses for a private car (category B in Sweden) participated. They were aged 19–57 years, M = 29.3 years, SD = 12,3 years, whereof 13 males and 9 females, and had had their driving licenses for 1–38 years, M = 10.1 years, SD = 12.3 years.

Design. There were three experimental conditions of EVA Message: baseline with no EVA message (EVA 0), EVA message on the instrument cluster alone (EVA 1), and EVA message on the instrument cluster and on the infotainment display in the center console (EVA 2). The design was 3 × 2 × 2 (EVA Message × Interface Order × Baseline Order) split-plot factorial, with EVA Message and Interface Order within groups, and Baseline Order between groups. EVA Message refers to the three experimental conditions (i.e., EVA 0, EVA 1, and EVA 2, respectively). In Interface Order 1, EVA 1 was presented first, whereas in Interface Order 2, EVA 2 was presented first. Baseline Order 1 had the EVA 0 baseline condition first and then either of EVA 1 and EVA 2, whereas Baseline Order 2 had either EVA 1 or EVA 2 first and finished with EVA 0.

Materials and settings. A proprietary small car simulator without motion cueing was used. The EVA message was presented as a yellow triangle with a blue waring light and a text message stating "Emergency vehicle approaching! Pay attention!". As the ambulance closed in, further instructions were displayed regarding yielding and slowing down. In EVA 2, the EVA message was additionally presented on the infotainment display in the center console. The EVA message was received 50 seconds before the ambulance was estimated to catch up with the participant's car, based on the relative speed difference.

Procedure. The test scenario took about 30 minutes to complete and was about 20,000 m long. An ambulance on an emergency call, with blue lights and sirens engaged, caught up with and passed the participant's car three times during the session (at about 3,000 m, 6,000 m, and 11,500 m from the start of the scenario). The scenario ended after the participant being passed by the ambulance for the third time, at about 20,000 m.

Results. There was a main effect of EVA message on distance to the ambulance when giving way, such that the two versions of EVA 1 and EVA 2 caused the driver to give way earlier (i.e., at a greater distance before the ambulance caught up). There was also an interaction effect between EVA Message and Baseline Order, such that when EVA 0 was the first condition (and EVA 1 and EVA 2 followed) drivers did not give way as early when there was no EVA message, but then gave way much earlier. However, when EVA 1 and EVA 2 initialized the test and EVA 0 finished it, the drivers gave way about as early even when there was no EVA message, which implies a learning effect.

Conclusions. EVA message had a significant effect on how early the drivers gave way, such that the EVA message made the drivers give way at much greater distances to the ambulance than when there was no EVA message. There was also a learning effect such that after receiving the EVA message, the drivers gave way early even though there was no EVA message. The EVA message thus improved the driver's propensity to give way early.

2.3.3 Demonstration of the solution

The objective of this WP was to provide compelling interactive demonstrations of the impact of EVA message introduction in real traffic. Demonstration of the solution and its applications have been shown at internal NordicWay meetings and will be shown as part of the Swedish Pilot Demonstrations. Attendance and interactive demonstration at the following conferences and events, continuously during the development process, have also been a major part of this WP:

- *Skadeplats 2018 Helsingborg, arranged by Brandskyddsföreningen with main focus on fire fighting.*
- *Framtidens skadeplats 2019 Linköping, arranged by Linköping University, CARER and KMC with focus on prehospital care.*
- *Mobila vårdens dag 2019 Linköping, arranged by Region Östergötland and Linköping university*
- *Skadeplats 2019 Upplands Väsby, arranged by Brandskyddsföreningen with main focus on fire fighting.*
- *Flisa, Karlstad 2019 arranged by Landstinget with main focus on medical care.*
- *Framtidens skadeplats 2020 Linköping, arranged by Linköping University, CARER and KMC with focus on prehospital care.*

3 Technical description

The simulator can provide multiple views of the same driving scenario, of which the two most important in this context are:

- the driver's view from an emergency and rescue vehicle,
- the driver's view in a truck or car being part of the same scenario, at the receiving end of an "Emergency Vehicle Approaching" message.

The scenarios are available both in a large moving base simulator for highly realistic driving as well as in a small custom simulator that can be easily transported for demonstration at different locations.

The driver environment is an authentical Volvo-chassi including an adjustable seatbelt, steering wheel with actuators, clutch, gas pedal and brake pedal. See Figure 4. Copying a real car gives the simulator high realism. The feeling of sitting in a car is a familiar situation which is connected with responsibility for the car and other road users. The measures are 190 × 123 × 159 cm (length × width × height). The weight is 270 kg.

Figure 4. Driver environment is made as realistic as possible.

The dynamical model of the vehicle used in the simulator is the same as in the simulator with a moving base, which has the following 14 degrees of freedom (DOF):

- Linear movement: longitudinal and lateral movement (2 DOF)
- Rotations: roll, pitch, and yaw (3 DOF)
- Vertical movement (1 DOF)
- Wheels vertical movement (4 DOF)
- Wheels rotating speed (4 DOF)

The vehicle dynamic model is implemented with Matlab-Simulink software. The model is divided into the following subsystems to facilitate adjustments and changes; brakes, steering wheel, powertrain, wheels, suspension, axels, chassis.

4 Evaluation Results

4.1 Technical evaluation

4.1.1 Method

This pilot differs somewhat to the others and measures of KPIs has not been made. However, the simulator has been shown a useful and appreciated tool for both emergency vehicle driving and general drivers receiving information about emergency driving. It would be therefore be possible to use the simulator to evaluate the effect of changed latency (KPI_Q08), of message success (KPI_Q10) rate or of cross boarder continuity of service (KPI_Q12). Cross-organizational/cross-brands data sharing (KPI_Q13) is also possible to test and evaluate in a simulator environment.

4.1.2 Results

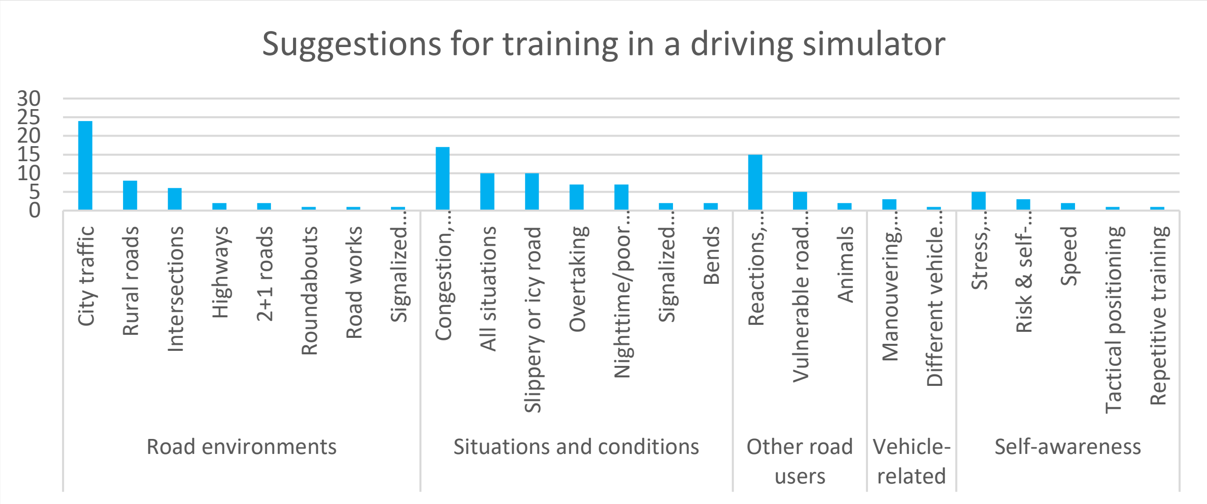

Figure 5. Answers provided by 79 participants to the question "What events or situations would you like to train in a simulator?". A total of 138 suggestions are divided into categories and presented in falling rank within each category.

A technical evaluation, made by professional emergency drivers, suggested the simulator useful for training many various situations, which can be difficult or illegal to train on the real road. See Figure 5.

Participant main suggestions of improvements and development of the simulator where the following:

- Possibility to practice reverse driving, maneuvering, and positioning at crash site.
- Driver feedback, both directly and afterwards.
- Logging of driving to facilitate education.
- Surrounding traffic is affected by the driving behaviour of the emergency driver. A driver who clearly shows his or her intentions will make other road users give way and act more rational.
- Possibility to change vehicle, for example from a light police car to a medium heavy ambulance and a heavy fire truck.

4.2 Service ecosystem

In collaboration with the Emergency vehicle approaching pilot a workshop discussing the service ecosystem for the EVA service was held on October 29th, 2019. The results are presented in the EVA pilot final report.

5 Other results

The work performed in this pilot has resulted in several invitations to demonstration events, such as conferences and branch meetings. There has also been a fruitful collaboration with the university in Linköping involving two master theses. Several publications have been accomplished, at conferences, in a scientific journal, reports. See further 0.

6 Dissemination

The dissemination activities include one paper in a scientific journal, one conference paper and a VTI-report.

Eriksson, G., Thorslund, B., Lidestam, B., Stave, C. (2020). Körsimulatorer och utryckningskörning: Erfarenheter från en förstudie. Transportforum 8-9 Jan, 2020, Linköping, Sweden.

Näsman, D. 2019. *Emergency Vehicle Approaching En inledande designstudie för utformning och utvärdering av användargränssnitt i en körsimulator för E.V.A-meddelande i mottagande civila fordon.* Kandidatuppsats. Linköpings universitet

Lidestam, B., Thorslund, B., Selander, H., Näsman, D., Dahlman, J. (2020). In-Car Warnings of Emergency Vehicles Approaching: Effects on Car Drivers´ *Propensity to Give Way. Frontiers in Sustainable Cities, 2*.

Lidestam, B., Näsman, D. (2020). Ett fordonsgränssnitt med varning för annalkande utryckningsfordon. *Transportforum 8-9 Jan, 2020, Linköping, Sweden.*

Lindström, A., Thorslund, B. (2020). Driving simulator – based training for emergency vehicle drivers. *Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020,* Helsinki, Finland.

Thorslund, B., Lindström, A., Lidestam, B., Stave, C., Dahlman, J., Eriksson, G. (2020). Simulatorbaserad träning för utryckningsförare: En förstudie. *VTI Rapport 1037.*

7 Conclusions and recommendations

The most difficult situations for emergency vehicle drivers are vehicles in front suddenly braking and failure in other vehicle drivers noticing the emergency vehicle. Desired behaviour in other road users is to yield to the right and if braking, brake smoothly. Most urgent to train in a driving simulator is city traffic with congestion, queues, obstacles and limited view, and other road users' reactions, unexpected behaviour and panic braking.

The attitude towards communication of EV driving to other road users is positive, regarding both pre-alerting drivers who are approaching an incident or crash scene and sending out EVA messages.

VTI will continue the user-involved agile work with the emergency driving simulator. There are also plans for more projects looking at how to present EVA messages to both manually driven and automated cars. For private road users, a project has been initiated to examine possible inclusion of driving simulators at the driving test.

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Appendix 4: Signalized Intersections report

NordicWay Activity 9
Signalized Intersections, Task 4, 5 and 6

Authors

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2020-09-01	0.52	Aligned with central template	
2020-09-15	0.53	Revision before “freeze” ?!	
2020-10-29	1,0	Frozen	
2020-11-30	1.1	Final edition	

Nordic WAY 2

Content

1 Introduction

This report is a summary of activities during the project time, 2018 – 2020 within the topic of signalized intersections and in accordance with the Grant Agreement, Activity 9 and Task 4, 5 and 6. It is a part of reporting the Swedish NW2 project.

The work has been divided in three tasks. Task 4 with use cases around “time to green”, TTG, and “time to red”, TTR. Task 5 has mostly dealt with workshops on themes around priorities for Public Transport – with a small showcase in Uppsala - and workshops with theme “signal violation warning” and “in-vehicle-signage – lane closure, speed and queue warning”. Task 6 has dealt with a use case of “green light optimisation advisory”, GLOSA.

The mentioned services are part of C-ITS defining of Day 1 and Day 1,5 services. The aim is to influence society values such as improving traffic safety, reducing environmental impacts etc. Also driving aspects influencing safety, calming down traffic are of value.

The C-ITS services are:

Signage applications:

- In-vehicle signage
- In-vehicle speed limits
- Signal violation/ intersection safety
- Green Light Optimal Speed Advisory
- Probe vehicle data

Day 1.5 services:

- Information on fuelling & charging stations for alternative fuel vehicles
- On street parking information and management
- Traffic information & Smart routing
- Cooperative collision risk warning

2 The services and use cases included in task 4, 5 and 6

2.1 According to service definition and use cases and messages.

The service is to provide information to road users to support safe and efficient crossing of signalised intersections. The implementation of the use cases should increase traffic safety and traffic flow efficiency and reduce adverse environmental effects following from erratic and stop-and-go driving (from Service Definition document).

The services which have been tested and demonstrated are Task 4, Time To Green, Time To Red, task 6, Green Light Optimal Speed Advisory, and in task 5, Traffic Signal Priority Request have also been tested and demonstrated. Predictions of phase shifts as time to green and time to red have also been used to enable new fuel efficiency functionality.

There have also been several workshops – task 5 - on some other services as signal violation warning, in-vehicle signage for lane closure, speed and queue warning services and to some extent also demonstration of priority for public transport.

More descriptions are presented in chapter 4.3 and 4.4 below and in the documents Service and Use Cases and Service Definitions Messages where all types of abbreviations and definitions are presented.

2.2 Terms and abbreviations

All terms and abbreviations in this document are to be found in the document Service Definition and Use Cases and Messages

2.3 Short description of Swedish conditions

The services have been tested in some signalized intersections representing different existing control strategies in Sweden. That has been an important part of the work as it influences the result of the services essentially. In Sweden they are Fixed Time control, Vehicle Actuated control and Adaptive Signal control and they include as well “large” intersections as “smaller” pedestrian crossings.

None of the signalised intersections in operation in Sweden have been developed for connection to vehicles of any type. Thus, there is a process to get data of good enough quality for the purpose of improvements in terms of efficiencies and support for drivers and at the end autonomous driving. Below is a short description of existing control strategies in Sweden.

Fixed Time control means that the signals shift and timings are predefined all days around and following that SPaT- messages are exact. This means that Fixed Time solutions are controlled by a clock based on assumptions on traffic flow over the day, time of day or week. These types of signalised intersections are not that common in Sweden nowadays.

Vehicle Actuation means that the vehicles can influence length of timings and also to some extent the order of phases. This includes specially prioritized Public Transport vehicles. The solution is based on sensors coupled to the control equipment measuring flow intensity in each of the lanes or the push bottoms for pedestrians. That data is handled by an algorithm controlling length of phase and order between them. The solution makes it difficult to predict when green or red is to come.

An example of this is “when will it be green” in a vehicle actuated signalised intersection? Today it is almost impossible to get that data on a good second level as nobody knows what will happen in the short-term future on second level, depending on the flexibility of actuation and meeting the demands of road users – so a new paradigm has to come.

These types of control are the most dominant ones in Sweden, both for so called isolated as coordinated control.

Adaptive Control – common abroad – is based on optimising algorithms iterating on short time intervals for a minute or so time horizon taking into account demands from e.g., pedestrians, Public Transport and thus the short-term predictions will be rather accurate and thus the timings, -SPaT-data, will have a rather high correctness. See further on for city of Uppsala.

3 Descriptions of the PILOTS

The pilots include technical tests/demonstrations on several locations with different actors as well as common workshops among the actors and described in 4.5. Each of the actors and their roles are also described below.

In this section are each of the services described in a principle way. In the Technical Description, is available in chapter 4 and include activities and methods.

Results and developments from NordicWay 1 and the Vinnova program Drive Sweden will be taken into consideration and will be reused where applicable. The infrastructure, Traffic Signals and system-architecture, will be re-used from the Drive Sweden project “KRABAT WP7 Connecting Traffic Signals and Signs”. This infrastructure is “under construction” and was available in end of 2018.

An important objective of NW 2 is that activities shall lead to commercial solutions that can be utilized and operated internationally, in the Nordic region, in Europe and hopefully in the global scene. Service Definitions will be taken into consideration when comparing with C-Roads.

We have worked in a collaborative and joint way and aiming for a “good enough” level of the actions. With “homework development” as a baseline we have coordinated all partners’ common level of progress, following tests/demonstrations with a certain level of quality and evaluate the performance and other parameters. The idea has been to develop the services in a “step by step” approach regarding complexity and other.

3.1 Pilot set up

Services within Task 4, 5 and 6 are described below

3.1.1 TTG, Time To Green and TTR, Time To Red, Task 4

Lead:	RISE			
Participants:	Swedish Transport Administration, City of Gothenburg, City of Stockholm, City of Uppsala, Volvo Cars Corporation, AB Volvo, Scania, Zenuity, Swarco, Technolution, Ericsson AB			
Timeframe:	Start	2017-01	End:	2020-12

Objectives

Purpose of Service TTG based on Traffic Signals is to provide solutions prepared for implementations / roll out in a near future.

3.1.2 TSP, Traffic Signal Priority, Task 5

Lead:	RISE			
Participants:	Swedish Transport Administration, City of Uppsala, Volvo Cars Corporation, Scania, Zenuity, Swarco and Technolution. Some of the partners attended only the Workshops and some other made the pilot tests in Uppsala			
Timeframe:	Start:	2017-01	End:	2020-12

Objectives

In practice demonstrate the technical dataflow from the bus to the traffic light in the intersection. Focus will be how we shall use the standard format "message" from J2735 specification, the Signal Request Message, SRM and the sub-sequent Signal Status Message SSM.

3.1.3 GLOSA, Green Light Optimal Speed Advisory Task 6

Lead:	RISE			
Participants:	Swedish Transport Administration, City of Gothenburg, City of Stockholm, City of Uppsala, Volvo Cars Corporation, AB Volvo, Scania, Zenuity, Swarco, Technolution			
Timeframe:	Start:	2017-01	End:	2020-12

Objectives

Purpose of Service GLOSA based on Traffic Signals is to provide solutions prepared for implementations / roll out in a near future.

In Task 6 we also have made an investigation regarding GLOSA from different perspectives such as what are the expected results, how could GLOSA be implemented.

3.2 Who have participated?

A prerequisite to achieve these services is a cooperation between several type of businesses and roles. They are and their role are described below. Project Leader and coordinator has been RISE.

3.2.1 Road authorities

The road authorities are:

- Swedish Transport Administration
- Urban Transport Administration, City of Gothenburg
- Traffic Office, City of Stockholm
- City of Uppsala

3.2.1.1 Swedish Transport Administration/ Trafikverket

The Swedish Transport Administration (STA) is responsible for long-term planning of the transport system for all types of traffic, as well as for building, operating and maintaining the national network of public roads and railways. It is an administration that takes road safety seriously, "Vision Zero" is in fact a Swedish policy innovation which requires continuous work.

In this part of NW2 we believe that STA´s most important contribution has been to be a speaking partner on questions concerning risks and safety issues of end functionality solutions in its combination with traffic signal control and Swedish traffic regulations. Together with the other road authorities we also overview and share our common points of interest.

STA connected one intersection in Gothenburg, E6.20 - Gustaf Larsons väg, to the interchange node. It delivers SPaT data according to J2735 except for prognosis data. The connection was established with RSMP through a platform outside STA´s ordinary process network. The adapter translating RSMP into J2735 was made by an in-house working group where the NW2 partner Technolution already was included. MAP-data was sent manually.

Latency measured from the traffic light controller to Volvo Cars was normally below 60 ms.

This intersection is fully signal group-controlled, traffic actuated and has implemented LHOVRA-strategy. Traffic actuated signal group control is the most common control strategy in Sweden. There is so far no efficient way to produce the prognosis values for this kind of control. No field tests were made in this intersection due to difficulties to produce prognosis of signal group status changes.

3.2.1.2 Urban Transport Administration, City of Gothenburg, Trafikkontoret

The Urban Transport Administration in Gothenburg has connected 6 traffic signal intersections. The connected signals provide digitalized traffic signal data (SPAT) to the Interchange Node according agreed J2735 standard. Also MAP data has been produced in J2735 standard but is sent manually to the cloud. MAP data is a digital twin of the traffic signal intersection, e g signal locations, traffic rules, stop lines, directions etc.

Apart from this we have developed a TTG and TTR prediction that is included in the SPAT data. SPAT and MAP is available for OEMs and 3rd parties connected to the Interchange Node. Latency end-to-end is usually less than 200 milliseconds (from traffic signal control system to the cars).

3.2.1.3 Traffic Office, City of Stockholm, Trafikkontoret

The Traffic Office at the City of Stockholm has taken part in NordicWay 2 mainly as a speaking partner and knowledge resource concerning the development of GLOSA, TTR/TTG and signal prioritizing services. Investigations and attempts to set up test- sites has been made during the project, but no active site has been deployed.

3.2.1.4 Urban Development Office, City of Uppsala, Stadsbyggnadsförvaltningen

The Urban Development Office has established a testing site in 6 signalized intersections at Luthagsesplanaden. The intersections are connected to a central control system used for traffic flow prediction and optimization (Swarco Utopia Spot). From the central service Traffic Light Forecast SPAT and MAP, according to the standards SAE J2735, ETSI TS 103 301 and ISO 19091 are sent. The local controllers in the intersections provide real-time for the SPAT which is sent to the Interchange Node while MAP data is uploaded manually upon change. All data from the city traffic signal is available in the Interchange Node.

The pilot tests at Luthagsesplanaden include TTG (Time to Green), GLOSA (Green Light Optimized Speed Advisory) and signal priority.

3.2.1.5 RISE, Research Institutes of Sweden

Rise Sweden's research institute and innovation partner. Through our international collaboration programmes with industry, academia and the public sector, we ensure the competitiveness of the Swedish business community on an international level and contribute to a sustainable society.

RISE has in this project, beside the role as Task Lead for Task 4, 5 and 6, conduct research within the C-ITS service GLOSA, contribute with expertise within Traffic Signals.

3.2.2 OEM´s

The OEM´s are:

- Volvo Cars Corporation
- Scania CV AB
- AB Volvo Trucks

3.2.2.1 Volvo Cars Corporation

Volvo Cars Corporation was founded 1927 and operates within the automotive sector. Volvo Car Group (Volvo Cars) is owned by Zhejiang Geely Holding (Geely Holding) of China. Volvo Cars has developed into one of the most well-known brands in the automotive industry. Volvo Cars produces a premium range of cars. Volvo Cars has high ambitions when it comes to sustainable mobility solutions, especially within electrification and autonomous drive.

In this project Volvo Cars developed a solution were VCC cloud receives traffic light information and development vehicles exchanging information with the VCC cloud using cellular network connectivity. The information from the traffic light signals was used for two purposes: support the driver waiting at a red light and to develop new energy efficiency functionality.

3.2.2.2 AB Volvo Trucks

The Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. Volvo Group also provides complete solutions for financing and service. Volvo Group employ some 100.000 PEOPLE, have production facilities in 18 COUNTRIES and sell products in more than 190 MARKETS. Our brand portfolio consists of Volvo, Volvo Penta, UD, Terex Trucks, Renault Trucks, Prevost, Nova Bus, Mack and Arquus. We partner in alliances and joint ventures with the SDLG, Eicher and Dongfeng brands. By offering products and services under different brands, we address many different customer and market segments in mature as well as growth markets.

Volvo Trucks is the second largest heavy -duty truck brand in the world with trucks sold and serviced in more than 140 countries and supported by over 2.300 dealerships and workshops. Volvo Trucks offers a range of medium and heavy-duty trucks with more than 95% of the trucks over 16 tons. The company also provides aftermarket products and service as well as specific offers. Volvo Trucks has a production structure based on global presence. About 95% of the company's production capacity is located in Sweden, Belgium, Brazil and the USA.

3.2.2.3 Scania CV AB

Scania was founded in 1891. Scania is a world leading provider of transport solutions in more than 100 countries. Together with our partners and customers we are driving the shift towards a sustainable transport system. Interaction with road infra structure is part of the sustainable transport solution.

3.2.3 System integrators, Hardware and Software developers

System integrators, Hardware and Software developers are:

- Ericsson AB
- Zenuity
- Swarco
- Technolution

3.2.4.1 Ericsson AB

Ericsson enables communications service providers to capture the full value of connectivity. The company's portfolio spans Networks, Digital Services, Managed Services, and Emerging Business and is designed to help our customers go digital, increase efficiency and find new revenue streams. Ericsson's investments in innovation have delivered the benefits of telephony and mobile broadband to billions of people around the world.

In this project Ericsson provided the NordicWay Interchange, it is described in detail in Final Report – Activity 9 Swedish pilot Appendix 1 NordicWay 2 data interchange node architecture.

3.2.4.2 Zenuity

Zenuity is a joint venture of Volvo Cars and Veoneer in the automated driving technology space. The company has a focus on design and development of driver assistance systems and autonomous drive systems for use in cars.

Connectivity is included in the platform and products developed by of Zenuity, provided to OEMs. In NordicWay 2, Zenuity contributed with a demonstration of Traffic Light Assist features, integrating Zenuity's cloud and in-vehicle logic. Zenuity's system solution included import of traffic light data, including MAP data defining location of connected traffic lights. Zenuity's cloud logic manages geo-localization of traffic lights and connected vehicles, in order to route relevant data to the connected vehicles.

3.2.4.3 Swarco

Swarco is a supplier of ITS and road marking solutions, founded in 1969. Swarco is present in 25 countries and the HQ is situated in Wattens, Austria. Among the technologies provided by Swarco one finds hardware and software for traffic monitoring and control such as traffic signals, variable message signs and central systems connected to them.

In NordicWay 2, Swarco has provided software solutions for traffic signal control and signal phase change forecasting/prediction.

3.2.4.4 Technolution

Technolution is an innovative project agency specialized in technical automation and we have been in the market since 1987. We develop hardware and software solutions for technical information systems and embedded systems. We advocate the use of open standards, open protocols and open source for scalable and sustainable solutions.

In NordicWay 2, Technolution has shared its experiences through workshops and other forums the importance of open protocols and interface when integrating roadside systems such as traffic signals and the possibilities in doing so for future services.

4 Technical Description

4.1 Geographical areas for the services

There are in practice two main areas where activities have been executed. They are in the Gothenburg area and in the greater Stockholm – City of Uppsala vicinity.

4.1.1 *Urban Transport Administration, City of Göteborg/Trafikkontoret*

The Test Area with connected traffic signals starts with Seminariegatan in North and ends with Sahlgrenska in South according below:

1. 4104 Övre Husargatan/Seminariegatan:	Actuated
2. 4101 Linnéplatsen:	Actuated
3. 3208 Dag Hammarskjöld/Carl Skottsbersgatan	Actuated
4. 3203 Per Dubbsgatan/Askimsgatan	Fixed Time (only day time and as long as no tram appears. Trams are prioritized. At night the traffic signals turn actuated)
5. 3207 Per Dubbsgatan/Sahlgrenska:	Fixed Time Controlled (same time plans as Askimsgatan)

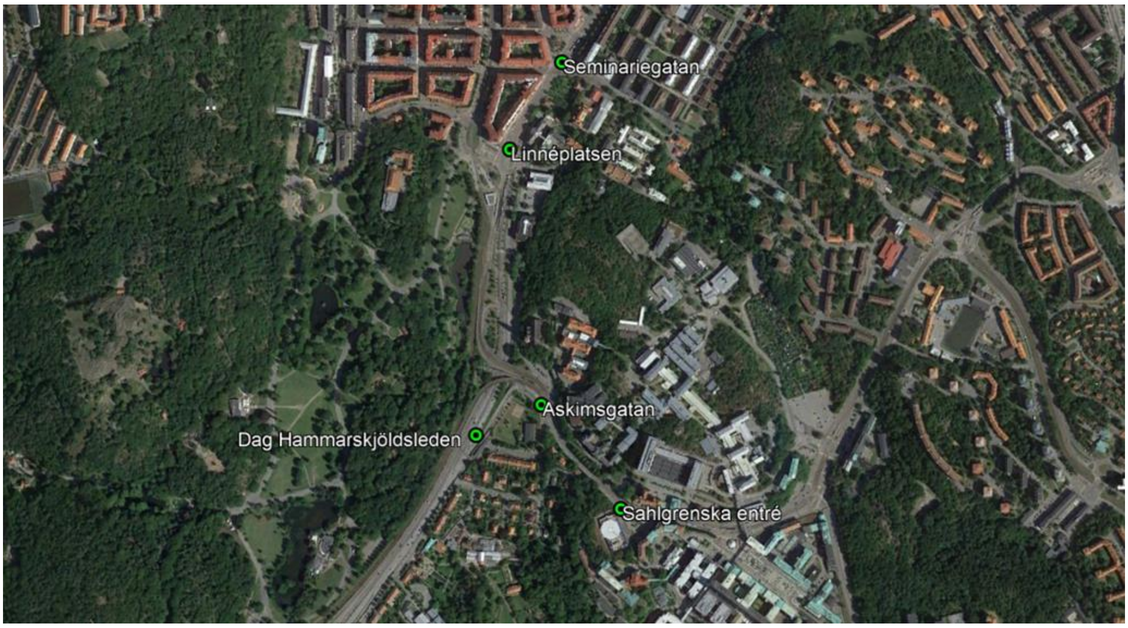

Figure 1. Test area in Gothenburg.

4.1.2 *Swedish Transport Administration*

STA connected one intersection to the interchange intended to be close to Volvo Cars for tests. Unfortunately, this test site was not ready for the field tests. This was much due to difficulties to produce estimates of "likely Time" and even "MaxEndTime" prognosis (see J2735) for signal group status changes of fully signal group-controlled, traffic actuated, LHOVRA-strategy intersections. If the control strategy where to be constrained estimates could have been obtained but traffic safety and control efficiency would have suffered.

The test site gave lots of experiences but can be seen like a proof of concept for the communication and the latency was quite low.

Figure 2. STA test intersection in the near surroundings of Volvo Cars in the outskirts of Gothenburg.

4.1.3 Urban Development Office City of Uppsala

The city of Uppsala has established a test site in six intersections at Luthagsesplanaden. The thoroughfare connects the city centre with the western parts of Uppsala. The traffic lights are coordinated and operate under a centralized adaptive control system Spot/Utopia 6 am to 7 pm. The Spot/Utopia traffic control detects vehicles in various sections of the network and optimizes the green times and timings in the traffic signals in order to minimize the overall delay for all vehicles in the system/network. The public transport vehicles are given higher weight/value in the optimization.

1. 305 Luthagsesplanaden/Götgatan
2. 304 Luthagsesplanaden/Sysslomansgatan
3. 303 Luthagsesplanaden/Kyrkogårdsgatan
4. 302 Luthagsesplanaden/Tiundagatan
5. 301 Luthagsesplanaden/Hildur Ottelinsgatan
6. 309 Luthagsesplanaden/Flogstavägen

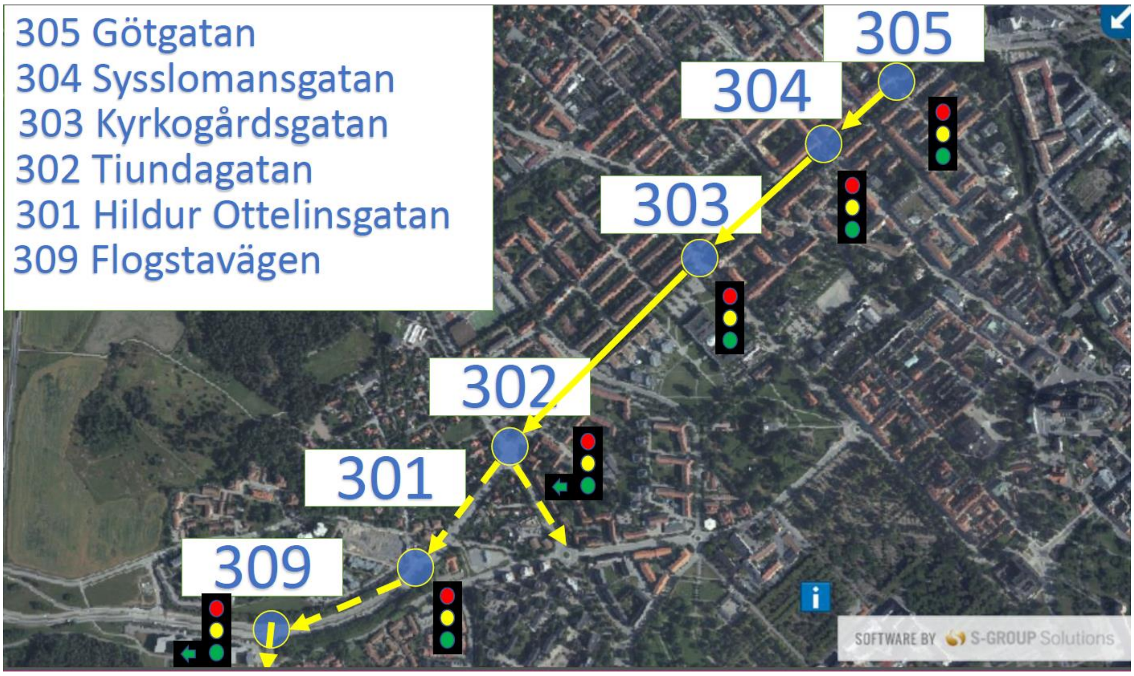

Figure 3. Luthagsesplanaden in Uppsala.

4.2 Architectural concept

The description of the data message flow “SPAT, MAP, SRM, SSM” are described in the following two pictures, the first for the services Time-To Green/Time-To-Red and Green Light Optimal Advisory where Time-To-Red is used to enable new fuel efficiency functionality. The second picture describes how Public Transport get their priority via Signal Request Message and Signal Status Message.

4.2.1 The Time-To-Green/Time-To-Red and Green-Light-Optimal-Speed-Advisory

In this simple architectural picture one can understand how timing, SPAT- and MAP-data, from Traffic Light Controller is generated and passes the Interchange Node for the goal, the OEMs´ different clouds. The services Time-To-Green and Green-Light-Optimal-Speed-Advisory etc are generated at the OEM side.

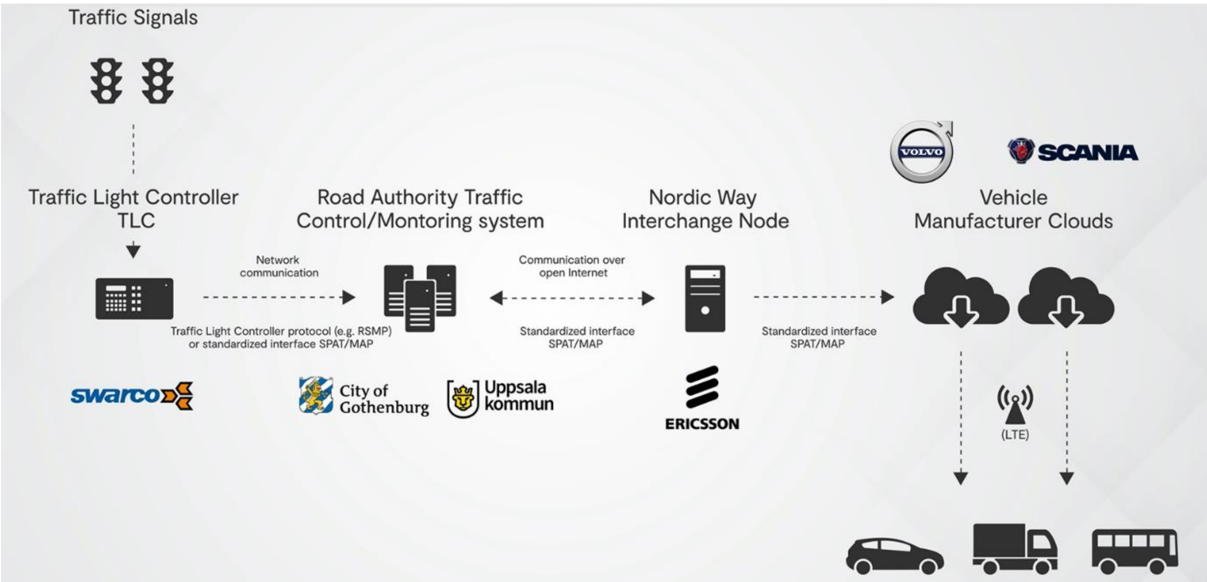

Figure 4. Architecture of for TTG/TTR and GLOSA, one-way communication.

4.2.2 Traffic Signal Priority Request

The TSP service is initiated from the vehicle side – in the picture where SCANIA is written, so it is a quite different flow. The request comes from PT vehicles and asks for priority at the Traffic Light

Controller, which executes it and sends a message back to the PT vehicle. A Public Transport actor is part of the data flow and decide if and how the PT-vehicle will be prioritised compared to other vehicles and as well other PT-vehicles.

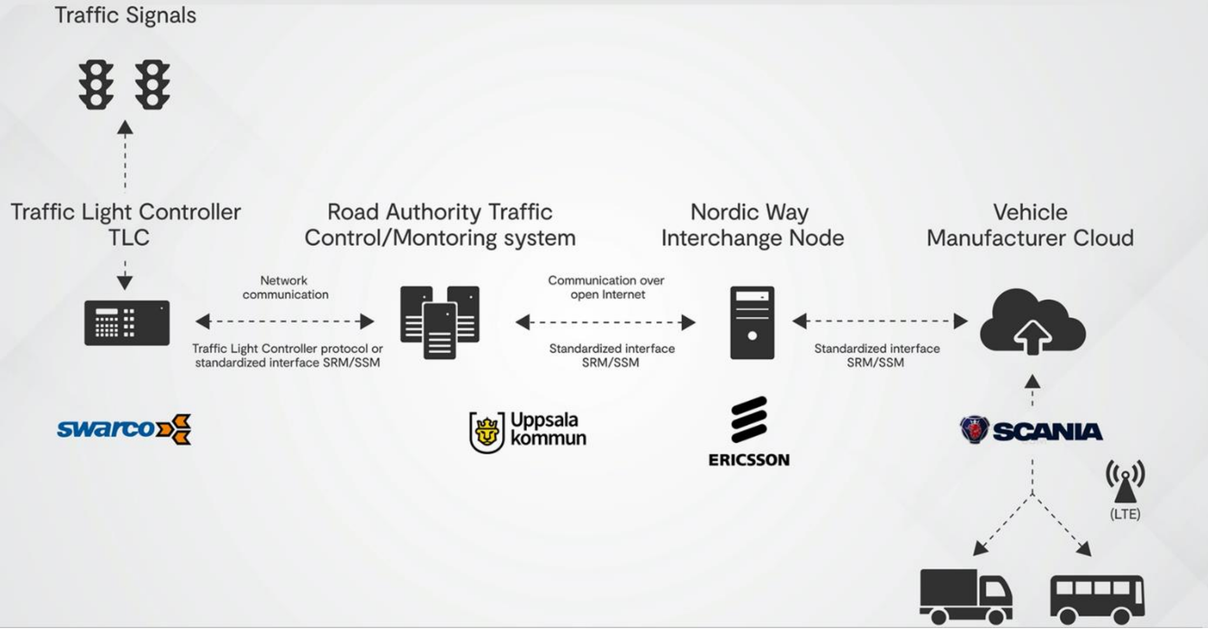

Figure 5. Architecture for Traffic Signal Priority, two-way communication.

4.3 Communication technology

The function of the Interchange is described in the Final Report – Activity 9 Swedish pilot Appendix 1 Nordicway 2 data interchange node architecture.

4.3.1 Interpretations – J2735

Base for interaction and the specifications are the SAE J2735 together with ETSI TS 103 301 and ETSI TS 102 894-2.

See attachment.

4.4 Volvo Car Corporation implementation

Volvo Cars designed a solution based on development vehicles exchanging information with the VCC cloud using cellular network connectivity. The information from the traffic light signals was used for two purposes: support the driver waiting at a red light and to develop new energy efficiency functionality by controlling the stop/start combustion engine in the vehicle.

4.4.1 Cloud setup

The cloud application responsibility is to receive the MAP and SPaT messages from the Interchange node, determine which vehicles are concerned and convey the relevant information to them.

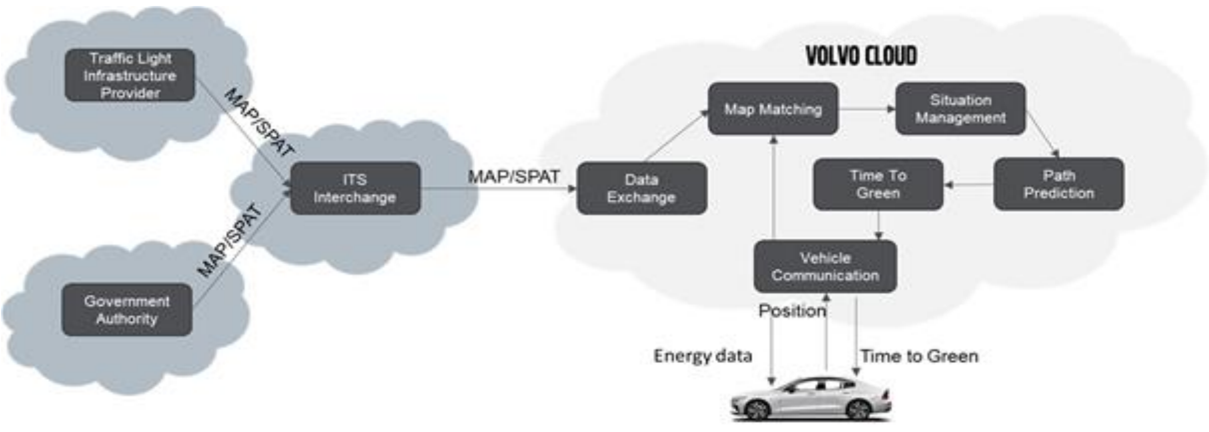

Figure 6. Illustration of Volvo cloud setup.

The test vehicle in the pilot was connected to the Volvo Cars cloud using the cellular network: reporting its position and receiving information back.

4.4.1.1 TTG displayed in vehicle

An HMI concept was developed for the NW2 project. Information was received through the cloud, and an approximate position of a traffic light group was shown with a traffic light symbol in the driver information module (DIM). Also, the position of the ego vehicle was shown on the same map. TTG was illustrated by showing the countdown to green light in seconds (see the second picture) when the ego vehicle was getting closer to the traffic light. The countdown information was removed from the DIM a few seconds before the traffic light turned green in order to get the driver to look at the real traffic light.

Figure 7. Example of HMI used in test.

As illustrated below, the concept made it possible to show for which direction the traffic light applied to. In this case the driver was going to continue driving straight forward, although there was a red traffic light also for those who were going to turn right. The countdown information was only shown for the driving direction.

Figure 8. Example of HMI used in test.

Energy efficiency

Predictions of phase shifts as Time To Green and Time To Red enable new energy efficiency functionality. Vehicles with combustion engines with stop/start have been prioritized during the development of the energy efficiency function. The stop/start function turns off the engine temporarily when the car has stopped e.g., at traffic lights or in a traffic queue, and then starts again automatically when the journey is resumed. The use cases are:

Predictive engine start

The engine starts 1-2 seconds before the light turns green. This will be used to pre-heat catalyst earlier and the engine start will also notify the driver that a green light transition is ongoing. This will increase driver awareness and increase through output from the intersection.

Predictive engine stop inhibition

The temporary engine stop at red traffic light will be inhibited if a traffic light shift to green is imminent. A very short engine stop is not beneficial for fuel consumption.

Long stop prediction

Long stops can be identified when predicted phase shifts are available. Energy storages like the battery can be prepared enabling the engine to be turned off during the entire stop. Prioritized energy consumers during long stops are air conditioning and heating for comfort of the driver and passengers. The engine will not get a start request with a battery control strategy that charges the battery if needed before a predicted long stop.

This use case requires both time to red and time to green predictions and with a longer horizon than the previous use cases. This is possible for fixed time-controlled traffic lights where the schedule as well as the changes in schedule during e.g., rush hours are known. But sensor-controlled traffic lights require more complex algorithms to predict phase shifts. The majority of the chosen traffic lights in Gothenburg are sensor controlled. We have spent less effort working on the long stop prediction use case, since it is more complex.

We need to know which traffic light signal to use independent of use case. This requires information about ingress and egress road. The figure below shows an example of a large intersection where the chosen ingress road enables driving straight ahead or to turning left.

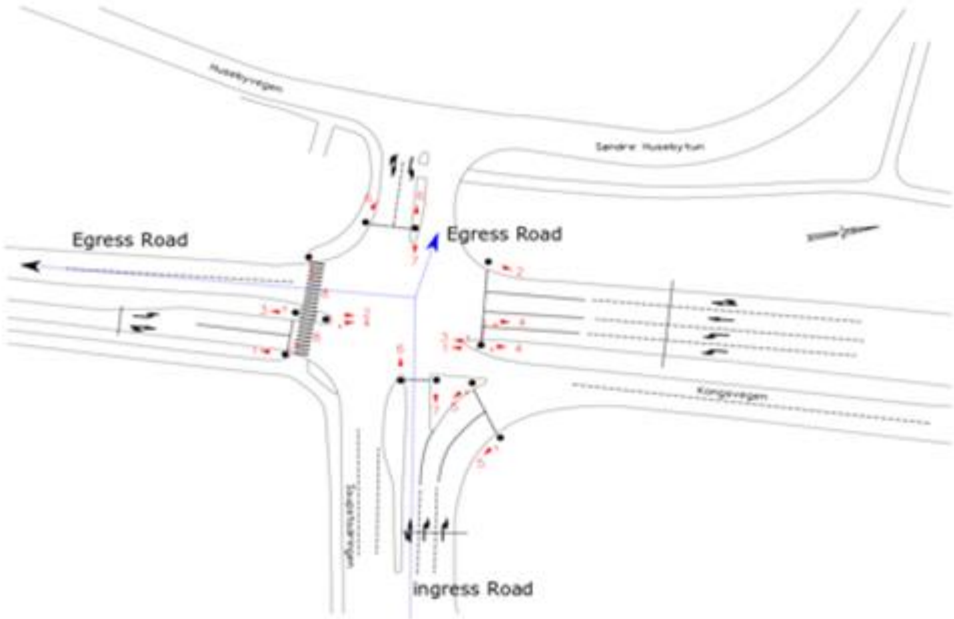

Figure 9. Example of a large crossing.

The ingress and egress roads are known if the driver has set a destination in the vehicle. Most Probable Path (MPP) or predictions using historical data are used if the driver doesn't use the vehicles navigation system.

We presented a latency requirement of max 0.2 s between each traffic light and Volvo Cars cloud for all use cases at the workshop in August 2018, which is still valid. The availability of SPAT predictions minutes ahead of each event would enable more energy efficiency functionality, e.g., long stop prediction.

5 Evaluation results

5.1 Technical evaluation

This part includes mostly measurements of latency and is described in more details below for the locations of City of Gothenburg, City of Uppsala and for Swedish Transport Administration. Each location has its own description and result.

5.1.1 Latency

Connected vehicles to traffic signals is a way to achieve expected improvements of different socio effects as traffic safety, smooth driving, improved alertness etc. One of the KPI´s of interest, mostly of safety reasons, is to investigate the time between the change in the traffic signal aspect (green, yellow or red) and what you see/sense in the vehicle - the latency. This is illustrated in the simplified figure below.

What is measured and described in this report is from a technical point of view and includes the time from the switch of signal at the infrastructure to the OEM Cloud. The HMI in the vehicle has not been involved in the process

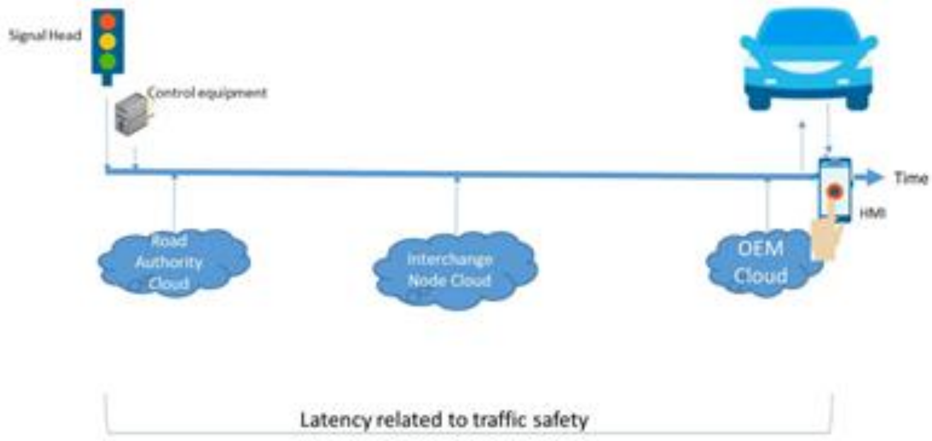

Figure 10. Principle description of Latency.

There have been some tests executed within the project on some different locations and they are described below in more details.

For traffic signal-based functions in the car to be usable there is a need to have low latency in the communication end-to-end. The SPAT-messages which contain the actual timings are the most urgent, that need to be transferred as fast as possible to the car, typically within less than 200 ms. Other messages types from the infrastructure for example VMS signs, are not very urgent at all, typically within less than 1 minute.

5.1.1.1 Urban Transport Administration, City of Gothenburg

Below follow some examples from the test route of five intersections, set up by the Urban Transport Administration in Gothenburg, where traffic signals are the starting point and the Volvo car Cloud is the end/receiver point. The “communication media” in this case is mainly “open internet”.’

The latter result in 2020 is not as good as the first one in 2018. Deviation is probably caused by the following reasons:
1. NTP synchronization error (agreed NTP server for the project has not always worked satisfactory
2. Capacity issues due to current maintenance work in the City

May 2018: latency is mainly less than 200 ms

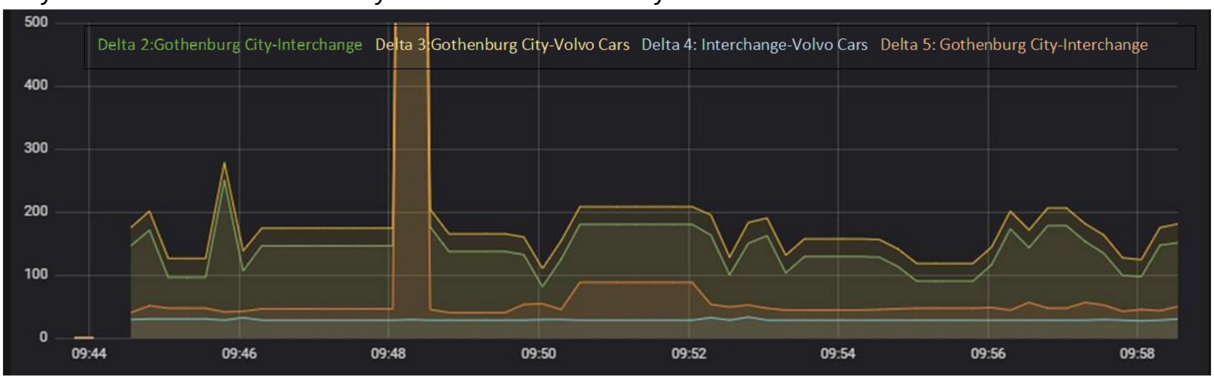

Figure 11. Latency measurements May 2018 in the Gothenburg test area.

June 2020: latency is mainly between 200-500 ms

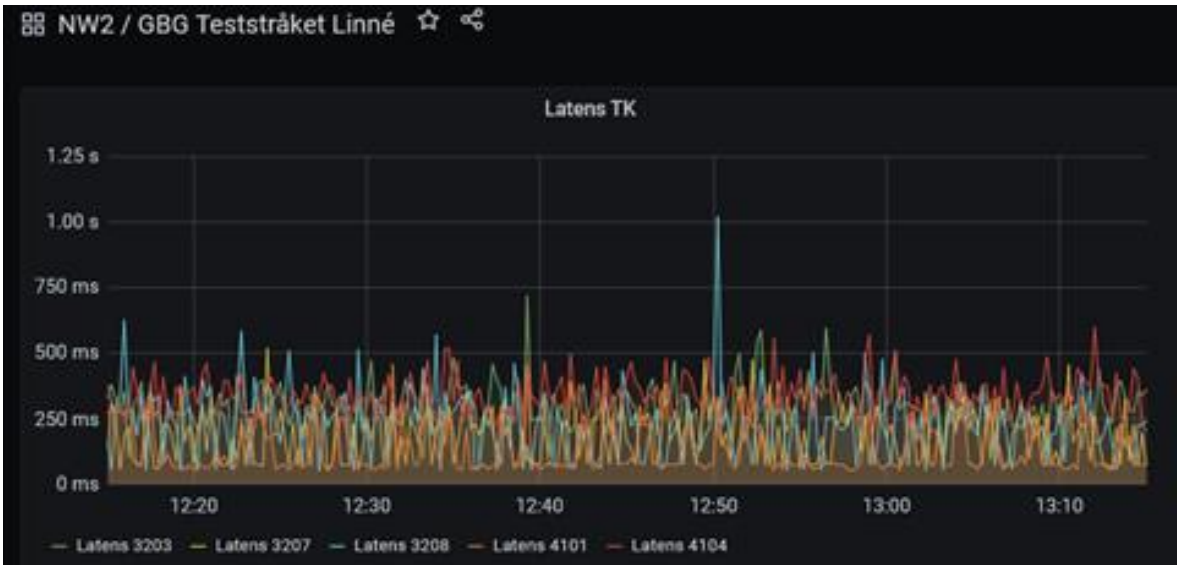

Figure 12. Latency measurements, June 2020 in the Gothenburg test area.

5.1.1.2 Urban Development Office, City of Uppsala

A number of tests of latency have been made by Volvo Cars in May/June 2020. The tests refer to 3 of the intersections and end to end communication of SPAT. This means the time it takes for the SPAT to be sent from the local traffic controller to the OEM cloud. The latency was at times rather high and could pose a problem for specific C-ITS services. In March when TTG and GLOSA were tested by SCANIA and Swarco the driver experience of the HMI was satisfactory and the latency did not affect the usability of the TTG and GLOSA services. For a C-ITS service as GLOSA an accurate and early estimation for the signal shift is more important than latency.

June 10th 2020. Latency in intersections 303 and 304 was 700-900 ms. Latency in intersection 305 was mainly 400 – 500 ms.

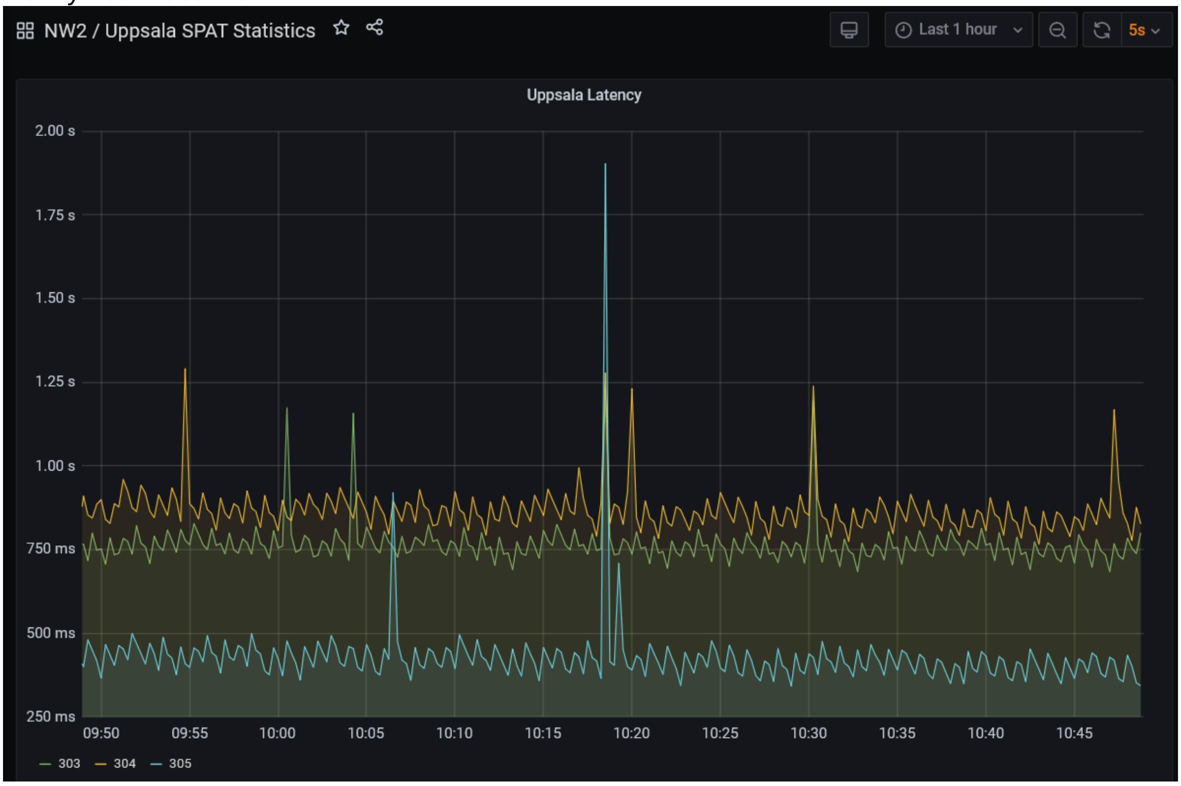

Figure 13. Latency measurements in intersections 303, 304 and 305 in Uppsala.

May 20th 2020. Latency in intersection 304 and 305 was 800-1000 ms. Latency in intersection 303 was roughly 1600 ms.

Figure 14. Latency measurements, May 20th 2020 for Luthagsesplanaden in Uppsala.

The difference in latency from different intersections might occur due to the full chain of hardware and software, including the communication link type, which might not be exactly the same in all intersections.

The value of low latency depends on the application. For a safety critical and/or vehicle control related application a low latency might be needed. But, as in the case of signal phase change prediction, when data is re-created and updated many times before a final value is reached, the value of low latency decreases. For a phase change prediction more than a few seconds in the future, it is not necessary to have this prediction within a very short time as it will change many times anyway.

In Figure 15. Prediction quality dashboard SWARCO below a screenshot of the prediction quality dashboard is shown. As a Traffic Light Controller operates in time intervals and not distance, the distance is measured in seconds and thus the real distance is implied by the local speed regulation.

Prediction error by distance

	Absolute error (group)						
Distance	<1s	2s	3s	5s	10	20	Unmatched
5	95,62%	2,44%	0,88%	0,37%	0,36%	0,21%	0,12%
10	78,07%	6,40%	7,53%	3,78%	2,75%	0,76%	0,72%
20	45,65%	14,48%	17,28%	6,52%	9,59%	5,36%	1,12%
30	27,28%	10,46%	14,06%	7,87%	21,98%	11,56%	6,78%
60	10,90%	4,51%	9,21%	8,10%	26,95%	26,90%	13,44%
90	7,80%	3,64%	7,94%	6,95%	22,62%	28,24%	22,80%

Figure 15. Prediction quality dashboard SWARCO.

The table shall be interpreted as:

'5 seconds before actual signal phase change, 95.62 % of the predictions had an error of less than 1 second'

'5 seconds before actual signal phase change, 95.62+2.44 % = 98.06 % of the predictions had an error of less than 2 seconds'

'10 seconds before actual signal phase change, 78.07 % of the predictions had an error less than 1 second'

'10 seconds before actual signal phase change, 78.07+6.4 % = 84.47 of the predictions had an error less than 2 seconds'

This means that the predictions will be more and more accurate the closer in time and space to the intersection the road user gets. It also emphasizes the reasoning around the low/no value of low latency in this case: there is no use of, within less than 1 second, getting a prediction of what happens 20, 30 seconds in the future.

5.1.1.3 Swedish Transport Administration

Below is an example from one of the Swedish Transport Administration's intersections in Gothenburg area where traffic signal "6830" is the starting point and the Volvo Car-cloud is the end/receiver point. The latency during the 1 hour 30 min time span was mainly less than 50 ms for *SPAT-messages*. The "communication media" in this case is mainly "open internet".

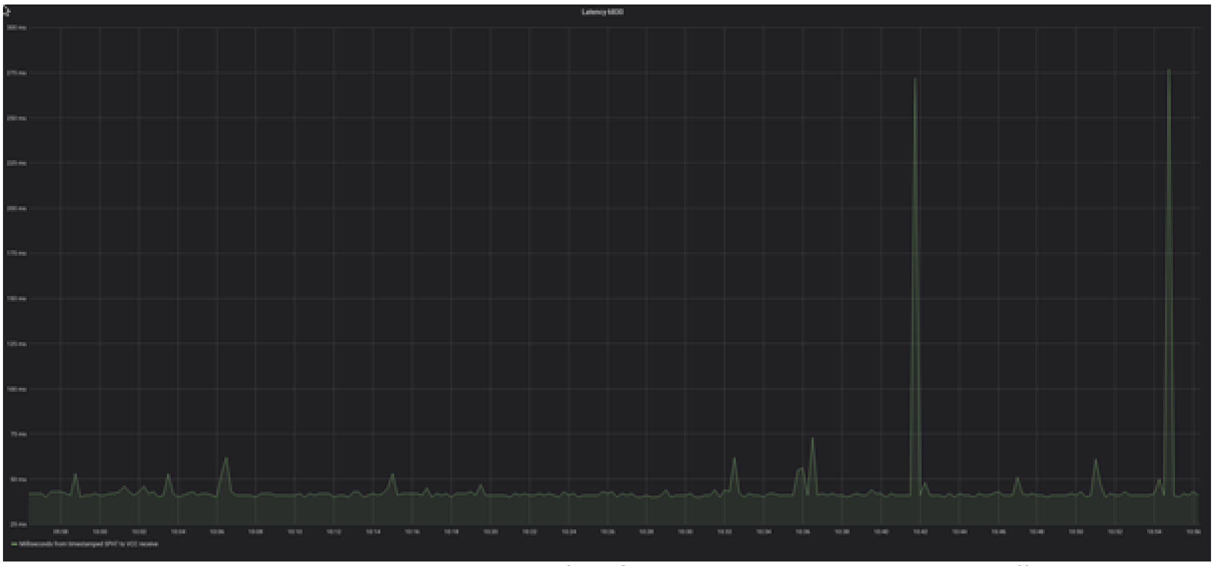

Figure 16. above shows the latency of SPAT-messages from Swedish Transport Administration's traffic signal "6830" in Gothenburg area to the Volvo Car-cloud.

5.1.2 Results and Summary

The variations in latency over time show how different factors and conditions in IT infrastructure can impact latency both short- and long- term. This highlights the need for designing solutions that are robust and scalable over time. It also shows the importance of constant monitoring of the key performance indicators of the complete system to make sure data is usable for end consumers.

5.2 Service ecosystem

5.2.1 Method

The service ecosystem has been constructed during the Service Workshop 27th of January, 2020. The method is described in detail in the NordicWay 2 Evaluation Report.

The objective of the workshop was to describe the current ecosystem of the services TTG and GLOSA, its actors and their roles, and to better understand the business potential and what is needed for implementation of the services. The workshop was divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilots. Thereafter a description of the current ecosystem, i.e. how the pilots are set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the workshop a scaled-up version of the ecosystem was constructed. This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

5.2.2 Results

5.2.2.1 Current service ecosystem

Description of challenges encountered, and lessons learned in:

Forming the ecosystem (consortium, others)	Quite easy to form this ecosystem since the group was already involved in another project before NordicWay (KRABAT-project). Each

	road authority has made their solution from their point of view, which was made in KRABAT, then improvements were made in NW.
The service formulation and provision phases	It is complex, the road authority has challenges to make a new organisation around these services.
Access to data and right to use the data within the pilot (within the consortium, with public actors, with commercial actors)	Discussions about how to generate the Map messages and how to keep them updated. There is no routine for that now and the road authorities need to find a way to do this. All the cities are waiting for STA to take lead on this work otherwise it will be many different systems for every municipalities. A harmonization work needs to be carried out all over the country.
Any other issues/challenges	There is a long chain to get the information from the traffic signals to the OEM cloud.

Table 1 Current status ecosystem

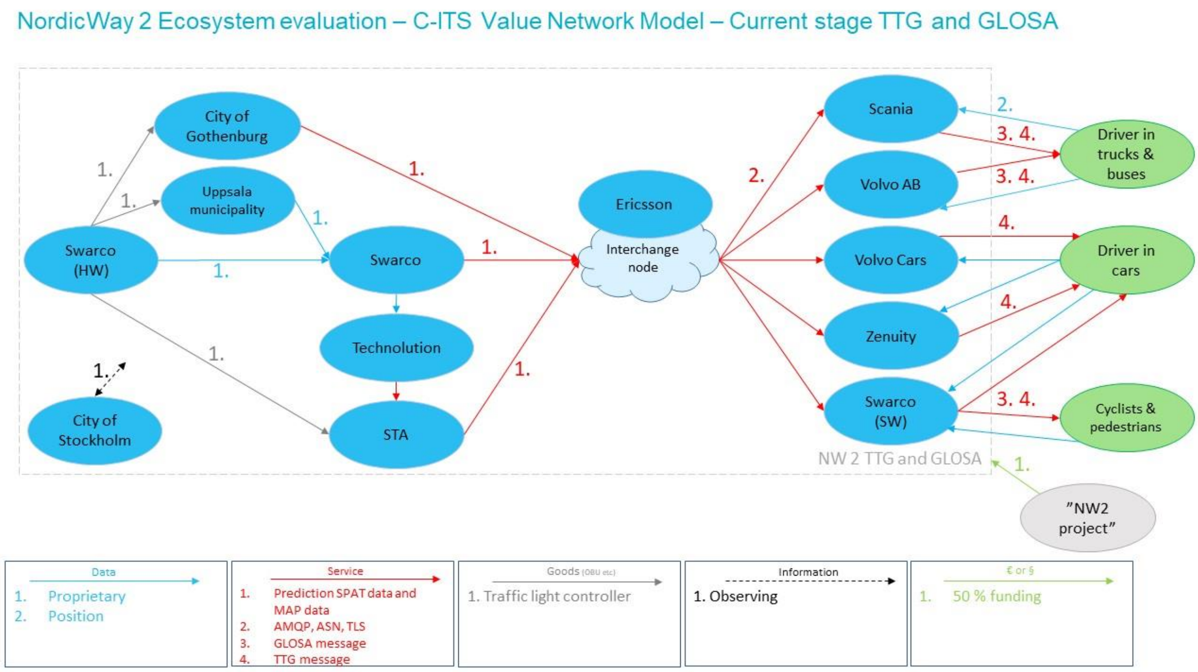

Figure 17 (31). Current status ecosystem for TTG and GLOSA.

Figure 17 describes the current status of the TTG and GLOSA ecosystem. Swarco is an actor which has several roles in the ecosystem and for pedagogical reasons Swarco was divided into hardware supplier, service provider and software provider in the figure. The software provider role is mainly for Swarco to be able to test their own solutions via an app that Swarco created. City of Gothenburg, Uppsala municipality and STA have slightly different set ups in how data is transferred between the traffic signals and the interchange node, which is illustrated in the figure. City of Stockholm is a partner in the project but does not have any connected traffic signals and therefore just observing the pilot. No money transactions exist in the ecosystem despite the 50 % funding from the NordicWay project.

Pains, gains, commitment chart

The participants were asked about their main pain, gain and commitment to be a part of the current ecosystem. Table 2 below summarizes the discussion.

Actor	Pain	Gain	Commitment
City of Gothenburg	• Other work (City upgrades) in Traffic Signal system interrupts test system frequently • Development, implementation, verification of data format communication protocol → Time consuming, not the city's core business	• Cooperation with Gothenburg industries and other road authorities • Prediction a few seconds before engine starts→ Decreased fuel consumption/emissions, smoother traffic flow	• The cities need to see clear socioeconomic advantages to get seriously involved • Very interested to collaborate with industry • Proactive work • Heavily involved in order to safeguard a sustainable city → Long term decisions, all traffic modes to consociate
Uppsala municipality	• Requires data quality standards (SPaT, MAP) • Requires an adjusted maintenance budget • Requires internal training	• Cooperation knowledge • Data from OEMs • Sustainable driving • Reduced costs for road maintenance • Improved air quality	• Maintenance of data (MAP, SPaT) • Internal training (MAP, SPaT) • Communication plan when data disruption
VCC	• Development in VCC-cloud and vehicle	• Understanding the complexity of the traffic light system and the work needed to get the traffic light information • Cooperation with different actors to understand traffic light data • Influenced the Swedish protocol for data exchange of traffic light data (mandatory fields)	• Active actor in the market/ecosystem • Involved in related R&D activities
Ericsson	• New roles, specifically for road administrators	• Society benefits • Less accidents, delays etc. • Cooperation and understanding	
Swarco	• Benchmark of data and prediction quality • Commitment to implementation	• New business • New areas • "rebranding" • HW→SW	• Very committed • Key area for Swarco
Technolution	• Open source protocols • RSMP++	• It has the potential to optimize the traffic flow when applied in right circumstances • It can impact the environment for the better with the reduction of the amount of stops for instance	• The usage of open standards, it is important to have an open standard to allow further development within the ecosystem. We believe that with the usage of Open Standards like RSMP / ETSI it will allow new companies to enter the ecosystem as well with bright new ideas to deploy.

Table 2. Pains, gains and commitment to be involved in this pilot for each actor. Input was only given from the actors present at the workshop.

5.2.2.2 Scaling up the service ecosystem

How should this service look/work in 5 years from now?

Most likely the actors that are involved in this pilot today will also be the ones providing this service in the future. In different cities there might be some new suppliers present. The City of Gothenburg needs a software provider who can use the RSMP standard efficiently with their solutions (all traffic signals in the City of Gothenburg are being upgraded with RSMP during 2019-2020).

In terms of geographical coverage of TTG and GLOSA, in five years from now there will probably be smaller scale installations such as certain spots, corridors or intersections where you can find these services. It is impossible to predict number of users; it will depend on where the service will be implemented. Fleets can use the services and commercial traffic will probably benefit the most from this service.

What is required to reach this vision?

In order to scale up more cities need to be interested to invest in this service and in order for that to happen cities/municipalities need to see the socio-economic value of the service. There are some negative discussions surrounding TTG and GLOSA where they are considered as technological solutions only for cars. City of Gothenburg do see the potential of TTG and GLOSA - in a fixed time-controlled system. However, in a vehicle actuated system (80% of the Gothenburg signals), it is quite impossible to make accurate time predictions for the near future. The reason is that the trams and buses have a very high prioritization. So even if there is a 4 second prediction for the cars counting down, it could be knocked out any time by a tram or a bus approaching the intersection. Maybe it could be useful a bit outside the city, but it's hard to see how it could be highly efficient in the centre of Gothenburg with current prioritization of the public transports (and this is politically controlled). The benefits of TTG and GLOSA, such as less emissions and smoother traffic, need to be highlighted. Values of the service are discussed below and illustrated in the scaled-up version of the ecosystem, see figure 18.

Some paying customers are needed but who that should be is unclear. Probably, it will be public actors who make the decision on implementing the technology. New data sources might also be needed; possibly the road users can be able to put in their data somehow. Today, a lot of data is provided from I2V but not so much other way around, V2I. Maybe we must allow the public sector to do business in order to get the revenue streams in place. Further, there will have to be new investments both in roadside and in backend.

Standard for protocols etc. on European level both for the OEMs but also to the local road authorities are needed. Much easier for OEMs and local road authorities to get instructions than investigate everything by themselves. Further, new investments to handle and process the big amount of data are also needed. Perhaps there will be new service providers that provides a new service/connection layer, doing the map data work, and selling this data to subscribers such as OEMs (Traffic technology service (TTS) in USA). Today TTS connect the traffic light in the cities, and they get someone to pay them for this and then they sell the service to the subscribers. If TTG and GLOSA are connected to the traffic management, the business case will be bigger since there will be more services connected. There could be an actor that provide Traffic Management as a service, where TTG and GLOSA are included.

How to manage a platform for data sharing also needs to be answered before implementation. The cities are quite dependent on this. The rules for the cities' data are quite different from the rules for data from a private organisation. The city will need to open up their data a lot and it could be a challenge to share these different types of data in a common platform.

Nordic WAY 2

Scaled up ecosystem

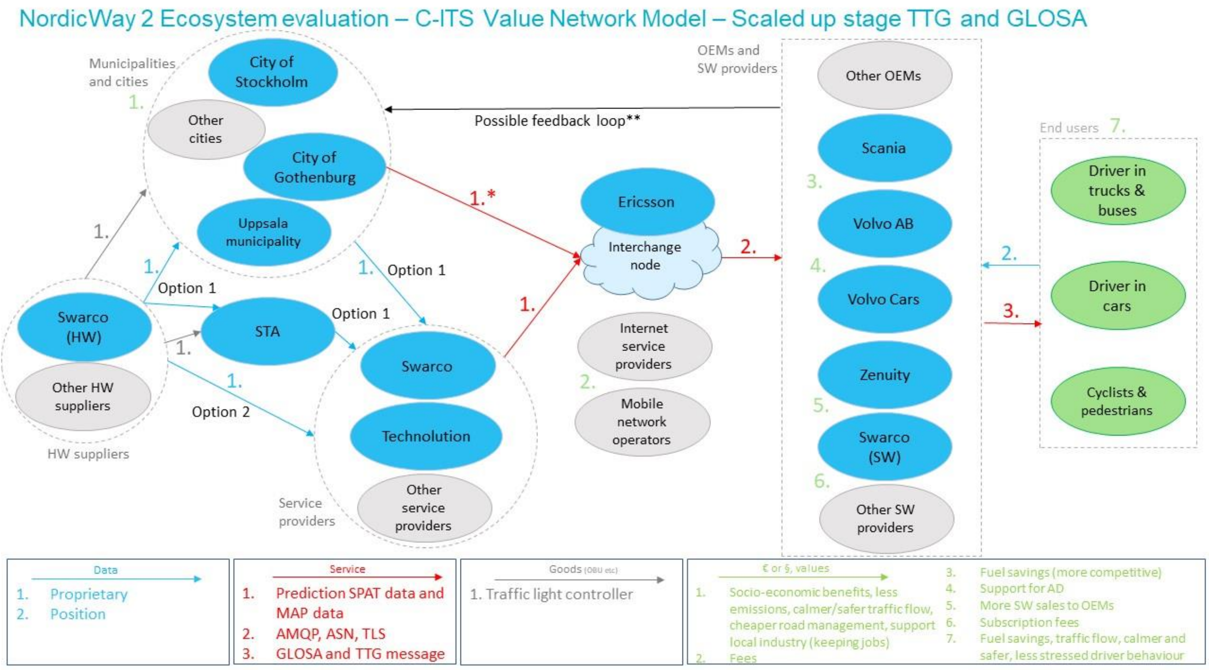

Figure 18. Scaled up ecosystem for TTG and GLOSA. *One potential scenario is that City of Gothenburg continues to process data from traffic lights and not using service providers. **See details of possible feedback loop in separate figure.

Figure 18 is a description of how a potential scaled up version of the ecosystem can look like. This ecosystem is not a description of a fully implemented version, more of a description of the next step in the development phase, which would be implementing the service in smaller areas such as corridors. In this ecosystem more cities/municipalities need to be involved. Service provider consulting could be Technolution or Swarco, but it could also be other actors. In the ecosystem there are two different options on how data from the traffic light to the interchange could be delivered. Either data is being delivered from the traffic light to a city/municipality or STA and then to a service provider (Option 1), or data from traffic light is delivered directly to the service provider (Option 2). STA have the same role, "infrastructure owners", as the cities/municipalities. Other new actors added are Internet service providers, mobile network operators and, more OEMs and software providers.

No revenue streams are illustrated in this ecosystem. However, the values of these services were discussed and illustrated by numbers in the figure. For the cities/municipalities, values are connected to socio-economic benefits such as less emissions, calmer and safer traffic flow and cheaper road management. From Gothenburg city point of view involvement in this service also support the local industry. Internet and telecom operators will get paid to handle more data although they are not active actors in the system. For the OEMs with heavy vehicles (Scania and Volvo AB) the services will lead to less stopping for the truck which saves fuel. This is a competitive advantage. For VCC the values are more service to the customers and also a technology that supports autonomous driving (AD). The value for software providers is revenue in terms of subscription fees. For Zenuity this technology will probably lead to more sales of software to the other OEMs. The values for the end users are fuel savings, calmer and safer traffic flow, and less stressed driver behaviour.

In a previous workshop the pilot partners discussed the role of traffic management centres (TMCs) and that the TMC wants to have the possibility to control the traffic signals. Traffic management can be improved if they get feedback from these new services. In other words, the cities could serve the end users much better if they get more data from the cars. This could be a win-win since the car drivers will get more green light if they are willing to share their data. There are also other services that could be improved if the cars sharing data, e.g., potholes and other objectives on the roads, salting etc which can give better and quicker road maintenance. A possible feedback arrow from the OEMs/end users to the cities and municipalities was therefore added in the ecosystem. Figure 19 is a more detailed version of the set up for the possible feedback loop.

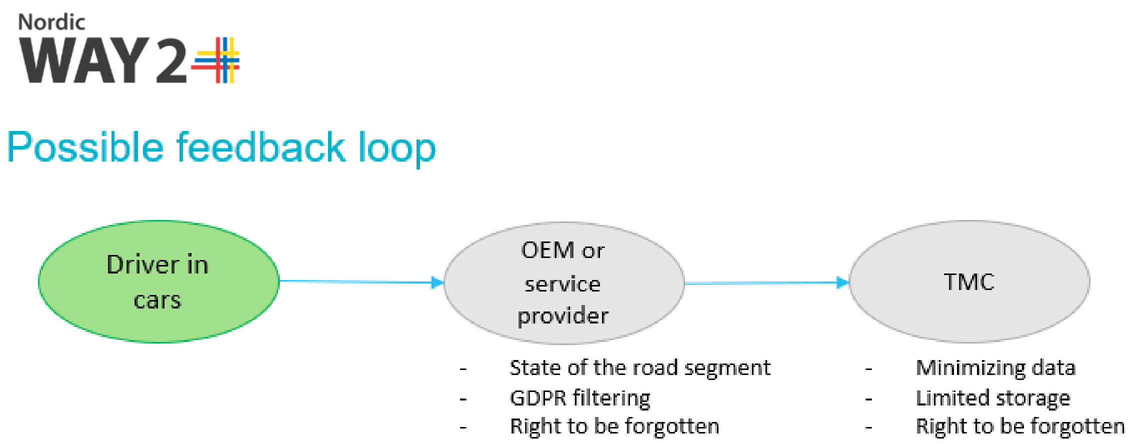

Figure 19. Feedback loop from end users to TMC.

The feedback loop is very similar to another service; probe vehicle data. The drivers send data on location and speed (temperature, slippery road etc. could also be reported) to the OEMs' clouds. Some washing of data needs to be done in order to protect the driver's private information. From VCC point of view they would never share any data from a single vehicle. They can however do some intelligent things in order to show the state of a road segment. The data could thereafter be sent to a TMC.

6 Other results

6.1 Background

During the project in NordicWay 2 and as well the initiative Drive Sweden Krabat several observations and experiences have been achieved. This both in the ongoing/lasting developments and in specific tests. As there are many actors involved, there also are different aspects of experiences and results – where some of them also influence key effects in respectively role and responsibilities - and some of them are documented below.

6.2 Handling of MAP

This is about new roles for the road authorities, new routines and tools to describe each signalised intersection in the MAP-format in a standardised way all of the Nordic countries so the user can understand the descriptions. This also includes when it is about changes in the intersection design with short- or long-term durations.

In connected traffic signalised intersections, according to C-ITS services, the connection between the illuminated traffic signals must be related to the intersection geometry and lane(-s) and in a digitised way be shared with the vehicle. It is also necessary to relate to the signal status and the legal meaning of the status, such as yellow, circular or arrow illumination meaning how to handle different types of conflicts between road users in different situations. The illustration of the intersection geometry respectively traffic signal is specified in what is called the MAP. This is specified in the SAE/ISO/J2735 standard.

The experiences so far are that there is a need for the road authorities to describe and maintain this description, change when necessary, e.g., at changes of geometry as well temporary as permanent. The way this is done should follow a procedure – same at every road authority – and be stored and distributed in a harmonised way all over each Nordic member state. Observe that this is a new role for every road authority. See also lessons learnt from Talking Traffic/Netherlands.

6.3 Lack of accuracy with respect to predictions

The experiences so far have been that short time predictions for sharing real time SPaT messages is crucial for the smooth driving when passing through signalised intersections. This is valid for vehicles approaching at green or a red traffic light or a red traffic light or when vehicle is standing at red traffic light. This is essential in vehicle actuated mode, that is, when there is any form of traffic actuation (ordinary vehicles/cyclists/pedestrians and/or prioritised vehicles) or influence on the length of green/red intervals – this is valid in as well most coordinated signals as in all isolated traffic signals control in operation in Sweden.

In other forms of control, such as fixed time control (coordinated or isolated) or adaptive signal control this need is taken into account and is built in this type of signal control.

6.4 Workshops

Some workshops have been held within Task 5 based on service definitions and messages.

6.4.1 Signal Violation

One workshop has been held to discuss issues connected to one of the most important traffic safety related effects of signalised intersections. The reason is mostly that when an accident occurs due to red light driving this is likely to be violent, especially when we talk about unconscious red light driving.

The aim of the workshop was mostly to have the opinions of different actors and no real conclusion was drawn. There is a lack of modern knowledge due to this type of accidents. Some twenty years back a lot of focus was for improved traffic signal control which still is valid. Today one can expect that working together - both with AI, new tech facilities and ADAS functions - between actors can handle the problem.

6.4.2 In-vehicle-signage – lane closure, speed and queue warning and traffic data

Within Task 5 there has been a couple of workshops to facilitate information from motorways with the highest traffic density in Sweden and where incidents are frequent - in the vicinity of Gothenburg and Stockholm. Those stretchers are equipped with systems for lane closure, for queue warning, for speed and the Swedish Transport Administration plan to distribute these data from a platform via the Interchange Node to the OEM cloud. The IVS services expects to harmonise speed, fewer stop and go events, reduce negative environmental issues and improve traffic safety as drivers are given alerts at sudden incidents. Besides, these systems also have a lot of traffic data, per lane and at each equipped gantry and with high dissolution.

In the workshops several findings have been established and expected to be used. Those who have participated are actors, such as Volvo Cars, road authorities, different system integrators such as Ericsson, Swarco, Zenuity, Technolution. The services are expected to be demonstrated in the NW3.

6.4.3 Priority for Public Transport

The service is named *traffic signal priority request* in the service definition. Within the NW2 there have been both workshops and tests performed.

In the workshops participated many actors from this type of business including PTA´s, PTO´s, OEM´s road authorities, PT standardisation body among several. It was said that the public transport sector stands before a large change in technologies.

However, a small test was performed in Uppsala with UL, the City, Scania and Swarco and further work is expected in NW3 on a Nordic basis.

The result shows that this is very much possible. The challenge is in the prediction of the vehicles path through the intersection. The traffic light controller needs to know inbound lane and outbound lane of the vehicle path through the intersection in order to be able to change status of the corresponding traffic light groups to fulfil the priority request.

This functionality could be used for any kind of heavy vehicle that authorities want to get quicker trough congested city centres.

Standards to follow are SAE J2735, Signal Request Message, SRM and Signal Status Message, SSM.

6.4.4 GLOSA study

As part of the NW2 work a systematic mapping study was conducted to survey state-of-the-art (with a cut-off date in May 2019) for the Day 1 C-ITS application GLOSA. The results were presented at the 47th European Transport Conference (ETC 2019) in Dublin, and published in the open access journal Transportation Research Procedia, special issue '*Facing the complexity of transport models and innovative developments in sustainable mobility*' (in press).

In the mapping study 60+ scientific publications--between 2006 and 2019--were reviewed to investigate what is known and what knowledge gaps exist regarding the Day 1 C-ITS application GLOSA. Among the main conclusions were that while an absolute majority of the publications report positive results--mainly for fuel consumption and travel time--the size of effects reported varies considerably between evaluations, where fuel consumption varies from 0.5% to 69.3% and travel time from 0.96% reduction to 50%. The few published pilot studies report results with less variation but also with more moderate effect sizes. It is furthermore clear that publications tend to focus mainly on the equipped vehicle, leaving considerable gaps in investigations of societal effects, for instance traffic flow, and how road and intersection layouts and traffic intensity affects the overall traffic flow.

7 Dissemination

Three important dissemination activities for this pilot can be identified: demonstrations at ITS- World Congress in Copenhagen 2018 and in Gothenburg May 2019 and a movie during May 2020.

7.1 Demonstration at ITS World Congress in Copenhagen 2018

The demonstration was a part of the ITS-World Congress in Copenhagen 17 - 21 September 2018.

Copenhagen Municipality connected the traffic light signals in two crossings and a temporary connected traffic light for vehicles leaving the demonstration area was added. Swarco TLEX was used since it has advantages regarding latency compared to Swarco Mizar, which is used at other demonstration sites within NordicWay. The MAP and SPAT messages were received in the Volvo Cars Cloud and relevant information was sent to the vehicles when approaching a traffic signalized intersection.

Predictive engine start (engine start 1-2 seconds before the traffic light turns green) and environmental zones were demonstrated at this early phase in the project. Traffic light status, time to green, time to red and information related to environmental zones were displayed in tablets for the attendees in the Volvo XC90 vehicles.

The test route is described in the figure below. 240 attendees from 60 different organizations and companies joined the test rides. The Norwegian Public Road Authorities also invited the Nordic Ministers for Transport to dedicated test rides.

Figure 20. Test area at ITS World Congress in Copenhagen.

7.2 Demonstration in Gothenburg 16th of May 2019

Description of the Demonstration in Gothenburg 16th of May 2019

The pilot included a demonstration in collaboration with the geofence pilot on the 16th of May 2019 with 29 participants from different partners within the NordicWay 2 project: cities and road authorities (Göteborg, Malmö, Trafikverket), OEMs and suppliers (VCC, Scania, Zenuity), suppliers to cities and road authorities (Technolution, SWARCO, Sweco) as well as a research institute (RISE) and MNO (Ericsson). Participants were invited to step into several demonstration cars to witness the traffic light functions in Gothenburg.

The city had defined a test stretch with connected traffic lights.

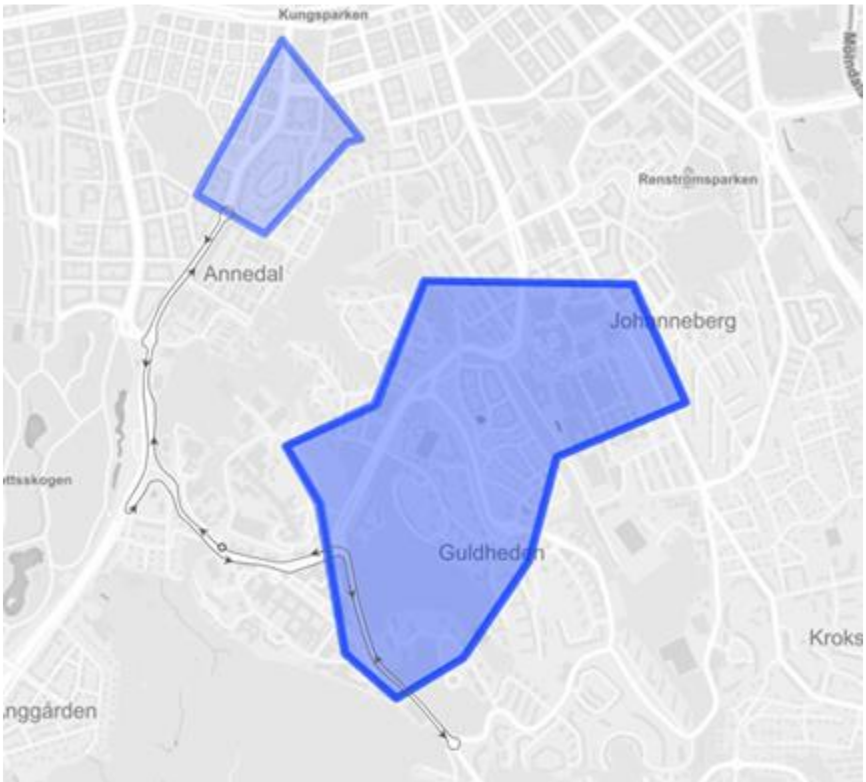

Figure 21. The driving route during the test drives with the connected traffic lights also showing the two environmental zones.

During the event we presented the connected traffic lights in Gothenburg and the connection between the interchange Node and the Volvo Cars and Zenuity clouds.

The participants were also able to make a test drive with vehicles equipped with different functions based on the connected traffic lights (from Volvo Cars and Zenuity). The Volvo Cars' vehicle had energy efficiency functions activated and had tablets presenting the traffic lights status at the demo.

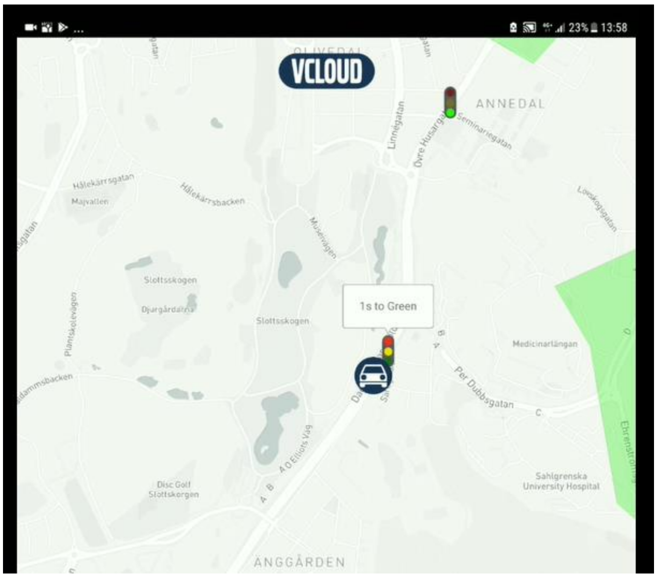

Figure 22. Example on HMI.

The Zenuity vehicle, connected to the Zenuity cloud, included an HMI graphics showing the state of connected traffic lights, relevant to the location of the demonstration vehicle. The in-vehicle HMI provided an opportunity for developers and audience to experience the accuracy of the information displayed to the driver, with respect to both goa-location and the jitter (small timing difference between traffic light and HMI, when the traffic light phase shifted).

The demonstration was well received and gave the participants a good overview and insights in the pilot's ambitions and tasks.

7.3 Making movies

Early in the project there was an explicit request from the pilot teams to produce a film showing the different services and possibilities with the C-ITS services that was within Task 4, 5 and 6. We decided to focus in filming TTG, GLOSA and Bus priority. Step one in that plan was to make one "Project internal" and later on one "public" film. The idea behind this was to get experience from the first film that was produced in spring 2019 to the "public" version produced early 2020.

The "internal" reversion was produced in Gothenburg and the "public" version was produced at two sites Gothenburg and Uppsala. In Gothenburg only TTG and in Uppsala TTG, GLOSA and Bus priority.

8 Conclusions and recommendations

During the project we have got experiences on different levels. Text below are extracts from text above and can serve as input to coming work, e.g., in NW3 or internally in Sweden. We have thus learnt and need to further elaborate with following:

- That from a technical point of view the whole data handling chain works from traffic signal to OEM Cloud with acceptable latency, that means with all different actors and variable technical solutions and versions included.
- That it is important to design the IT-infrastructure for robustness. As well as for different and diversity in loads and low latency in the communication chain. Thus, we have observed variations depending on different technical solutions and organisations, load in the dataflow which also means that this is important to constantly follow up for the whole system as KPI´s. This also means that the potential for operational solutions is very good.
- That timings are essential; all clocks have to be synchronized. Time stamps needs to be checked 24/7/365. The QA system should be able to handle this in real-time.
- That short time predictions – part of the SPaT message – need to be improved for all vehicle actuated signalized intersections to get as correct data for the effectiveness of traffic flow. This lack of correctness in timings influence most of the number of Swedish signalised intersections. An explanation can be seen i chapter 9 Reference "4" Short Time Predictions (text in Swedish).
- So short time predictions need to be improved for all vehicle actuated signalized intersections to get as correct data for the effectiveness of traffic flow. This lack of correctness in timings influence most of Swedish signalised intersections.
- That from an organisational point of view the handling of MAP-data need to be investigated carefully. It is about updating the digital description of the intersections even at temporary reconstruction of the intersection. It is about the road authority roles and where MAP data is to be stored.
- How should and could a business model for the *traffic signals concept* be arranged including sharing of relevant data. Roles and what mandate etc need to be described and accepted.
- How does the C-ITS add value for the cities and the road authorities local and on national level? Evaluation is essential.
- How to exchange more relevant data between the C-ITS world and the Public Transport world?
- All other services related to the *traffic signals concept,* e.g., Motorway Control Systems (MCS), Time to Red (TTR), Red Light Violation Warning (RLVW) should be included in the connected solution.
- If body of scientific knowledge relating to the Day 1 C-ITS application GLOSA is representative to C-ITS applications in general, it is an uncertainty whether the claimed positive impacts of such applications can be expected in practice. While the over 60 scientific publications about GLOSA indeed report positive results, there is considerable variation in observed effects. Furthermore, the majority of publications report results from simulation and few from real-world studies. In addition, the majority of studies focus on the equipped vehicle only, leaving knowledge gaps in how other road users are affected. So, more studies in real-world are of value. For further information see reference 3 below.

9 References

1. Swedish interpretation of J2735, SAEJ2735 - Cloud Communication Proposal
2. Movies describing the set-up, see NordicWay 2 Homepage

3. The Day 1 C-ITS Application Green Light Optimal Speed Advisory— A Mapping Study, Oct 2019, RISE
4. Short Time Predictions (text in Swedish).

Nordic WAY 2

Appendix 5: Dynamic Access Control for Designated infrastructure report

Final report – Dynamic Access Control of Designated infrastructure

NordicWay 2

Version 1.0

Date: 16th September 2020

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Connecting Europe Facility

Document Information

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Distribution

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Content

Nordic WAY 2

1 Introduction

High accessibility is necessary for favorable social and socio-economic development in big cities. In the coming decades, the population of the Swedish urban areas is expected to continue to increase, leading to greater traffic volumes for both freight and passenger traffic. In order to avoid costly infrastructure investments, alternative ways of effectively utilizing existing road infrastructure should be explored.

The NordicWay project is a collaboration between the road authorities in the Nordic countries that coordinate innovative demonstration activities in each country. The purpose of NordicWay 2 is to develop various C-ITS (Cooperative Intelligent Transport Systems) services where digital communication between infrastructure and vehicles allows for increased traffic safety, more efficient traffic systems and smart traffic management. New solutions are based on utilizing cellular networks (mobile phones) and internet-based information exchange between different actors. The pilots will hopefully lead to new cost-effective opportunities to organize traffic, creating conditions to improve the performance of the road transport system from various aspects such as the environment, road safety and capacity utilization.

One of the pilots is dynamic access control of designated infrastructure. The purpose of the demonstration project is to test dynamic access control to enable future optimization of existing road capacity in accordance with the so-called “four-step principle”. The practical demonstration was conducted in March 2020 just south of Stockholm where a Scania vehicle was allowed to drive in public transport driving fields for a week on a 3.1 km long stretch of the E4 / E20. Decisions about if the truck may utilize public transport lanes were made based on predefined requirements of the vehicle and on the basis of current traffic conditions. Under the right conditions, the truck will be given access, otherwise the truck will be denied access to use the public transport lane.

1.1 Background

Within the framework of the completed collaborative project “Ring Road Logistics”), organizations from the public sector, business and academia jointly explored the potential and possibilities of developing and implementing systems for dynamic priority for socially beneficial people. The hypothesis for the project was that socio-economic benefits can be achieved by granting access to freight traffic in priority lanes under certain conditions. To investigate this, a simulation was carried out on a stretch of road in Gothenburg, where time gains and economic benefits were calculated. The conclusion is that the implementation of dynamic lane prioritization for goods would have socio-economic benefits on the specific route where the simulation was carried out. Prioritizing certain freight traffic on bypass routes can also create incentives for more sustainable freight transport and contribute to the fulfillment of transport, environmental and business policy objectives at both local, regional and national levels. This requires development of functionality that can monitor vehicles and only allow access to priority lanes for vehicles that meet certain predetermined requirements, such as fuel, degree of filling, etc.

The technical system that was defined within the Ring Road Logistics project is currently being developed within the EU-funded project NordicWay 2 (involving the infrastructure authorities from Sweden, Norway, Denmark and Finland. There will be several demonstrations and pilots linked to different services, of which dynamic access control is one. This is also seen as a primary step for development towards a more autonomous traffic system.

2 Description of the pilot

2.1 Pilot set up

Lead:	Technolution, Scania and Sweco			
Participants:	Edwin Mein, Anders Innala, Oremus Bas + Scania crew, Thomas Sjöström and student at KTH.			
Timeframe:	Start:	20200309	End:	20200310

The project demonstration took place when a Scania truck on the E4 / E20 drove in the public transport lane on a 3.1 km long distance between Trafikplats Bredäng, Trafikplats Västertorp and Trafikplats Västberga. The purpose was to test dynamic access control in order to optimally use existing road capacity. At E4 / E20, the test vehicle sends a request to a simulated traffic control center to use the bus lane. Under the right pre-conditions, the test vehicle was granted access, otherwise denied. The practical demonstration always granted access when safe to do so which was determined by the truck driver.

Permission was required by the County Administrative Board to carry out the test. The project submitted an exemption that was granted (decision JT35 142/19 in December 2019) a permit to use the bus lane during low traffic (09.00-15.00) for the period 9 March 2020 - 13 March 2020.

The registration number of the test vehicle was YJH 917. The vehicle had a blue container on the flange with corrugated plate with a sign that informs the public that testing is ongoing.

Map of demonstration route

The dispensation covered a stretch of the E4 / Södertälje Road south of Stockholm in a northbound direction, see figure 1. This section was most suitable during a workshop in February 2018 with representatives from the Swedish Transport Administration, the City of Stockholm and the Stockholm County Council (current Stockholm region). This is because, along this route, fewer buses run in public transport lanes that could possibly be disturbed than on many other possible routes. The road stretch was also well suited for filming both on bridges and landing sites for the use of drone. No police permit was needed to film with the drone.

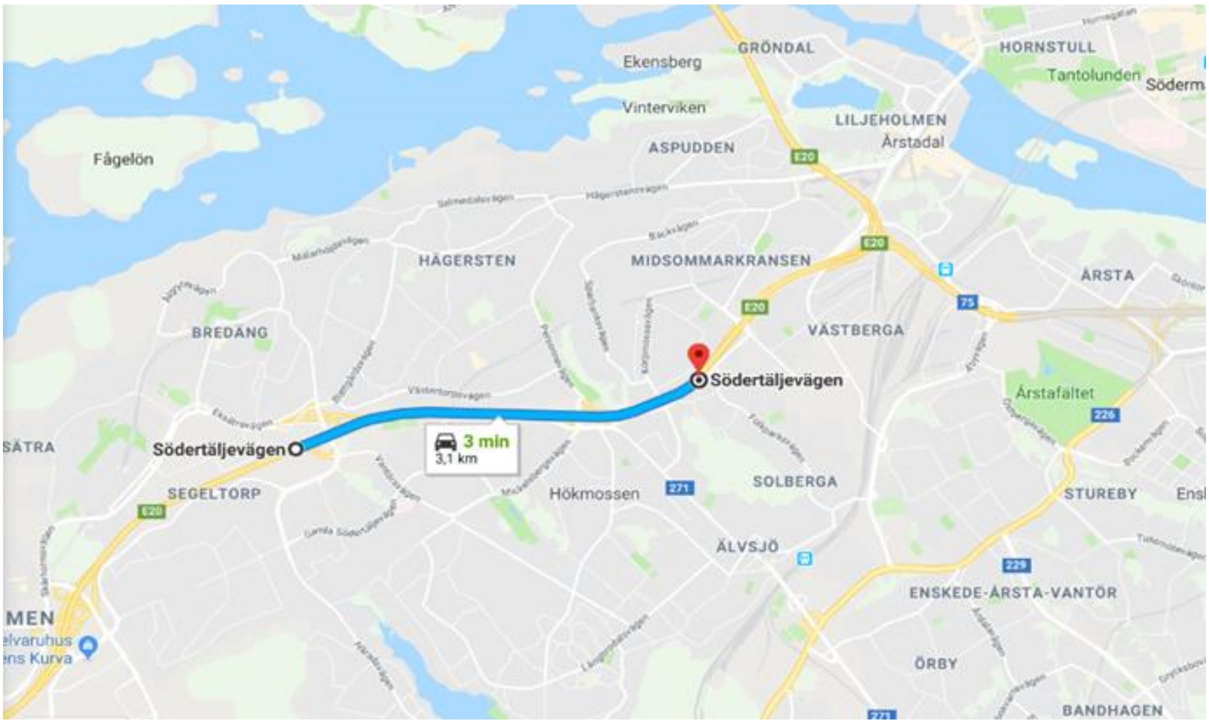

Figure 1. Map over demonstration area.

2.2 Objectives

The main objective of the pilot was:

- To optimize traffic flow into and out of the city by spreading traffic over the road network with different applications, such as access to road segments with low utilization. This needs an active traffic management which will be developed and tested in this use case.

In order to accomplish the main objective, the following underlying objectives have been identified:

- Explore how to use existing infrastructure in an optimum way resulting in a proposal.
- Obtain necessary documents and permissions.
- Test technical system and exchange of data between Technolution and Scania.
- Demonstrate the complete pilot setup in a real-life situation including a traffic operator.
-

2.3 Activities

The project has conducted the following activities during the project:

- Developed a use case/service definition.
- Defined messages- define content to be included in the messages between service provider (STA/Technolution) and service user (Scania).
- Define JSON messages on geofence definition.
- Secure exchange of data with Interchange Node details. To start simulating messages certain details needs to be set up in the cloud (e.g. topic). Technolution developed software to be integrated in the simulated traffic management center (TMC). Scania developed software to retrieve information from the topic at the interchange node.
- Tested dynamic access control between Technolution and Scania including communication between Technolution and Scania with messages. Scania collected geographical data of the geofenced lane from the Swedish Transport Administration National Road Database to define the road demonstration area. Tested system with complete messages in closed environment as well as the possibility to send requests to TMC to enable a vehicle to receive yes/no and cancel request in real-time to use access the bus lane.
- Application for permission of lane use: Permission to use bus lane for a week for in real traffic testing. Scania was the formal applicant as owner of the test vehicle for the demonstration period 9-13 March 2020. Signed approval documents from STA and from SLL was included as attachments to the application.
- Test run to secure message distribution and test run road stretch and live test demo on defined road-stretch with developed story board to define when to film what in sequence.
- Workshop service development from a service provider perspective.
- Workshop to gain input from road owners and from an operational perspective in an up-scale scenario.

3 Technical description

3.1 System Architecture

The pilot's system architecture is shown below, see figure 2.

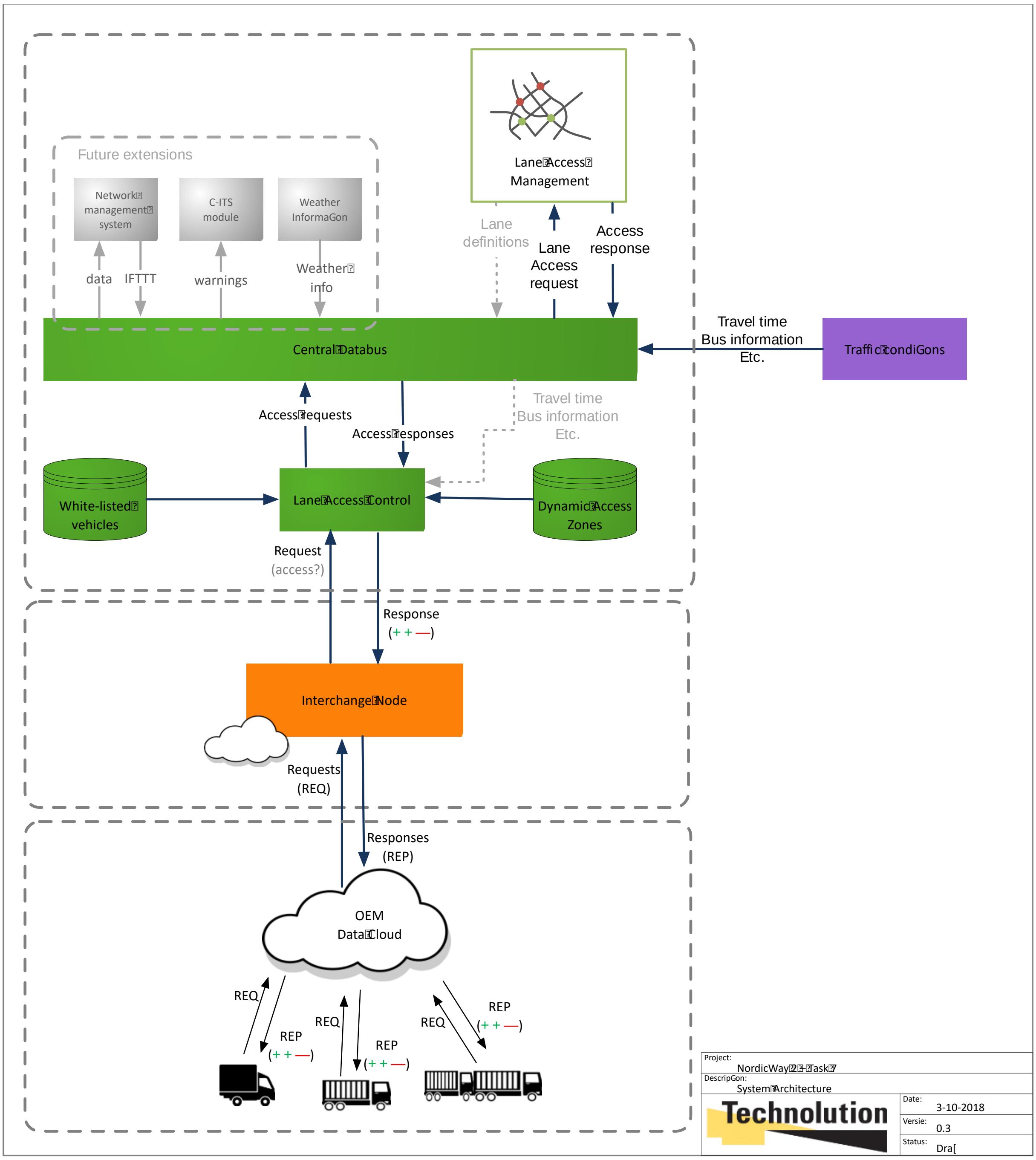

Figure 2. Illustration of the piloted system architecture.

The architecture shows the three main sub-systems and their modules:

- **Traffic Management Center (TMC)**. The TMC contains systems from Technolution for the exchange with the interchange node, the interaction with the traffic operator and the central databus for traffic data.
- **Interchange Node**. The central data exchange is based on the NordicWay 2 Interchange Node that offers a common platform for information exchange between business and governmental systems.

- **OEM digital environment.** Scania develop an interface making it possible to send request for access and receive message for approved or denied access provided through the Interchange Node.

The architecture includes a set of future extensions where the dynamic access control can be connected to C-ITS solutions, traffic network management systems and weather systems for additional information from external sources.

As part of the pilot we didn't exchange the lane definitions through the system but around the system using JSON specified lane geographical specifications. However, in a final system the digital exchange of the lane definitions is essential to be part of the entire ecosystem from a TMC' perspective.

3.2 Use cases

The two main user stories that had been identified are:

A vehicle approaches a designated road stretch where certain requirements need to be fulfilled to be able to access. The driver sends a request to a traffic management operator and receives an approval or denial depending on if requirements are met and if the traffic conditions are right.

and

A traffic management system checks that vehicles requesting access to a designated road stretch, fulfill set requirements and sends a message of approval if they fulfill set requirement and if traffic conditions can allow access. It will also be able to cancel the given approval if conditions change.

The main system consists of a stretch that can be opened for specific vehicles, given time, vehicle characteristics and traffic conditions.

The main goal is a system that can grant access to a vehicle so the vehicle knows that it can use the stretch. The stretch is a dynamically controlled zone, a stretch definition where access can be switched on or off. The message is not a broadcast to all vehicles, but only to allowed vehicles.

- A driver requests access to the controlled zone using the HMI in the vehicle. This request is sent to the central system, through the nodes, for validation.

  - *Automated handling of requests*: the system checks the conditions for the controlled zone according to the given parameters. When the controlled zone is 'open' the system only has to check the vehicle's permission for access. When the stretch is 'closed' the request will be declined automatically. No human intervention is involved here.

    This approach supports for a large group of vehicles and prevents the operator intervening with every request and taking him away from his actual job. The downside is that the system could overlook something a human could have seen, such as a broken down bus or similar where cameras are required.

  - *Manual handling of requests*: the vehicle's requests pops up on the operator's HMI and depending on the conditions the operator can grant or deny access to the stretch. The system itself can give additional information like traffic conditions and whether the vehicle has permission, if applicable. The final decision is up to the traffic operator.

    The advantage is that the final decision from the operator who can check for additional parameters such as camera views. The downside is that it can be a demanding and a bit boring when numerous vehicles request access. A 'grant access for all' is most likely to happen in that case.

These main user stories require underlying user stories to be in place in order to facilitate this. Therefore, these stories can be split into sub-user-stories which together create the main one:

- **Management and maintenance of Dynamic Access Service**
  - Define a controlled zone defining a Dynamic Access Service.
  - Edit a controlled zone and parameters of a Dynamic Access Service.
  - Delete a controlled zone belonging to a Dynamic Access Service.
  - Shutdown / pause the Dynamic Access Service

- **Monitor traffic conditions**; to evaluate if there is satisfying conditions in traffic and level of available capacity approve priority requests
    - This is preferably an automated process where the system architecture gathers enough information to make the decision on its own. It could also be either a manual/partly manual process done by the TMC.
    - This will be possible through communication in the system architecture with number of requests, either at a specific time slot or ad hoc, and the data from public authorities in order to predict how many requests that can be approved in the priority lane.

- **Cancel controlled zone**; cancellations of approved requests for priority due to e.g. changes in transport assignment or route
    - The driver should be able to cancel the approved request for entering the controlled zone.
    - TMCs will be able to cancel approved request for entering the controlled zone due to e.g. accidents or changed traffic conditions.

3.3 Service Message Description

Scania and Technolution worked out a specific protocol for the exchange of access requests and responses to these requests. Existing standards like DATEX II have no complete support for the dynamic access lane information and request <-> response data flow.

The following paragraphs show the message elements in more detail.

3.3.1 Access Request

Field name	Type	Description	Mandatory	Comment
id	String	GUID, matching response	☒	
Publication Time	Date Time	Timestamp for when this version of the request is created	☒	ISO 8601 time format
Publication Creator	 String String	Subfields: • **country** • **national Identifier**	☒	e.g. “se” “Scania”
Request Type	Enum	Enumeration: • **access Request** • **cancel**	☒	Cancel could be sent both while waiting for response and after getting granted access.
Controlled ZoneId	String	GUID matching Zone Definition message	☒	
Vehicle Id	String	VIN number	☒	Used to check if vehicle is on the whitelist (hardcoded in demo). VIN number could be sensitive from a GDPR perspective.
Date	Date Time	Estimated Time of Arrival at the controlled zone (bus lane)	☐	ISO 8601 time format
Vehicle Position	 Number Number Number Number	Subfields: • **lat** • **lng** • **heading** • **speed**	☐	
weight	Number	Gross Combination Weight in tons	☐	Not used in the demo.

3.3.2 Access Response (including revocation)

Field name	Type	Description	Mandatory	Comment

id	String	GUID, matching request	☒	
publicationTime	DateTime	Timestamp for when the response is created	☒	ISO 8601 time format
publicationCreator	 String String	Subfields: • **country** • **nationalIdentifier**	☒	e.g. "se" "Trafikverket"
responseStatus	Enum	Enum values: • **allowed** • **denied** • **postponed**	☒	DENIED can be used when revoking a previously allowed/granted request. POSTPONED could be used when the operator is too busy at the moment of request. This could be an automated response when there is no response within say 5 minutes. For the demo we could skip this response type.
reason	Enum	Reason why the access request was denied. Enum values: • **unknown** • **roadClosed** • **accident** •	☐	Optional.
validityTime	DateTime	A timestamp for when the access to the bus lane expires	☐	Optional. ISO 8601 time format.

3.3.3 Example of messages

Access Request


```
{
  "id": "0f8fad5b-d9cb-469f-a165-70867728950e",
  "publicationTime": "2019-02-19T12:42:18.008Z",
  "publicationCreator": {
    "country": "se",
    "nationalIdentifier": "Scania"
  },
  "requestType": "accessRequest",
  "controlledZoneId": "7c9e6679-7425-40de-944b-e07fc1f90ae7",
  "vehicleId": "YS2XX1234X8901234",
  "eta": "2019-02-19T12:47:18.008Z",
  "vehiclePosition": {
    "lat": 57.3,
    "lng": 19.8,
    "heading": 193.7,
    "speed": 79.5
  },
  "weight": 24.7
}
```

Access Response


```
{
  "id": "0f8fad5b-d9cb-469f-a165-70867728950e",
  "publicationTime": "2019-02-19T12:45:18.008Z",
  "publicationCreator": {
    "country": "se",
    "nationalIdentifier": "Stockholm Traffic Control"
  },
  "responseStatus": "allowed",
}
```


or


```
{
  "id": "0f8fad5b-d9cb-469f-a165-70867728950e",
  "publicationTime": "2019-02-19T12:45:18.008Z",
  "publicationCreator": {
    "country": "se",
    "nationalIdentifier": "Stockholm Traffic Control"
  },
  "responseStatus": "denied",
  "reason": "accident"
}
```


4 Evaluation Results

4.1 Technical evaluation

4.1.1 Latency

- The following method was used to measure the selected KPIs.
- Method **"Stopwatch"**
  - We have performed several demo-sessions in real-life and as desktop study measuring the system's speed from A to Z. The first approach we used was using an old-fashioned stopwatch to measure the latency between access request from within the truck to the operator and back again to the truck.
  - Preconditions: All systems have to fully operational. The operator is instructed to re-spond at fast as possible on an incoming request.

4.1.2 Latency results

- Using the stopwatch, we measured a latency of 20 seconds between the driver's request and response from the traffic operator. This latency compasses all individual steps in all systems.
- The largest part of this delay is due to human interaction from the traffic control centre and driver response.

  Based on 589 measurements during the pilot demo days we measured an average latency of 271 ms between transmission and reception in the

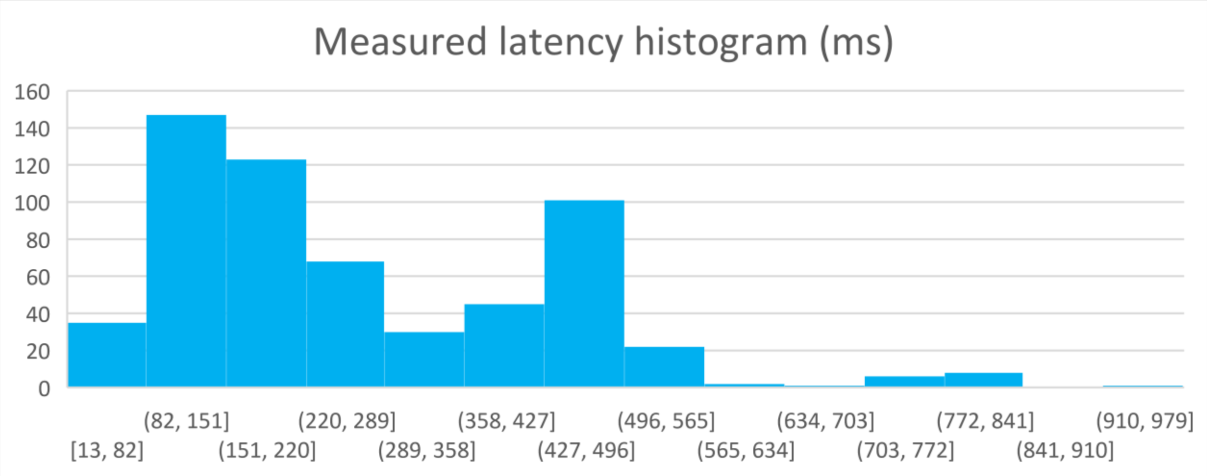

Figure 3. Histogram of communication latencies.

- The histogram graph shows that most messages are well within 500ms. Every column in the histogram shows the number of measurements that fit within the range [from, to]. For example [82 ms, 151 ms] contains a little over 145 measurements. As can been seen, most significant columns are within 500 ms.

4.1.3 Data and transport security

Method of checking this technical requirement was inspection of the technology chosen.

4.2 Service ecosystem

4.2.1 Method

The service ecosystem has been constructed during the Service Workshop @ February 4th, 2020. The method is described in detail in the NordicWay 2 Evaluation report. The objective of the workshop was to describe the current ecosystem of this pilot, its actors and their roles, and to better understand the business potential and what is needed for implementation of the service. The workshop was divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilot. Thereafter a description of the current ecosystem, i.e. how the pilot is set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the workshop a scaled-up version of the ecosystem was constructed. This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

4.2.2 Results

4.2.2.1 Current status of service ecosystem

Encountered challenges and lessons learned

Forming the ecosystem (consortium, others)	STA: It is difficult for STA to take the role we actually should do in a real implementation, primarily because of the lack of a test environment. Technolution: a good process to find the appropriate partners in the development of the consortium / ecosystem.
The service formulation and provision phases	Technolution: development of the service formulation was a tougher process than expected. This was also related to the uncertainties about the actual allowed tests on street. Once the service was clear, it was a clean process to come from the first idea to the actual implementation. We started with a very broad idea of possibilities and didn't

	scope these ideas early enough. A lesson for us was to start scoping down possibilities and expectations as early as possible.
Access to data and right to use the data within the pilot (within the consortium, with public actors, with commercial actors)	Technolution: as this service was almost directly between Technolution and Scania, the process of defining a protocol, exchanging data and so forth was a nice process. Both technical teams worked close together for the exchange of ideas.
Any other issues/challenges	Technolution: this service started later than we should have started in hindsight. Other services had higher priority and therefore this service was put back on the planning. This resulted in some team changes, project leader changes and idea changes which also required additional time. At the end it still was a bit of a quick process from development to test.

Current status ecosystem description

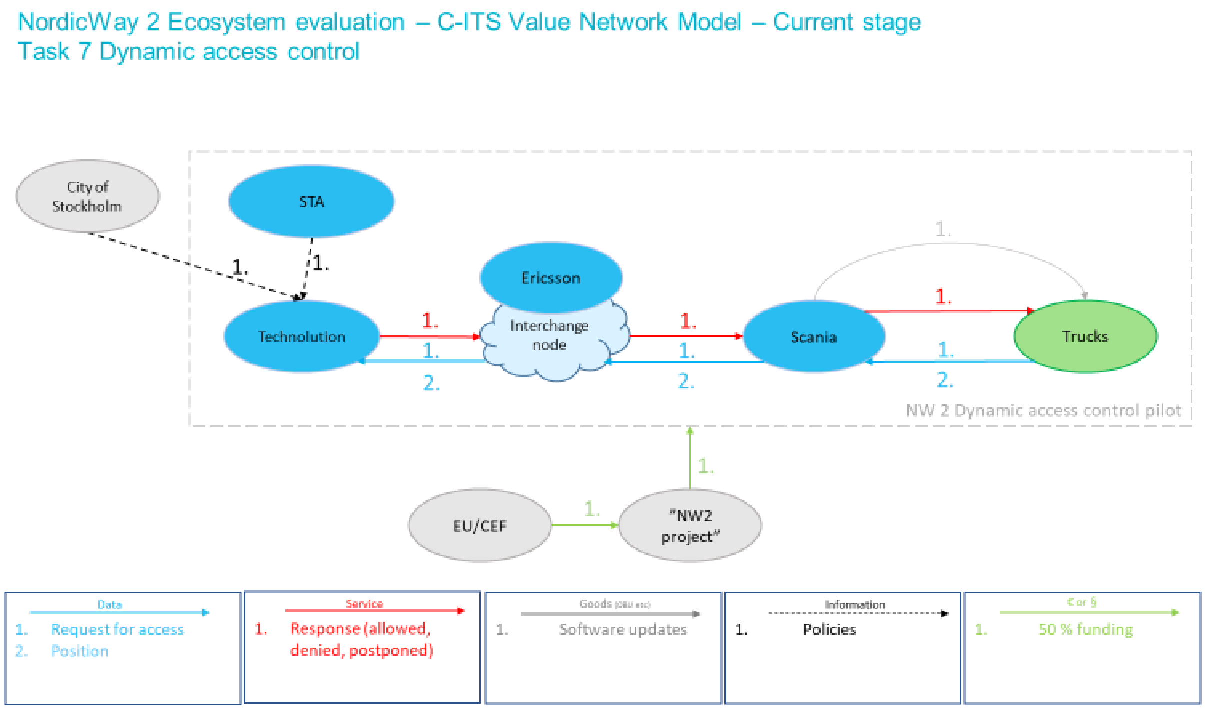

Figure 4. Current status ecosystem for Dynamic access control.

In the current Ecosystem, the first step that occurs in the service is that a Scania truck sends a request for access that ends up in Technolution by passing Scanias cloud and the interchange node. Technolution then creates the service by sending a response (allowed, denied or postponed) back to the truck. The truck then responds by sending data on its position. The end user (Truck) includes both the driver and the OBU and telematics unit.

STA is not present in the ecosystem of the pilot other than exchanging information with Technolution. The City of Stockholm is also exchanging information with the pilot (permits for driving on the road etc).

Pains, Gains and commitment

Actor	Pain	Gain	Commitment
Scania	• Permit on specific vehicle limited time • Very fragmented ecosystem (non-scalable), locally on city level	• Learning from interaction with other participants in the ecosystem • Positive effect on Scania image on sustainable transport	• These types of interaction with infrastructure will become useful when going into automation

	• Dependency on external party for key information • Difficult to get business case or competitive edge (open ecosystem)	• We can use present hardware in vehicle, business as usual	• These types of functions will help our customers in getting better flow in traffic • Scania clearly states to be driving the shift towards a sustainable transport system
Technolution	• New software • New concept • Other road users complain • Should be nationwide • Upscaling demands changes in thinking • Manual responses can overwhelm the operator	• New market → clients • New standards (Open, EU) • More automation • Less CO2 • Better traffic flow • New concepts changing way of thinking with regards to road usage • Better usage of existing infrastructure	• Active actor in Sweden • Integrator of systems • Cooperation with OEMs and road authorities • Perfect example to other parties and countries
STA	• Involvement from Traffic Centre needed, more work and investments needed there • Too much manual work in the demo-version • The demo-setup will be hard to scale up in an efficient way	• Better and more efficient use of current road infrastructure if we implement and scale up the use case.	• Road operators need to find ways to use current road infrastructure in a more efficient way

4.2.2.2 Scaling up the ecosystem

How will the service look 5 years from now?

From Scania's point of view, this service is feasible if it is implemented over a bigger geographical area and not just some cities and regions. Several countries should decide on implementing the service for OEMs to be able to invest time and money in it. STA can implement a solution from where static and dynamic traffic regulations can be provided in a secure way. The same solution could be used to give response to requests for access to a public transport lane. The entity in direct contact with the STA solution could be an OEM backend, a service provider, an aggregator or an interchange node provider. Technolution adds that they would like to see for example, STA being in the center of the service as its now directly connected to the city's environment. When scaling up, OEMs would like to connect to a single point of entry. Therefor a centralized concept, for example hosted by STA, can offer this single point of entry and every city / region uses their systems to feed the central platform.

Scaling up ecosystem description

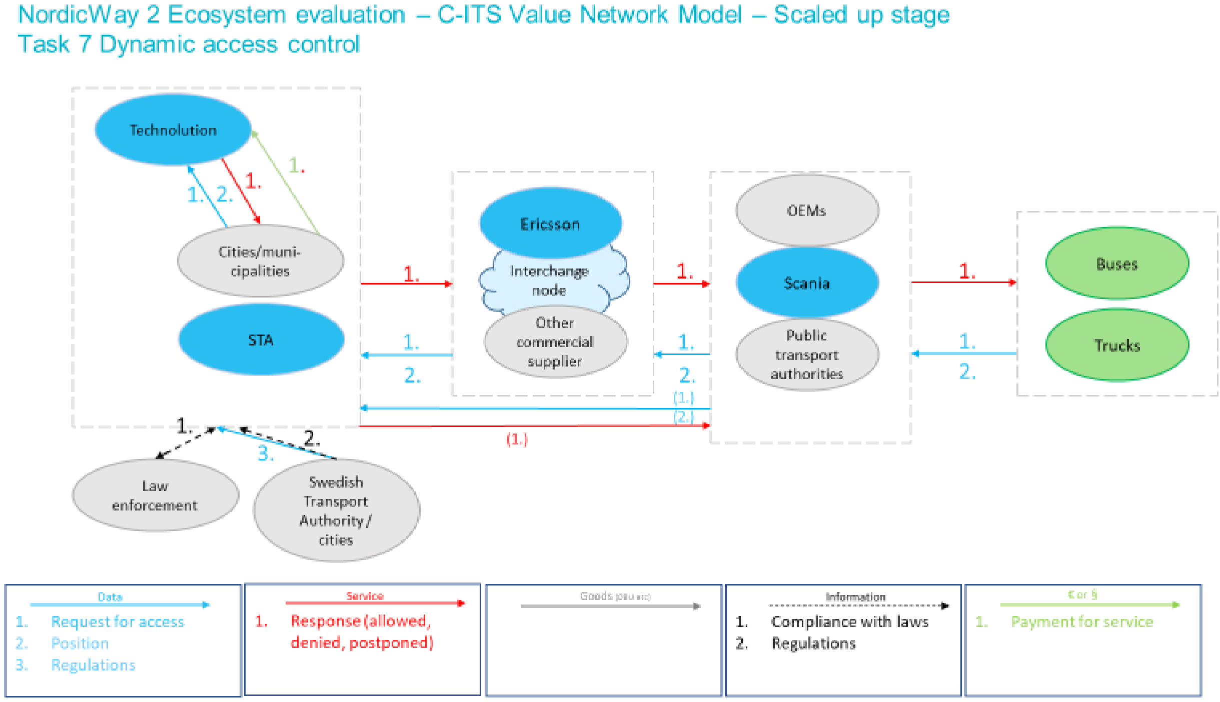

Figure 5. Scaling up ecosystem for Dynamic access control.

Figure 5 displays one possible scaled up version of the ecosystem. In this example; Technolution can be contracted by STA. STA can take data directly from Scania, through a commercial service association or through the interchange node. Scania can send data anywhere but prefers to send it to STA. More end users (trucks and buses) can use the service in this scenario in e.g. public transport authorities and other OEMs might be interested in using the service. An exchange of information and data between the road operators and STA/cities is important as well as a collaboration with law enforcement to make sure the traffic rules are being followed.

Part of the service can be financed by the public side, fleet owners etc. It is still not clear who makes the investment and who gets the revenue. The service needs to be bundled to sell better and can possible be joined with other services in order to make the whole set of services profitable.

5 Results from workshop

The aim of the workshop was to gather different stakeholders with operational input to the demonstrated service. 15 persons representing Swedish Transport Administration, Traffic Management Centre, City of Stockholm, Closer, Sweco, Technolution and Scania participated at the workshop in Stockholm, November 2019.

The participants were divided into groups to discuss six questions. The text below the respective questions presents the main conclusions.

Question 1: What pre-conditions must be fulfilled for a truck to be allowed to use the buss lane (e.g. vehicle characteristics, traffic environment)

- How to use existing infrastructure is a strategic consideration, should a bus lane allow trucks or instead have designated lanes which any vehicle could request access to. If so, generic criteria should be defined grating/or decline access for individual vehicles types, e.g. environmental, time critical, prioritization etc.
- Data is the key for monitoring lane status, so technically the vehicles and infrastructure should be ready.
- Type of transport that may use buss/dedicated lane could be delayed transport, dangerous goods, vital or sensitive cargo. A political issue to allow the possibility to but capacity or only allow for transport vital for the society.

Question 2: How can traffic management handle a request from a truck to use the bus lane? How to manage 150 requests from 30 different geographical locations?

- The purpose with traffic management is to monitor safe and efficient throughput of traffic in the road network. A service with designated lanes for requesting vehicles provide an efficient steering tool to manage the road network, e.g. in congested areas.
- We recognize a transition from a human controlled system to an automated system. From an operational point of view a fully automated system for the management of all requests is desirable and a “kill-switch” to stop the system if needed.
- Travel plan for flights are known prior take-off, the same strategy could be applied to this service, e.g. trucks routes are known in advance.

Question 3: What is the potential with geofencing for traffic management and how to include new functionality in operative traffic management?

- The full potential is a complete redesign of traffic management.
- Provides knowledge of road the infrastructure demand (when routes are known in advance) and enable pro-active traffic management.
- We identify another transition period where connected cars can obey the new rules, but the older cars depend on the human's reaction to the rules, which may create conflicts.

Question 4: How to manage conflicting interests to use the bus lane?

- The system should not be an adhoc system but designed with predefined rules how to manage capacity and requests.
- The rules must be based on the city's rules/strategies and may change in time.
- Sharing road infrastructure have similarities to the rail system where different actors request priority.

Question 5: Who is the target group for this service and how does the service affect road owner, the city, bus operator and traffic management?

- Possible target groups are bus companies, transport operators and logistic companies.
- The service has synergies with the implementation of Mobility as a Service (MaaS).

Question 6: Future applications building on this service – what could that be?

- Evacuation plans in case of an emergency.
- A data base must be created to manage different geofenced roads.
- We need to start tests on how to use the available road capacity.

6 Dissemination

6.1 Filming 9th and 10th of May- experiences from the demonstration

When doing a practical demonstration, unforeseen events will happen even with thorough planning. In our case we faced a new situation with the demonstration road area, personal resources and malfunctioning hardware. We did however solve all issues in a good team spirit, good communication and every partner had clear roles and knew what to do. And, we had a lot of fun and despite technical disturbances the demonstration was a success from a technical perspective.

Swedish Transport Administration is currently constructing a major road “the Stockholm bypass project” (Förbifart Stockholm) which operate close to the NW2 demonstration area. Road works were ongoing at night and we did not know the availability of the bus lane upon arrival on the first demonstration day (Monday morning 9th March). We had planned for 3 film sites to capture different stretches but in practice we could use only one. This disturbance did affect the movie.

We applied for a permit (allowing the truck to drive in the bus lane) lasting for one week but were only allowed to film off peak hours. We should have re-applied to film during rush hour. March is not good to film demo due to bad weather conditions. The truck gets dirty and the road is dirty and dusty. A clean truck gets dirty the next day so April-October would be better from filming perspective. The demonstration area was good spot, even though a spot north of Stockholm should have been considered due to disturbance by The Stockholm Byass Project.

Figure 6. Picture from the demonstration truck, source Scania, March 2020.

The filming was planned to maximum of 4 days, but we only used 2 days to complete the movie covering filming spots on E4, Scania headquarters in Södertälje and filming at the simulated Traffic Management Centre at the Royal Institute of Technology. We planned to film the truck driving on E4 on bridges and by drone so the truck would have to drive the same lap about 10 times due to the turning requirements of the truck. A complete lap of the test vehicle took about 25 minutes. During the demo we had constant communication between film crew and the truck crew.

The Traffic Management Centre is since 2019/2020 classified as security object where filming and visitors are strictly forbidden and with very restricted access. In addition, the TIC in Stockholm recently moved from Kristineberg to the inner city which made it more difficult to free personnel resources, the reason why no person from the TIC could act as a traffic management operator in the film. But a special thanks to KTH/ ITRL, to let us use their lab as a traffic management center.

We faced problems and in good spirit manage to solve them by being flexible and adaptive with, time resources, additional staff, meeting points etc.

We used a nearby hotel as “base”, well suited for briefing and recap meetings, for lunches and became a natural meeting point for all involved persons to the demo.

6.2 Movie release summer 2020

During the demonstration a film crew was procured to record the different steps on site. The movie shows the service functionality from when the driver requests permission to enter the buss lane to the traffic operator allowing the request and notifies the driver who enter the lane. The movie can be viewed by the following link: https://we.tl/t-0cwVTAT7CZ

7 Conclusions and recommendations

The section present conclusions based on the results of the demonstrated pilot and recommendations for further development from different perspectives:

Swedish Transport Administration (STA) perspective:

Dynamic geofencing is foreseen as a future tool and method for proactive traffic management. A road operator can use dynamic, digital traffic regulations to manage the traffic and use the current road infrastructure in a more efficient way in order to promote better traffic flow, safer traffic and less environmental impact. Connected vehicles and communication infrastructure like LTE/5G is an enabler for dynamic geofencing. Access to dedicated lanes for specific traffic users is only one of many use cases that will be possible with future dynamic geofencing capability.

The pilot has shown that geofencing technology is a possible way for road authorities to dynamically control a prioritized bus lane and allow trucks or other kind of vehicles to use the bus lane when traffic conditions and other prerequisites are met. An eco-system of data exchange needs to be in place to allow for real implementation and up-scaling. An Interchange Node as implemented in NordicWay can be part of such an eco-system and help to distribute information regarding dynamic lane access to relevant stakeholders like Scania and fleet operators.

The demo has shown that it is technically possible to implement dynamic access to designated road infrastructure, but more challenging is probably to comply with current regulations and to get social/political acceptance for this use-case. As for now dynamic traffic regulations need to be available in the actual road infrastructure, only digital availability is not accepted. Even more challenging might be to get acceptance to use a bus lane for other purposes than for public transport as promoting public transport is key for the politicians. It can also be challenging to get acceptance from drivers of ordinary vehicles that trucks drive in the bus lane.

Scania perspective:

This pilot show that current technology is sufficient for this type of functionality. However, the practical and legal parts of making this scale, is not in place today.

- The process of getting the pilot going show that a lot of manual work needed to apply for authorization from authorities for each and every stretch of road to be used and also for every vehicle.
- From OEM point of view it is desirable that this functionality become standardized in Europe to simplify integration.

Technolution perspective:

The pilot showed very well that a cooperation between Scania, STA and Technolution enables an experiment with the dynamic control of a bus lane.

- Communication protocols.

  We identified early in the pilot development process that no existing standard could support us in the development. We investigated ETSI standards and DATEX II standards, but the pilot use case required a bi-directional information flow: access request ←→ access response. Together with Scania we established a really good definition of messaging between both systems through the Interchange Node (see 0 for more details). This process went really fluently, and it showed that if two technical companies work together, these communication issues are solved easily.

  Advice: With the current development of geofences, urban zones, restricted zones, UVARs etc. it is essential that our findings land in these developments. Especially in the development of for example a DATEX II standard the bidirectional communication flow is essential for dynamic access lane control.

- User interface.

  Early in the development of the user interface we had a workshop (February 2018) with all stakeholders involved. This enabled an early check on the user interface input from the stakeholders. This has proven very valuable to do in an early stage. At that moment the user interface was a graphical mock-up which eased making small alterations based on the feed-back.

Advice: An early workshop on all aspects including the graphical user interface is valuable throughout the project. An intermediate workshop could help in establishing the baseline with all stakeholders.

- Movie making.

  The process of movie making was a pleasant experience where all stakeholders contributed together with much power, enthusiasm and creativity. We organized a couple of rehearsals before we did the actual filming and that showed effectiveness in finding issues upfront. A complete storyboard was not present at the filming day and we solved this with improvisation also due to changing roadworks circumstances in the filming area.

  Advice: Organize enough rehearsals to solve issues early in the process and have a storyboard with flexibility for changing circumstances when making the movie.

Appendix 6: Dynamic Environmental Zone report

Final report –
Dynamic Environmental Zones

NordicWay 2

Version 1.0

Date: 2 December 2020

Co-financed by the European Union
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Nordic WAY 2

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Acronyms

AMQP	Advanced Message Queueing Protocol
APACHE	The Apache HTTP Server, colloquially called Apache, is a free and open-source cross-platform web server software, released under the terms of Apache License2.0.
avc	automated vehicle container
BEV	Battery Electric Vehicle
BI	Basic Interface
C-ITS	Cooperative Intelligent Transport Systems
CAM	Cooperative Awareness Message
CRL	In cryptography, a Certificate Revocation List (or CRL) is "a list of digital certificates that have been revoked by the issuing certificate authority (CA) before their scheduled expiration date and should no longer be trusted.
DENM	Decentralized Environmental Notification Message
ETSI	European Telecommunications Standards Institute
EU	European Union
gic	GNSS/Ground Integrity Channel
GHz	Gigahertz
GIS	Geographical Information System: is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.
GNSS	Global Navigation Satellite System, system used for positioning and road segment identification
HLN-RLX	Hazardous Location Notification - Railway Level Crossing
HMI	Human Machine Interface
hop	In computer networking, including the Internet, a hop occurs when a packet is passed from one network segment to the next. Data packets pass through routers as they travel between source and destination. The hop count refers to the number of intermediate devices through which data must pass between source and destination. Since store and forward and other latencies are incurred through each hop, a large number of hops between source and destination implies lower real-time performance
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ID	Identifier
IEC	International Electrotechnical Commission
IEEE 802.11	See IEEE 802.11P
IEEE 802.11p	IEEE 802.11p is an approved amendment to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE), a vehicular communication system. It defines enhancements to 802.11 (the basis of products marketed as Wi-Fi) required to support Intelligent Transportation Systems (ITS) applications. This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure, so called V2X communication, in the licensed ITS band of 5.9 GHz (5.85-5.925 GHz).

IP	Internet Protocol
IPv4	Internet Protocol version 4 (IPv4) is the fourth version of the Internet Protocol (IP). It is one of the core protocols of standards-based internetworking methods in the Internet and was the first version deployed for production in the ARPANET in 1983. It still routes most Internet traffic today, despite the ongoing deployment of a successor protocol, IPv6. IPv4 is described in IETF publication RFC 791 (September 1981), replacing an earlier definition (RFC 760, January 1980). IPv4 is a connectionless protocol for use on packet-switched networks. It operates on a best effort delivery model, in that it does not guarantee delivery, nor does it assure proper sequencing or avoidance of duplicate delivery. These aspects, including data integrity, are addressed by an upper layer transport protocol, such as the Transmission Control Protocol (TCP).
IPv6	Internet Protocol version 6 (IPv6) is the most recent version of the Internet Protocol (IP), the communications protocol that provides an identification and location system for computers on networks and routes traffic across the Internet. IPv6 was developed by the Internet Engineering Task Force (IETF) to deal with the long-anticipated problem of IPv4 address exhaustion. IPv6 is intended to replace IPv4. In December 1998, IPv6 became a Draft Standard for the IETF, who subsequently ratified it as an Internet Standard on 14 July 2017.
ISO	International Organisation for Standardization
IETF	Internet Engineering Task Force is an open standards organization, which develops and promotes voluntary Internet standards, in particular the standards that comprise the Internet protocol suite (TCP/IP). It has no formal membership or membership requirements. All participants and managers are volunteers, though their work is usually funded by their employers or sponsors.
II	Improved Interface
ITS G5	ITS-G5 is a European standard for ad-hoc short-range communication of vehicles among each other (V2V) and with Road ITS Stations (V2I). ITS-G5 uses the approved amendment of the IEEE 802.11 (standard IEEE 802.11p). This technology (possibly others) uses the 5.9 GHz frequency band to support safety- and non-safety ITS applications.
IVI	Infrastructure to Vehicle Information
IVIM	Infrastructure to Vehicle Information Message
KB	Kilobyte
MAPEM	MAP (topology) Extended Message
m	Metre
ms	Milliseconds
MS	Member State
OCSP	The Online Certificate Status Protocol (OCSP) is an Internet protocol used for obtaining the revocation status of an X.509 digital certificate. It is described in RFC 6960 and is on the Internet standards track. It was created as an alternative to certificate revocation lists (CRL), specifically addressing certain problems associated with using CRLs in a public key infrastructure (PKI). Messages communicated via OCSP are encoded in ASN.1 and are usually communicated over HTTP.
OEM	Original Equipment Manufacturer
OV	Organization Validated
PHEV	Plug in Hybrid Electric Vehicle

PKI	A public key infrastructure (PKI) is a set of roles, policies, hardware, software and procedures needed to create, manage, distribute, use, store and revoke digital certificates and manage public-key encryption.
rcc	Road Configuration Container
REST API	Representational State Transfer Application Programming Interface
RFC	Request for Comments
RO	Road Operator
RTA	Road Traffic Authority
RSP	Roadside ITS-G5 System Profile (short also Roadside System Profile)
SPATEM	Signal Phase and Timing Extended Message
SREM	Signal Request Extended Message
SSEM	Signal Request Status Extended Message
SW	software
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security (TLS), and its now-deprecated predecessor, Secure Sockets Layer (SSL), are cryptographic protocols designed to provide communications security over a computer network. The TLS protocol aims primarily to provide privacy and data integrity between two or more communicating computer applications. When secured by TLS, connections between a client (e.g., a web browser) and a server should have one or more of the following properties: - The connection is private (or secure) because symmetric cryptography is used to encrypt the data transmitted. The keys for this symmetric encryption are generated uniquely for each connection and are based on a shared secret that was negotiated at the start of the session. The server and client negotiate the details of which encryption algorithm and cryptographic keys to use before the first byte of data is transmitted. The negotiation of a shared secret is both secure (the negotiated secret is unavailable to eavesdroppers and cannot be obtained, even by an attacker who places themselves in the middle of the connection) and reliable (no attacker can modify the communications during the negotiation without being detected). - The identity of the communicating parties can be authenticated using public-key cryptography. This authentication can be made optional but is generally required for at least one of the parties (typically the server). - The connection is reliable because each message transmitted includes a message integrity check using a message authentication code to prevent undetected loss or alteration of the data during transmission. In addition to the properties above, careful configuration of TLS can provide additional privacy-related properties such as forward secrecy, ensuring that any future disclosure of encryption keys cannot be used to decrypt any TLS communications recorded in the past. TLS supports many different methods for exchanging keys, encrypting data, and authenticating message integrity. As a result, secure configuration of TLS involves many configurable parameters, and not all choices provide all of the privacy-related properties.
TTL	Time to live (TTL) or hop limit is a mechanism that limits the lifespan or lifetime of data in a computer or network. TTL may be implemented as a counter or timestamp attached to or embedded in the data. Once the prescribed event count or timespan has elapsed, data is discarded or revalidated.
V2I	Vehicle-to-Infrastructure Communication; Information exchange between vehicles and infrastructure.

V2V	Vehicle to Vehicle Communication; information exchange between vehicles.
V2X	Vehicle-to-any communication; X is either infrastructure or car; Including communication between vehicles as well as between vehicles and infrastructure.
WAVE	Wireless Access in Vehicular Environments
WG2	Workgroup 2
WGS84	World Geodetic System is a standard used in cartography
Wi-Fi	Wi-Fi is a family of radio technologies commonly used for wireless local area networking (WLAN) of devices. It is based on the IEEE 802.11 family of standards.
WLAN	Wireless Local Area Network
X.509	In cryptography, X.509 is a standard defining the format of public key certificates. X.509 certificates are used in many Internet protocols, including TLS/SSL, which is the basis for HTTPS, the secure protocol for browsing the web. They are also used in offline applications, like electronic signatures. An X.509 certificate contains a public key and an identity (a hostname, or an organization, or an individual), and is either signed by a certificate authority or self-signed. When a certificate is signed by a trusted certificate authority, or validated by other means, someone holding that certificate can rely on the public key it contains to establish secure communications with another party, or validate documents digitally signed by the corresponding private key. X.509 also defines certificate revocation lists, which are a means to distribute information about certificates that have been deemed invalid by a signing authority, as well as a certification path validation algorithm, which allows for certificates to be signed by intermediate CA certificates, which are, in turn, signed by other certificates, eventually reaching a trust anchor.
e.g.	In Latin “exempli gratia” which stands for: “For Example”
i.e.	In Latin “id est” which stands for “In other words”

Nordic WAY 2

Content

1 Introduction

More and more European cities are now implementing environmental zones in urban areas which aim to protect the inhabitants of the cities and municipalities against emissions, e.g. noise and air pollutants. The new acronym for such implementation is UVAR=Urban Vehicle Access Restrictions. UVAR includes low emission zones, emergency pollution schemes, urban road tolls information and access restrictions. These are new data types to be considered for the updated RTTI categorized as UVAR data.

If the requirements of a zone are known it is possible for a plug-in hybrid electric vehicle, PHEV, to adjust the characteristics, accordingly, e.g. automatically shift from hybrid mode to pure electric mode when accessing a designated environmental zone, reducing emissions in desired zone.

In addition, a dynamic environmental zone could change status due to occurring air quality and noise emissions, or other events in particular areas, creating dynamic zones when and where they are needed for better environment and air quality.

Furthermore, dynamic environmental zones can be used to encourage transition to more environmentally friendly vehicles with effective incentives, e.g. if the service is used the road user will be offered lower road tolls or free parking.

This final report covers all the aspects of the dynamically controlled zones pilot the stakeholders researched in Gothenburg. The report contains the service definition, the pilot description, technical and architectural setup, evaluation results, dissemination of results and conclusions and recommendations.

2 Service definition

The service developed is to enable cities to create and distribute dynamic environmental zone descriptions to road users. The purpose is to reduce local emissions (air pollutants and noise) in urban dense areas. This will improve environment and air quality in urban areas. A service definition report is available where Dynamically controlled zones service is described in chapter 5.5. (NordicWay 2, 2020).

Enable road authorities to create and distribute zone description of an environmental zone in an urban area to vehicles which can adjust vehicle characteristics, accordingly, e.g. shift from hybrid mode to pure electric mode when accessing a designated environmental zone.

3 Description of the pilot

3.1 Pilot set up

Lead:	SWECO (TRV)			
Participants:	Volvo Cars, Ericsson, Gothenburg City, Technolution			
Timeframe:	Start:	May 2018	End:	April 2020

The City of Gothenburg, Ericsson, Technolution and Volvo Cars partnered in the development of a geofencing proof-of-concept for dynamically controlled zones. The idea was simple: if environmental emissions are too high in a city area, it is possible for a Plug in Hybrid Electric Vehicle, PHEV, to automatically shift from hybrid mode to pure electric mode, reducing emissions in desired zone. Together the project developed a pilot consisting of a graphical user interface (GUI) for the operational management tool, the exchange format with Volvo Cars, the connection to Gothenburg's City Innovation Platform (i.e. FIWARE) on the NordicWay (Ericsson’s) Interchange Node. Volvo Car's PHEV demonstrated the ability to automatically switch to run in pure electrical mode, when the cars enter the geofenced area controlled by the city’s traffic operator via the interface.

This would be a service which drivers of plug in hybrid electric vehicles can activate if they are willing to take actions on their awareness of environment and particularly city centres’ air quality. The interest would most likely increase with incentives like lower toll, free charging or free parking, but it was difficult to define suitable incentives in the pilot.

The target group for this pilot are therefore drivers with an interest to support environmental cause. No information from the vehicle or driver is needed by the city. Therefore, the area of integrity and GDPR is not in focus in this pilot.

3.2 Objectives

The overall object is to enable cities to create and distribute dynamic environmental zone descriptions to road users. The purpose is to reduce local emissions (air pollutants and noise) in urban dense areas to improve environment and air quality. The pilot aims to do this by enable cities to create and distribute virtual, dynamic environmental zone descriptions where the characteristics of the vehicles can be adapted.

The object of this pilot was to develop city, interchange and OEM cloud and vehicle software enabling a demonstration and a proof of concept of dynamic environmental zones in the city of Gothenburg.

3.3 Activities

The main user story developed here for a city operator to have a platform to inform a vehicle entering/leaving a dynamical environmental controlled zone about the actual restriction.

This main user story requires underlying user stories to be in place in order to facilitate this. Therefore, these stories can be split into sub-user-stories which together create the main one:

- **Manual management of a dynamic controlled zone**
  - Create, delete, add a dynamic controlled zone;
  - (Un)restrict a controlled zone;
  - Manage and monitor a controlled zone.
- **Exchange the dynamic controlled zone information / status with the Interchange Node**
  - Transform the controlled zone information / status as Interchange Node data;
- **Informing the vehicle of the controlled zone (un)restriction**
  - Collect dynamic controlled zone information from the Interchange Node (push);
  - Embed the controlled zone information into the OEM cloud;
  - Identifying vehicles concerned affected by the controlled zone information;
  - Exchange the controlled zone information with the vehicle.
  - Inform the driver of the vehicle

Part of the scope discussion was about the dynamic adaptation of controlled zones and automated control from the management system, where we concluded these elements are part of future extensions of the solution e.g. in NordicWay 3 or similar projects.

4 Technical setup

The technical setup uses the architecture as depicted in Figure 1.. The main stakeholders in this picture are:

The City of Gothenburg offers a test version of a City Innovation Platform (CIP) which is in development currently as part of the EU project IRIS. Project description can be found on IRIS project website, https://irissmartcities.eu/.

- This CIP delivers a common means for data exchange and storage from a smart city perspective. Exchange of controlled zone information, restrictions, status etc. is most suitable through this platform. A detailed description of the Gothenburg setup of the test version of CIP for NordicWay 2 can be found in the report produced by the City, "Uppdragsrapport, NordicWay 2, task 8 Smart routing based on infrastructure policies – using geofencing for providing dynamic environmental zones" (2020).
- The central data exchange is based on the Ericsson NordicWay 2 Interchange Node that offers a common platform for information exchange between business and governmental systems.
- Technolution deploys an installation of their traffic management suite MobiMaestro, https://www.technolution.eu/en/mobility/mobimaestro/ For this purpose, the existing central data-bus is extended with support for controlled zone information. MobiMaestro exchanges the controlled zone information with CIP through a standardized REST API.
- Volvo Car extends the cloud enabling the controlled zone information to be received and pushed to vehicles in the area. Test software in the vehicle ensures that vehicle

automatically runs on pure electric within the zone. A prototype HMI (Human Machine Interface), has been developed enabling information to the driver.

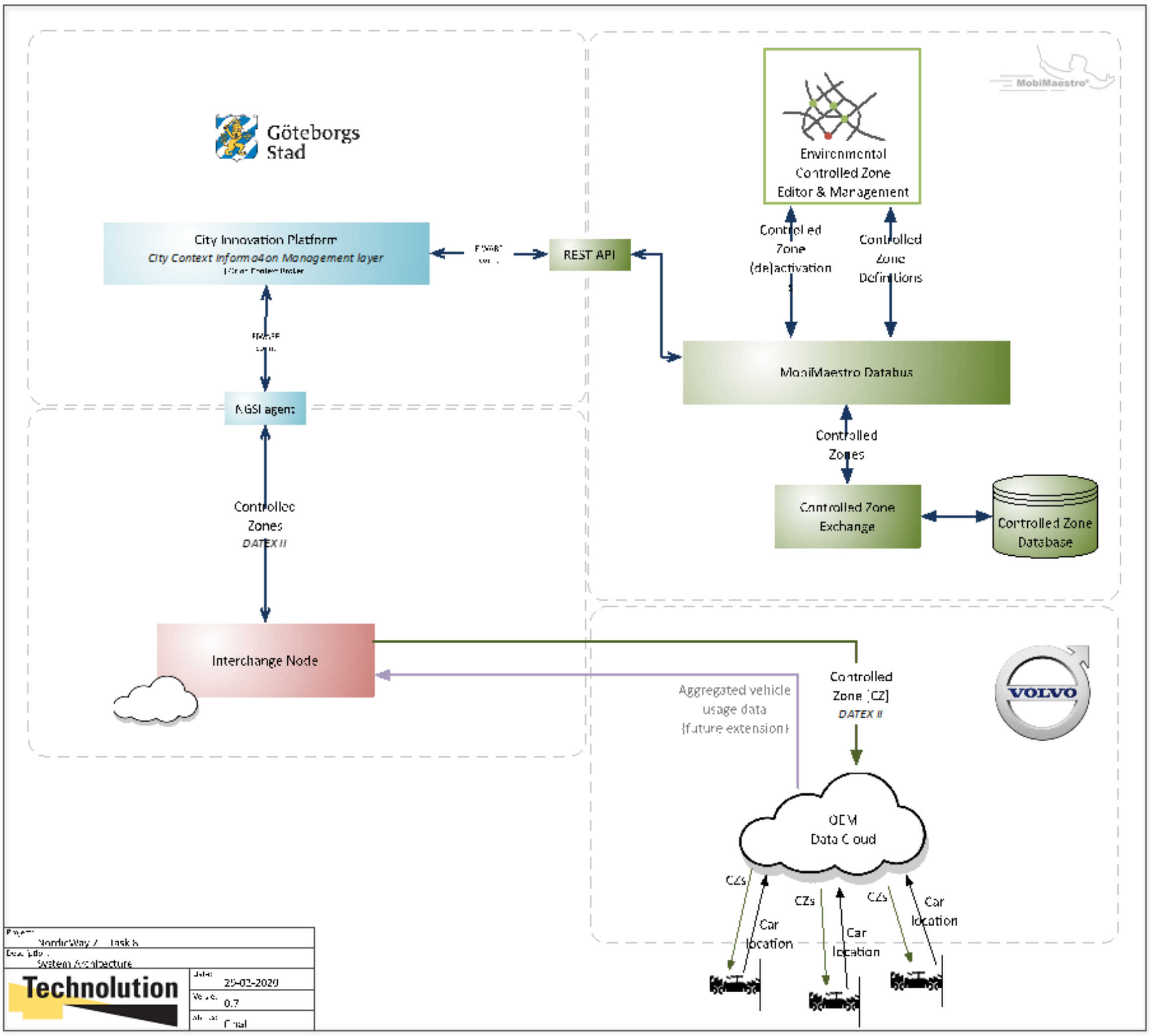

Figure 1. Dynamic controlled zone architecture.

4.1 Functional requirements

As a starting point for the functional requirements, a use case diagram can help in getting a better understanding of how the system works from a functional perspective (Figure 2).

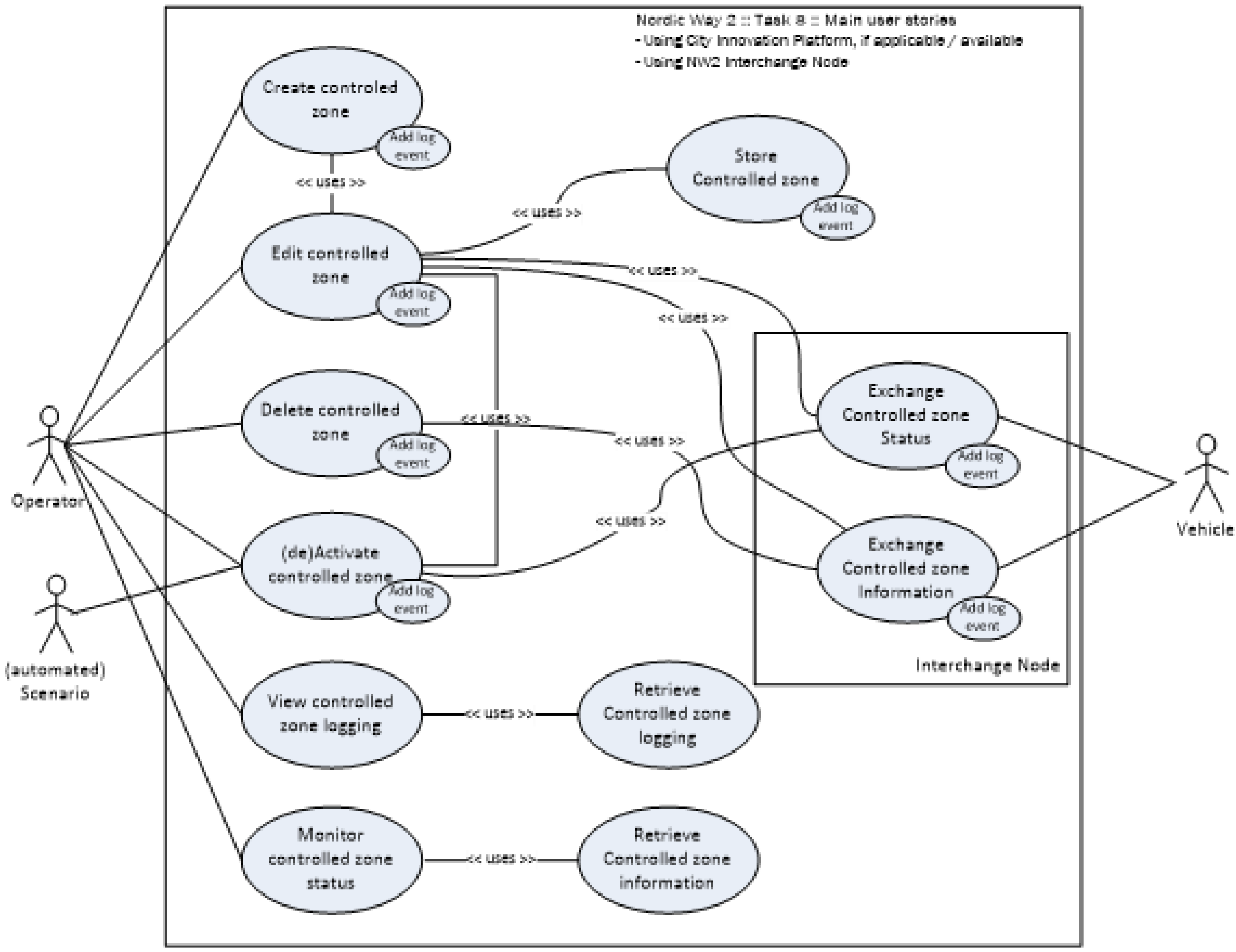

Figure 2. Functional perspective diagram.

The actors included in the diagram are:

- *Operator*, this actor represents the city traffic operator working daily with the system and who has the authority to change controlled zone settings;
- *Scenario*, a future extension where an automated scenario in the system that can act automatically on time, traffic or environmental conditions, if applicable.
- *Vehicle*, this actor represents the 'consumer' of the controlled zone information.

The use-cases in the picture above are those use-cases with which actors have direct interaction and it shows supporting use-cases as well.

- *Create controlled zone*; this use-case creates a new controlled zone into the ecosystem using a graphical map-based approach where an operator can define a new controlled zone.

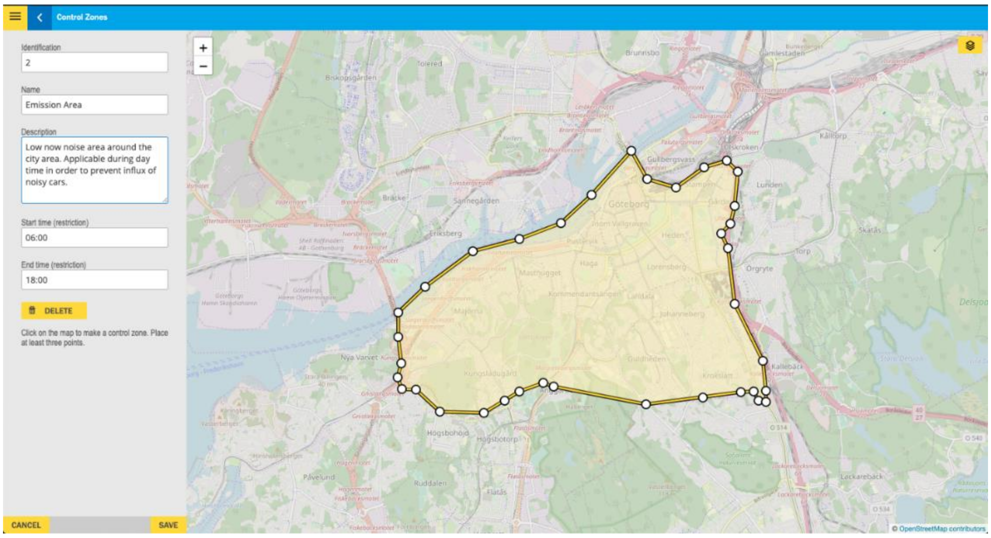

Figure 3. screen shot from the Technolution's MobiMaestro GUI.

- This graphical user interface is part of Technolution's MobiMaestro where the user can interact with the map and define the shape (Figure 3).

  The controlled zone's shape as defined above is a shape on the map without any specific behaviour with a set of controlled zone properties:
  - *Name*, the name as to be displayed in the application
  - *Identifier*, internal unique identifier
  - *Description,* for additional information on the controlled zone
  - *Start time,* for automated controlled zones it indicates the start time
  - *End time,* for automated controlled zones it indicates the end time

- This approach also supports the already existing dynamical controlled zone (in Swedish "Miljönzon") in the city:

  - The behaviour with respect to controlled zones is initially controlled manually by a traffic operator of the city. Such a manual or futuristic automated **RESTRICT** or **UNRESTRICT** results in a message towards the City Innovation Platform and from there towards the Interchange Node and Volvo's cloud.

    The combination of a controlled zone with any reason and any rule ensures a flexible usage of controlled zones without the need of reprogramming the software. It requires configuration together with the city.

- *Edit controlled zone*; this use-case allows for changing the controlled zone properties like the name, additional information etc. Changing a controlled zone's shape is similar to the creating part where the manager can add, delete or move the controlled zone's shape dots.

- *Delete controlled zone*; this use-case supports deletion of a controlled zone.

- *(un)Restrict controlled zone*; this use-case restricts or un-restricts a controlled zone and ensures that the information is shared with the other systems.

  The traffic operator has the ability to restrict or un-restrict a controlled zone manually. A reason has to be included for a restriction, so the receiving parties understand why the controlled zone became restricted.

- *View controlled zone logging*; this is a future extension use-case enabling an actor to view the controlled zone action logs in the centralized logging register. As can be seen, every use-case has a small sub-use-case that ensures that the actions are logged as events. The logging is based on these events.

- *Monitor controlled zone status*; this use-case shows the actual status of a controlled zone.

The supporting use-cases for the use-cases above are:

- *Store controlled zone*; this use-case ensures that controlled zone information is stored in the database or for example export the controlled zone to another system.
- *Retrieve controlled zone logging*; this use-case enables retrieving logged events from the event database.
- *Retrieve controlled zone information*; this use-case ensures that controlled zone information can be retrieved from the database.
- *Exchange controlled zone status*; this use-case implements the methods of exchanging the controlled zone status using an open protocol to external actors. Status will be 'RESTRICTED' or 'UNRESTRICTED'.
- *Exchange controlled zone information*; this use-case implements the methods of exchanging the controlled zone information using an open protocol to external actors. Information contains the shape of the controlled zone, its description and so forth.

4.2 Non-Functional Requirements

The non-functional requirements are mainly focused at the Interchange Node as part of the solution:

- **Response times of the Interchange Node**
  < 10 seconds (typical performance is 60 ms including signal transmission Trondheim – Lund – Trondheim measured in the NordicWay 1 project)

- **Data and transport Security within the Interchange Node**

  TLS certification or PKI

- **Availability of the Interchange Node**

  99,95% (4 hrs per year off)

- **Capacity of the Interchange Node**

  10 controlled zone messages / day for the production period

  10 controlled zone messages / minute for the test period

- **Logging**
- Interchange Node: Monitoring (e.g. up-status information)

  City Innovation Platform: Monitoring (e.g. up-status information)

  OEM platform: Monitoring + message tracking

  MobiMaestro: Monitoring + message tracking

4.3 Technical communication requirements

The technical communication requirements are based on the existing proposals for an open, standardized protocol to be used for the controlled zone exchange through the City Innovation Platform and the Interchange Node to external stakeholders.

The protocol shall be based on a DATEX II extension that supports controlled zone information, status information and everything required as indicated in the functional requirements or XML version of the same information.

As part of the project we developed our extension using existing DATEX II elements (Figure):

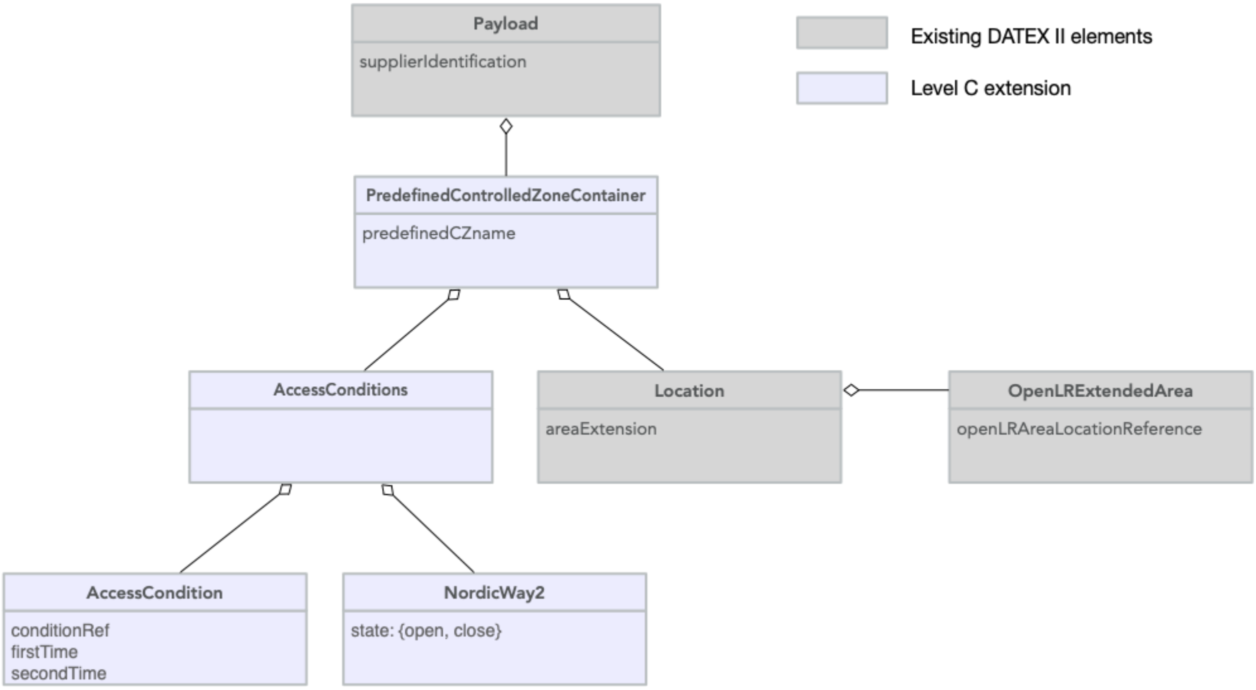

Figure 4. DATEX II elements included in the dynamical controlled zone.

Within Task 8 we adapted a DATEX II 2.3 extension (Level C extension) based on this TC278 WG17 work related to controlled zones. This extension is visualized above.

The specific elements are described in a simplified way here:

- Controlled zone
  - Name
  - Area Definition
  - Access Conditions
    - Start time
    - End Time
    - Regulations
    - NordicWay 2

We have added a specific NordicWay 2 part as part of the access condition part of the controlled zone message. During the project it became apparent that a clear definition of ‘open’ / ‘close’ or ‘unrestricted / restricted’ was needed. For this purpose, we choose for ‘open’ indicating that the controlled zone is open for any traffic and ‘close’ for a restricted area where only cars on electrical mode are allowed.

This specific NordicWay 2 element will have to be removed in future developments of the standard.

Message tracking

A means of message tracking shall be part of the entire system's solution in order to facilitate the evaluation of the system. When a message has been created it will have a unique identifier and will be logged in the logging facility of the creating system with a timestamp. From that point on the message is processed in the other systems and when possible logged in those systems with their timestamps. At last the message arrives at its destination and this final system logs the message with the final timestamp. When all logs from the creator through the intermediate systems until the destination are combined, it is possible to evaluate the message processing including time aspects in that processing.

Timestamps shall be according to DATEX II definitions and ISO 8601 (e.g. 2018-12-04T09:19:09+00:00)

Controlled zone stages

Controlled zone (un)restriction will have an impact on the vehicles towards or within the controlled zone. Currently a controlled zone has two possible stages:

- **Restricted for (specific) traffic**, the controlled zone has restrictions activated on the type of vehicles that are allowed to enter the controlled zone, e.g. only battery driven cars are allowed to enter.

- **Unrestricted for (specific) traffic**, the controlled zone has no active restrictions, so traffic is allowed to enter the controlled zones. In future extensions of the standard these unrestrictions could be limited to a particular type of vehicles.

Future development could include a stage 'going to restrict' in order to give vehicles enough time to plan for a change or another route. This is especially important when time to notice becomes shorter with more and more dynamical controlled zones.

4.4 Volvo Cars application

In the pilot, Volvo Cars developed software in both the cloud and in the vehicle (Figure 5Figure) that uses geofences to:

- Turn off the combustion engine in green zones, automatically switching the car to pure electric mode.
- Ensure that the car has enough energy stored to travel within zones in an electric mode.

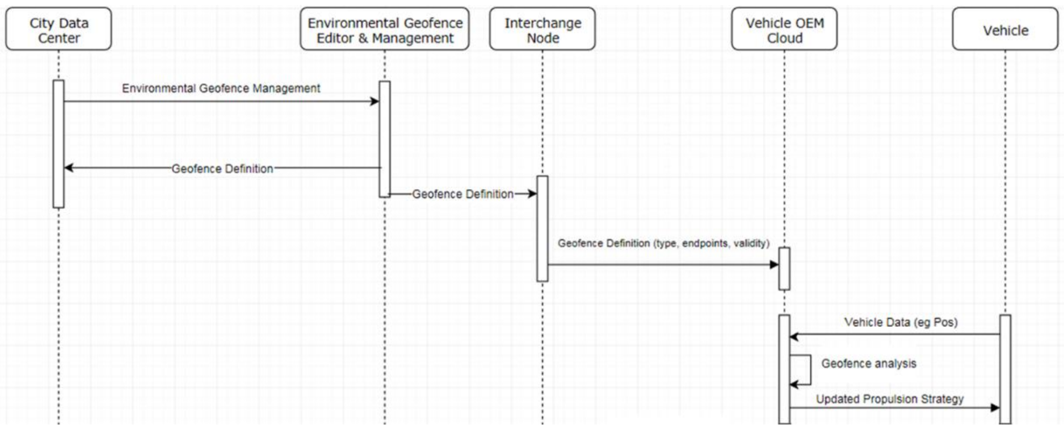

Figure 5. System sequence diagram.

It is possible for the driver to change the drive mode and to start the combustion engine within the zone. A vehicle zone energy usage report can be sent to cities offering tax incentives if the owner allows this.

Figure 6. Plug-in hybrid Volvo car charging.

4.5 In- vehicle HMI

An intuitive HMI is a good support for the driver to understand what happens to the vehicle (Figure 6) in the zero-emission zone, so a development HMI for the zones is also a part of the pilot. The purpose is to inform the driver about rules for the zone and how the vehicle behaves. A screen replaces the DIM that is moved to the glove box. The computer and other needed equipment are stored in the luggage compartment in the test vehicles.

The HMI was developed and used in the demonstration and then further improved and refined during the pilot until it reached the final status shown in Figure 7 and in Figure 8.

Figure 7. Driver information shown in the HMI when the vehicle approaches the zone. This is an HMI prototype for research projects, not intended for production.

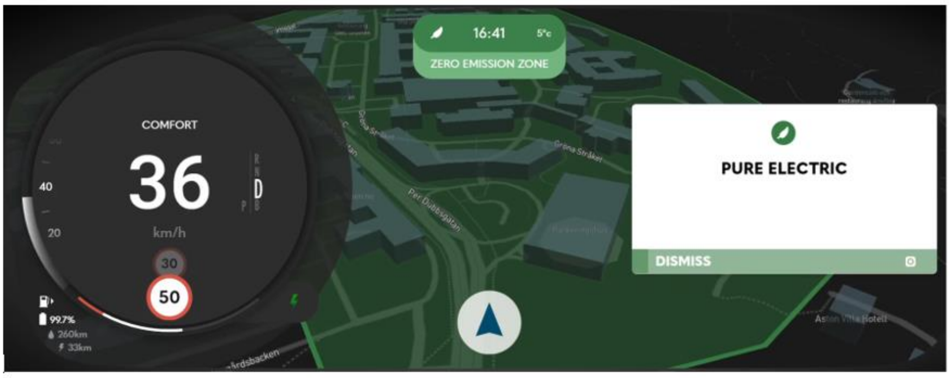

Figure 8. Driver information shown in the HMI when the vehicle enters the zone. This is an HMI prototype for research projects, not intended for production.

5 Evaluation Results

5.1 Technical evaluation

5.1.1 Latency

The latency was measured by the **"Stopwatch" method.** The project has performed several demo-sessions in real-life and as desktop study measuring the system's speed from A to Z. The method used an old-school stopwatch to measure the latency between changing a geofence state in the GUI and the actual response in the vehicle.

Preconditions: All systems have to be fully operational.

5.1.2 Latency results

– A max latency of 10 seconds between the GUI change and the actual response in the car was measured. This latency compasses all individual steps in all systems.

5.1.3 Data and transport security

Method of checking this technical requirement was inspection of the technology chosen.

5.1.4 Data and transport security results

The transport to and from the Interchange Node uses an SSL TLS secure data-protocol using AMQP.

5.2 Service ecosystem

5.2.1 Method

The service ecosystem has been constructed during the Service Workshop @ January 22, 2020. The method is described in detail in the NordicWay 2 Evaluation Report.

The objective of the workshop was to describe the current ecosystem of this pilot, its actors and their roles, and to better understand the business potential and what is needed for implementation of the service. The workshop was divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilot. Thereafter a description of the current ecosystem, i.e. how the pilot is set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the workshop a scaled-up version of the ecosystem was constructed. This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

5.2.2 Results

5.2.2.1 Current service ecosystem

Description of challenges encountered, and lessons learned in:

Forming the ecosystem (consortium, others)	Difficult to agree on an incentive-based solution due to legal framework and the political dimension. This may differ a lot between different cities. Process of ecosystem forming went quite smoothly as most actors had a general idea what the use-case contained. The level of detail was sufficient for this process (Figure). The project proposal was well prepared. That enabled a smooth setup of the project. The legal framework in Sweden does not fully support an efficient, incentive-based introduction of PHEVs using geofencing.
The service formulation and provision phases	It took some time for the different actors to understand each other's roles in the eco-system. The service formulation gave some additional discussions on the availability of data flows back and forth and possibilities of exchanging these.

	In particular the service was challenging due to limited previous experiences from working with dynamic geofencing
Access to data and right to use the data within the pilot (within the consortium, with public actors, with commercial actors)	Data flow includes only the status of the zones and is not a privacy related information. Since there are no incentives in this project there is no need for the vehicle to report any status back. Also, we deleted the compliance check from the eco-system which also made reporting from the vehicle not required anymore. The absence of an existing standard required additional time to develop a workable solution. At the end this workable solution has been input to other initiatives as well.
Any other issues/challenges	The project started too early to use the Controlled Zones standard which should be used in future projects. Robustness of cloud solutions must be secured. Code freezes help in establishing a solid starting point for a demo / test. An earlier inclusion of Ericsson into the project would have improved the process with respect to expectations from the Interchange Node's perspective. More and better planned common tests would have improved the project results and would have made us learn more.

The current ecosystem is illustrated in Figure 9. The geographic boundary within the pilot is the City of Gothenburg. Technolution provides the geofence management system to the City. Gothenburg provides data about digital regulation (geolocalised regulations) to the interchange node. The money in the ecosystem is coming from the project NW2 (CEF-funding 50%). The other 50% is from Technolution, Volvo cars and people of Gothenburg (taxes).

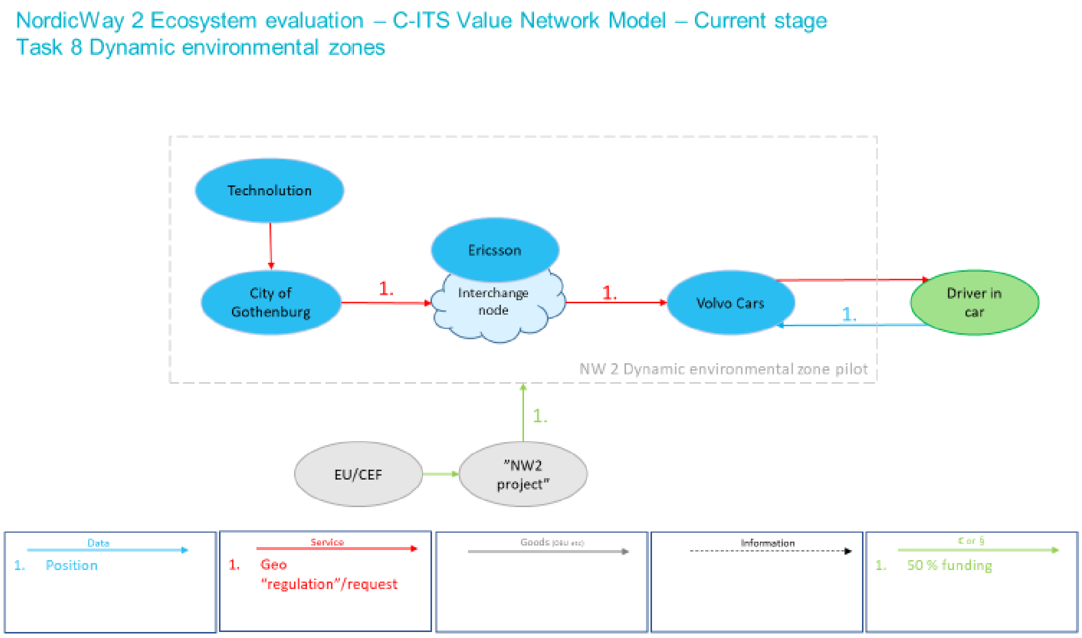

Figure 9. NordicWay 2 ecosystem evaluation- c-ITS value network model- Current stage.

Pains, gains, commitment chart

Actor	Pain	Gain	Commitment
STA	• Regulation • Maybe hours worked	• Knowledge of a future role in digital eco-system	• For other applications, very out of a strategic perspective, groundwork for future more dynamic transport system
Technolution	• So far non	• New technology • Being part of eco-system	• Full, from a business perspective we see potentials for geofence in Traffic management
Volvo Cars	• The service needs to consider GDPR & integrity • Requires development of software, cloud and in a vehicle • Incentives, something that encourages the driver/owner to activate the function environmental zones in the vehicles	• Competitiveness for PHEV • Cooperation with other actors to understand the possibilities with “geofence”	• Involved in related R&D activities • Active actor in the market if this has a benefit for our customers of plug-in hybrid (personal or for the greater good)
City of Gothenburg	• Cost and limited resources (internal competition)	• Knowledge	• According to terms agreed in the contract with STA
CLOSER	• Business model • Regulation/voluntary (Area of conflict) • National/international harmonization for scale-up ecosystem?	• Knowledge • Raises questions that need answers to scale up • Connecting needed stakeholders for first steps of deployment	• Involved in several R&D activities • Has a supportive role on connecting ongoing initiatives to avoid silos
Ericsson	• Running a multiyear research project • EU-project bureaucracy	• Creating an ecosystem with a future business potential	• Service level on the cloud infrastructure

5.2.2.2 Scaling up the service ecosystem

How will the service look 5 years from now?

Within 5 years it would be possible to use the service without putting much changes in the actual regulation. Within 10 years it might be possible to change regulation, and then there will be about 5 years of testing.

It is important to distinguish if it is an incentive-based or regulation-based service. The public sector might not be involved if it is incentive-based but could be. However, if the services are connected to any form of regulation or incentive it is important to have a trusted sender. There could be a lot of different scenarios and cities can be involved in many ways.

Congestion charging was also discussed. If you talk about the regulatory implementation scheme, there is a challenge to have an international standard.

From an OEM perspective it would be good to have a more global software solution than this local use case, but of course it can be introduced in steps.

There are several possible end users; Local commercial hubs, for example, that can make their own regulations, they will be the one that defines and operates the zones perhaps without any municipalities on board. Regions/cities procure a lot of transport for goods and for people and can use the regulations in the procurement process.

Nordic WAY 2

<u>Conclusion</u>

All participants agreed that there would be a lot of different scenarios in the furure. In 5 years, the service would be incentive-based but in 10-20 years it might be regulatory driven. It is not only about this specific service; it is about the set of services. A start is to use the service as an incentive and in parallel start the process with the regulatory work.

How to reach this vision?

In order to reach this vision, it is important to have more end users, public transport stakeholder, heavy vehicle transport operators etc. that can include these functionalities into their systems. There will also be a need for more data such as trusted sensor data on the current air quality.

From an engineering point of view, more efficient dynamic regulation could be added. If it is a true regulation, then we must make a legislation that anyone can act upon even if you don't drive a car that can use the service. Physical signs have to be used for example. In an incentive way it makes more sense investing in the digital equipment. Ultimately the politicians will decide.

It is important to see this service as a step in gradually introducing automatic systems. If the system should be efficient in the future it needs to be coordinated with other services. There will have to be an entity that coordinates these services.

Regarding the business model; if the service is used as a prerequisite for procurement this would give a push/pull for the technology. It could then be interesting for the transport fleet to invest in the technology.

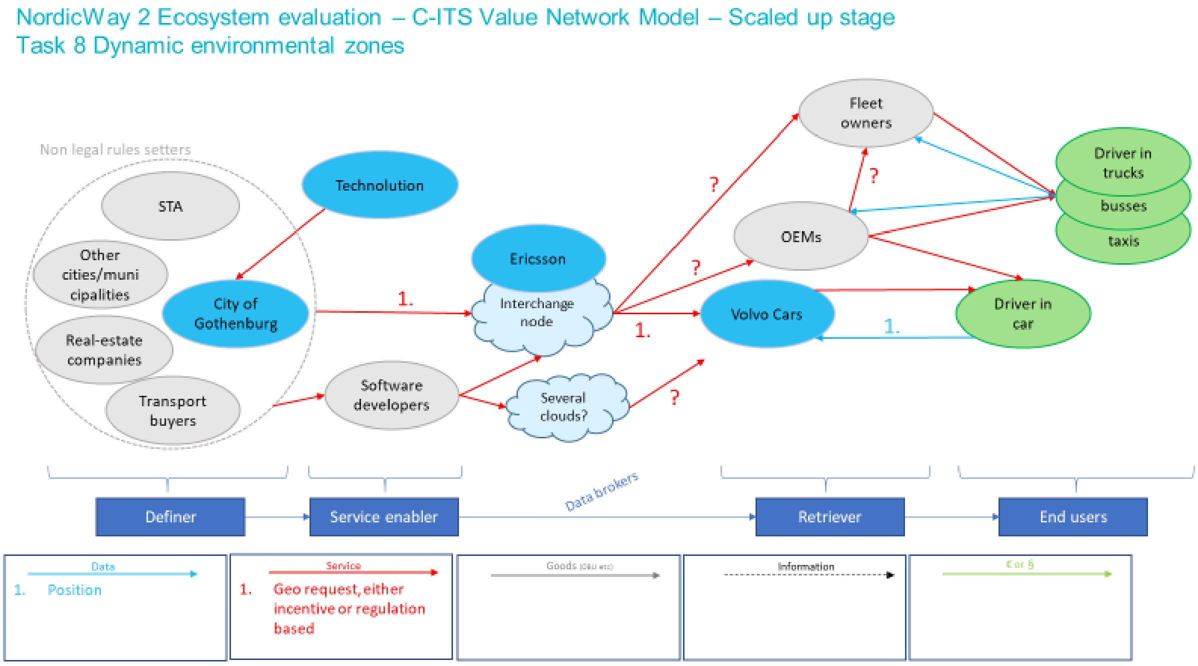

Figure 10. Nordicway 2 ecosystem evaluation. C-ITS value network model. Scale-up stage.

The model above shows one possible technical set-up (Figure 10) for an up-scaled version of the ecosystem. The question marks are not technical issues, but uncertainties regarding the set-up of the system. In the scaled-up ecosystem there will be new users such as more OEMs, fleet owners etc. There will also be more regulation setting actors such as transport buyers, real-estate companies, STA and other municipalities/cities.

Regarding the new data input that is needed, there are sensor data available on the internet (Open data) that could be accessed and used in the service.

How will the interchange node be handled? Will the STA have their own node? If the system is covering the whole of Sweden it could be good to have several nodes. Cloud brokers could be city driven or national, there are a lot of different ideas on the nodes. One example that for instance local commercial hubs, can use is to have a simple model; you might not need an interchange. In the city of Gävle in Sweden, Technolution uses a geofencing for a specific bus lane and they don't use any interchange node.

Fleet owners such as logistic companies operating in different cities, need a lot of updates from every city. The wider geographical spread an actor has, the higher level of the system will be "needed" from a practical point of view.

Regarding the data; someone needs to decide that the information is correct and is to be act upon. That role can be taken by many different entities. It depends on for example the size of geographical area. Basically, all the “rule setters” need to define the scene.

The ecosystem could also be described in the terms of different roles:

- Definer: e.g. cities, STA
- Service enabler: e.g. Technolution, software developers
- Data broker: e.g. Interchange node
- Retriever: e.g. OEMs
- End-users: Action by the end-user (whether it is forced or not forced upon the driver)

One problem with this ecosystem is probably for the retriever to know what service is applicable to the driver and how to distinguish them? Therefore, it is also important to have one trusted authority that provides the true source. It should be the authorities that have the responsibility of acting as a trusted source and all intermediate systems who are trusted to forward the information trustworthy and untouched.

6 Dissemination

Three important dissemination activities for this pilot can be identified:

6.1 Demonstration Gothenburg 16th of May 2019

The pilot included a demonstration in collaboration with the Traffic signals pilot on the 16th of May 2019 with 29 participants from different partners within the NordicWay 2 project: cities and road authorities (Göteborg, Malmö, Trafikverket), OEMs and suppliers (VCC, Scania, Zenuity), suppliers to cities and road authorities (Technolution, SWARCO, Sweco) as well as a research institute (RISE) and MNO (Ericsson). Participants were invited to step into several demonstration cars to witness the geofence’s system in Gothenburg.

The city had defined two environmental zones for this demonstration (Figure 11 and Figure 12).

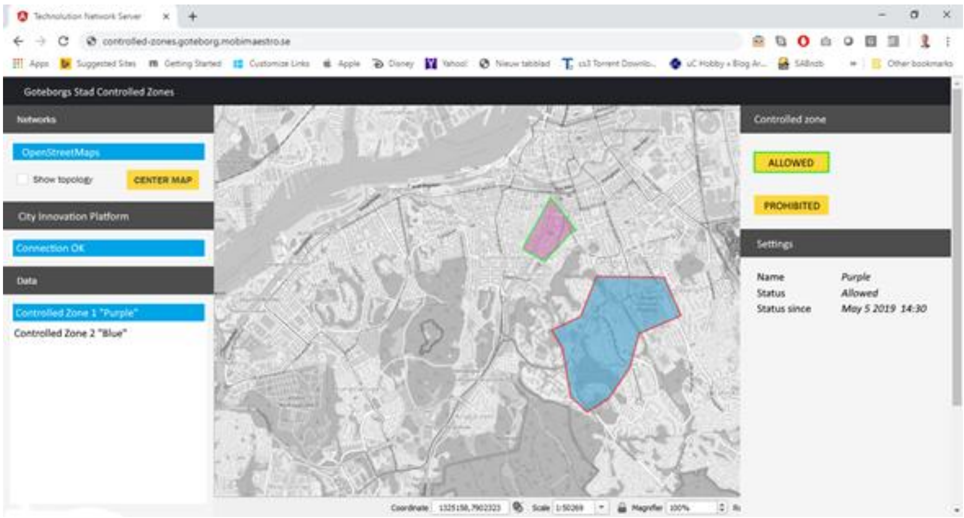

Figure 11. Screen shot from the interface of the municipality operator desktop.

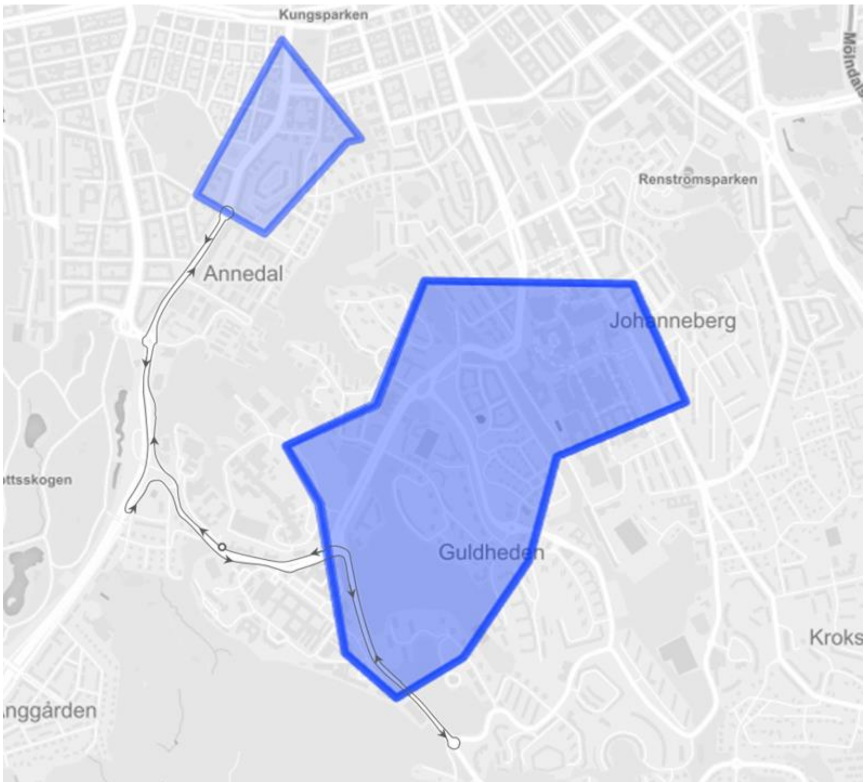

Figure 12. The two environmental zones and the driving route during the test drives.

During the demonstration we showed live how a change of the status of the dynamically controlled zone goes from Technolution's application through the city and interchange node to the Volvo Car's cloud).

The participants were also able to make a test drive with two vehicles equipped with the geofence functionality. One of the vehicles had a development HMI and one had tablets present at the demo.

The demonstration was well received and gave the participants a good overview and insights in the pilot's ambitions and tasks.

6.2 Filming on the 26th of November 2019

This demo's main purpose was using the entire system to combine this into a compelling movie that tells the story of geofencing in a human comprehendible way. The aim with the film was to describe for a wider audience how a dynamic geofence could be used to improve the local emissions in a city by showing a person commuting to work and passing through different zones and the vehicle automatically switches to pure electrical. The technical setup basically the same as at the demonstration, but with the vehicle HMI was improved and refined.

Figure 13. Four scenes from the filming activity in Gothenburg on the 26th of November.

However, this demo was without other participants other than the people involved directly in the development and demonstration (Figure 13).

6.3 Movie release on the 1st of April 2020

The movie pieces filmed in November 2019 are combined and edited throughout the first months of 2020 and the storyboard focuses on three different scenes:

- Morning time with two parallel scenes: the operator is activating the environment zone at the office and the driver is driving in the car to work thereby passing through the recently activated environmental zone. The zone is shown in the HMI and the vehicle automatically switches to pure electric mode.
- During the day the traffic operator deactivates the geofence for high emissions.
- At the end of a working day, the driver is driving back home passing the hospital and the static zone is shown. The vehicle automatically switches to pure electric mode.

The film is available at the NordicWay 2 website and YouTube channel, https://www.youtube.com/watch?v=IRNbpBbyYXY.

7 Conclusions and recommendations

Geofencing is a new, dynamic method of traffic management that can be considered as upcoming technology. It could be used to give road authorities more direct control on traffic flows and enable them to alter or block traffic from particular areas (UVAR).

The pilot has shown, based on available technology, that geofencing technology is a possible way for road authorities to dynamically alter vehicle characteristics in defined areas in the city. With the collaboration of centralized systems, like a City Innovation Platform and an Interchange Node, the geofence information, e.g. an environmental zone with restrictions, can be distributed freely to OEMs like Volvo Cars.

The pilot has shown that this system could support the development of sustainable, attractive and more liveable cities in the future.

The following text gives the reader the specific perspective from one and each partner.

7.1 The City of Gothenburg's perspective

Some of the points which were highlighted by the City of Gothenburg are the following:

The possibilities with geofencing as a method for the road authority to provide digital dynamic traffic regulations is interesting and worth more investigation. To mention some examples it could be used to make sure electrical drive is used in sensitive areas at certain times to lower the noise or emission level, as tested in the pilot, or to make sure vehicles in an area keep a speed adopted to pedestrians in areas and times when a lot of people move around. In a future society, with autonomous cars, regulation needs to be digital, and to fully achieve the potential it also has to be dynamic. The legislation of today is however not yet adopted to this future scenario.

In the pilot, the case tested was digital dynamical environmental zones. From the City's perspective, to move on to a future real-life implementation of this specific case, the expected benefits for the citizens needs to be high to motivate the work needed and the resources required. From the pilot we cannot tell if the case tested really would improve the environment for the citizens. For a next step it would be good define a real problem and then try to solve it through the technique and through identifying what changes in legislation is required, and then to test if we can achieve the objectives defined in the problem description.

In the pilot, a service was introduced where the vehicles automatically switched to pure electric mode in environmental zones if they were activated by an operator. The driver of the vehicle could anytime deactivate the service by changing drive mode, since it is not legally possible today to force this behaviour. Neither is it possible for the city to use incentives to encourage drivers who act "correctly". The use of incentives would require a reporting back functionality from the vehicle to the road authority and would require a storing of driver behaviour information. If the road authority cannot force correct behaviour or use incentives, the usage of the geofence might not be high enough to make a difference in emission level or noise level.

For a first real-life implementation the city believes that there must be an operator that turns on and of the restrictions of a zone, as we would not rely on an automatic change before it has been tested and evaluated. This is most important if the zone has forcing restrictions or incentives connected to it and is not only based on the drivers´ willingness to do the right thing.

Technically to provide dynamic regulations in real-life, the road authorities needs to make sure that the system that provides the regulations are highly reliable. How to handle errors in the communication needs to be investigated further on both a technical and an organisational level. Further research and development of the communication standards when it comes to dynamic regulations needs to be done in line with desired functionality.

More details about the City perspective can be found in the report produced by the City, "Uppdragsrapport, NordicWay 2, task 8 Smart routing based on infrastructure policies – using geofencing for providing dynamic environmental zones" (2020).

7.2 Technolution's perspective

Further research and development will be required to combine the existing static geofences (like the environmental zones, speed zones etc.) with dynamic elements like restrictions based on measured traffic conditions, detected crowds or environmental sensors. Furthermore, research and development need to be conducted in order to come to a full-fledged and supported standard for geofences or UVARs. Both developments will result in new requirements for a geofence management system as well and how all stakeholders will work with such a system. Not only at a technical level, but also on a political level.

7.3 Volvo Car's perspective

Volvo Car Corporation, founded 1927, is one of the most well-known brands in the automotive industry with high ambitions when it comes to sustainable mobility solutions, especially within electrification and autonomous drive. The company is continuously developing industry-leading solutions that further promote safety, well-being and sustainable experiences for the customer.

This pilot is well in line with the company's ambitions and the focus has been to develop a solution that receives the status of a controlled zone and adjust the vehicle characteristics while still ensuring that the experience for the driver is seamless and easy to understand. It is also important that the function supports the driver, by automatically switch to pure electric mode, but still allows the driver to be in control, by allowing the driver to change drive mode if needed.

The focus in this pilot was to develop a service that drivers of plug in hybrid electric vehicles can activate if they have an interest in environment and city centre air quality. One could assume that the interest for this service could increase with incentives like lower toll, free charging or free parking. Target group for this pilot are drivers with an interest in environment and no information from the vehicle or driver back to the city is needed.

In the pilot, the vehicles automatically switched to pure electrical drive when entering the restricted zone. The vehicle will behave like a BEV, Battery Electric Vehicle, with reduced performance within the zone i.e. a zero-emission vehicle. A function like the one in this pilot must be highly reliable both when it comes to data security and that only the permitted actor can make changes of the zones.

7.4 Ericsson's perspective

The cellular networks can support Intelligent Traffic System services on top of all other communication use cases delivering excellent economy of scale and nationwide coverage from the start. Combined with a neutral data sharing platform: The federated network of Interchange nodes Nordic and European service continuity can be swiftly deployed – for all NordicWay use cases.

8 References

Gothenburg City (2020). Uppdragsrapport, NordicWay 2, task 8 Smart routing based on infrastructure policies – using geofencing for providing dynamic environmental zones (2020).

IRIS (2020). IRIS project website. https://irissmartcities.eu/.

NordicWay 2 (2020). NordicWay Service definitions – services and use cases. Deliverable D22 (part 1). Version 0.0.8.

Appendix 7: Road Works Warning report

Final report – Roadworks Warning RWW

NordicWay 2

Version 1.0

Date: 21. Oct. 2020

Document Information

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Distribution

DATE	VERSION	DISSEMINATION
20200505	0.1	First version
20200615	0.2	Added authors and text
20200703	0.3	Expanded structure and text under technical description
20200910	0.4	Add dissemination/conclusion/recommendation, ecosystem evaluation results
20201002	0.5	Added content to 4.2, 4.3 and 4.6
20201009	0.6	Full document update
20201016	0.7	Minor corrections (e.g. references)
20201021	1.0	Final version

Content

1 Introduction

The purpose of the HLN – RWW (Hazardous Location Notification – Road Works Warning) task has been to specify, implement, integrate, test, and provide a possible solution for RWW with different partners in the NordicWay cluster.

RWW is a EU priority C-ITS service and provides the possibility to share safety related traffic information.

Results and best practice from NordicWay 1 project has been reused and improved on where applicable.

2 Service definition

The RWW service definition can be found in the NordicWay 2 deliverable *“D22 NordicWay Service Definitions Services and Use Cases”*, where also the other services are defined.

3 Description of the pilot

3.1 Pilot set up

Lead:	Kapsch TrafficCom AB			
Participants:	Ericsson AB, Volvo Cars, AB Volvo, Scania AB, STA, Springworks (original partner put left the project), Zenuity (original partner put left the project), RISE			
Timeframe:	Start:	January 2018	End:	December 2020

3.2 Objectives

In the deliverable *“D 9.9.1 Overview of requirements and frameworks on RWW in C-ROADS and NordicWay countries”*, Section 2.4, the desired functionality is described by each partner.

3.3 Activities

2018	Definitions of requirements
2019 May	Workshop on enhanced positioning
2019	Development of RWW unit and RWW node
2020 Jan.	Workshop on service ecosystems
2020	Installation and integration on TMA vehicle
2020	E2E system testing and confirmation of functionality
2020 Feb.	Delivery of *“D 9.9.1 Overview of requirements and frameworks on RWW in C-ROADS and NordicWay countries”*
2020 Sept.	Delivery of *“D9.9.4 Data exchange interface specifications for RWW”*

4 Technical description

The scope of the work in NordicWay 2 Road Works Warning includes the parts from development of the transmitting unit on the TMA vehicle, the backend message until the RWW messages finally are received in the vehicles and information is displayed in the vehicle’s HMI.

4.1 Dataflow overview both over backend cellular network and ITS-G5

Figure 1 shows the system description and the message flow of RWW.

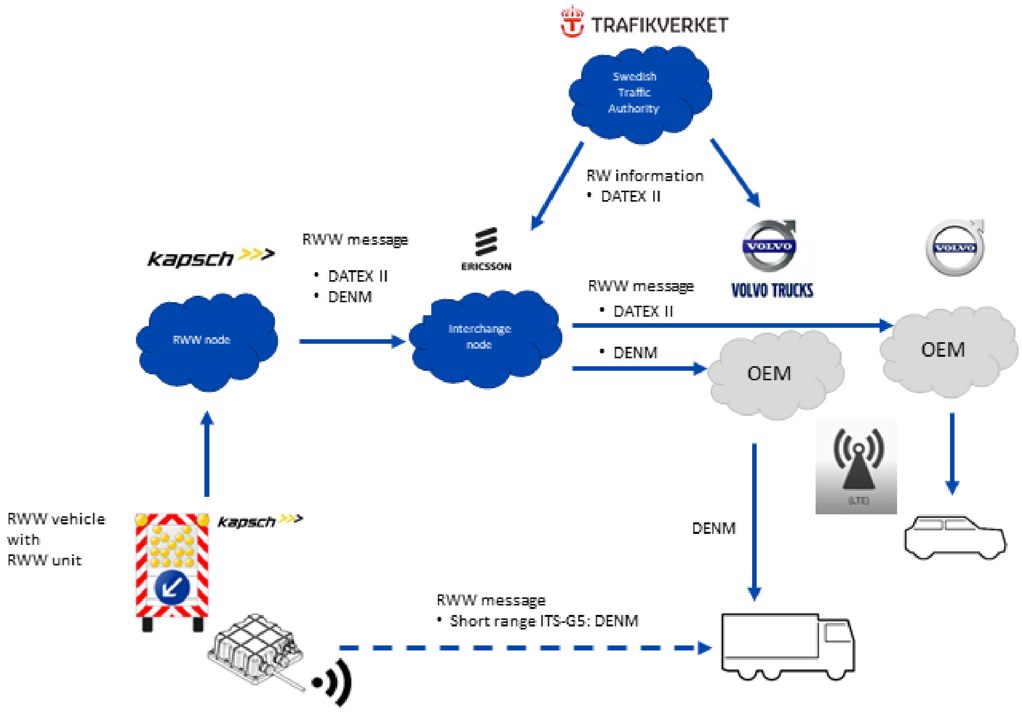

Figure 1. RWW message flow.

4.2 Service Message Description

The service and warning message for RWW is generated at the RWW unit mounted on the TMA vehicle. The description of the service and message format is described in the NordicWay 2 deliverable *"D9.9.4 Data exchange interface specifications for RWW"*.

4.3 From Kapsch Unit to Interchange Node

Kapsch developed in the NordicWay 2 project an RWW unit. Figure 2. shows a picture of the RWW unit.

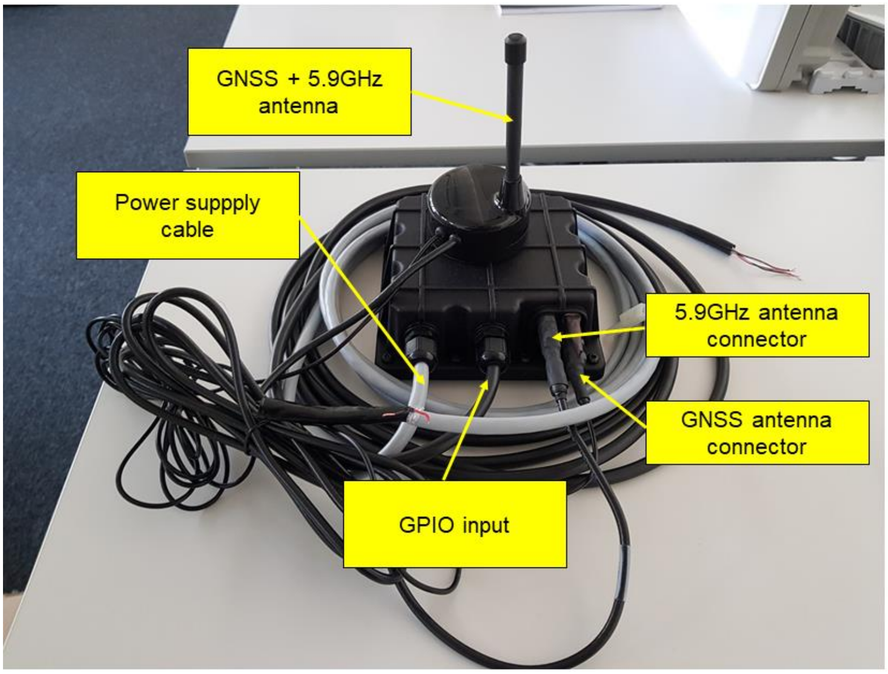

Figure 2. Kapsch RWW unit.

The RWW unit mounted on the TMA vehicle generates the roadworks warning. The trigger for starting sending RWW is when the TMA vehicle attenuator is lifted down. Beside the trigger of RWW activation there are triggers for the passing rule (trafficFlowRule called in the ITS-G5 DENM), i.e. if the vehicles have to pass on the right lane, left lane or no passing is allowed (arrow sign on the back of the TMA vehicle). This functionality is realized with GPIO lines at the RWW unit. Figure 3 shows the logic of the GPIO trigger lines.

White:	transmission activation
Pink:	passToLeft
Green:	passToRight
Pink&Green:	noPassing
Brown:	ground
Others:	not used

white	pink	green	value	DENM
0	0	0	0	No Tx
0	0	1	1	No Tx
0	1	0	2	No Tx
0	1	1	3	No Tx
1	0	0	4	No trafficRule
1	0	1	5	passToRight
1	1	0	6	passToLeft
1	1	1	7	noPassing

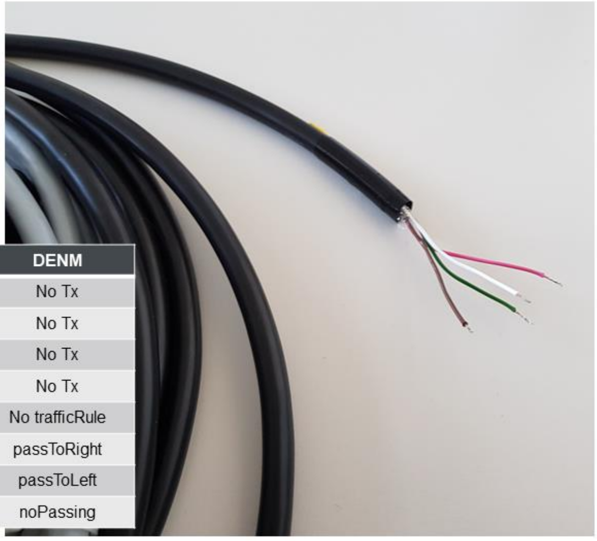

Figure 3. GPIO trigger lines logic.

Figure 4 and Figure 5 show the mounted RWW unit on the TMA vehicle.

Figure 4. RWW unit mounted on TMA vehicle.

Figure 5. RWW unit mounted on TMA vehicle - overall view.

Figure 6 shows the message flow from the RWW unit via the RWW node to the Interchange node.

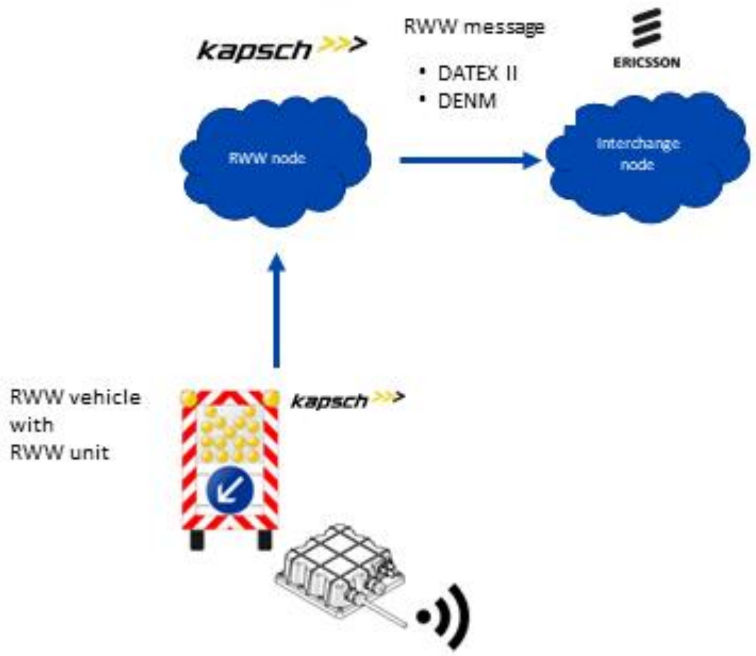

Figure 6. Message flow from RWW unit to interchange node.

If a RWW message is triggered on the RWW unit, it starts to send the warning message via a proprietary protocol to the RWW node. The RWW node is generating a RWW message in the DATEX II format and sends both, the DENM format and the DATEX II format of the RWW message to the interchange node. As transport protocol AMQP v1 (Advanced Message Queuing Protocol) is used.

4.4 The NordicWay Interchange Node

The Interchange node was developed by Ericsson in NordicWay 1 and developed further in NordicWay 2. Interchange nodes has also been developed in Norway and Finland. It is an AMQP publish-subscribe message broker and it is further described in *"Final Report – Activity 9 Swedish Pilot, Appendix 1; NordicWay 2 Data Interchange Node Architecture"*

4.5 From Interchange Node to Vehicles

Two different OEMs participated in this pilot, both connected via their backend to the Interchange node, one of them also using ITS-G5. An intuitive HMI is an important support for the driver. Therefore, the development of HMIs for both cars and trucks, in order to visualize the RWW message, were also included in this pilot.

4.5.1 Volvo Car Corporation

The test vehicle in the pilot was connected to the Volvo Cars cloud using the cellular network: reporting its position and receiving information back.

4.5.1.1 Cloud application

The cloud application responsibility is to receive the RWW message from the Interchange node, determine which vehicles are concerned and convey the relevant RWW information to them, see Figure 7.

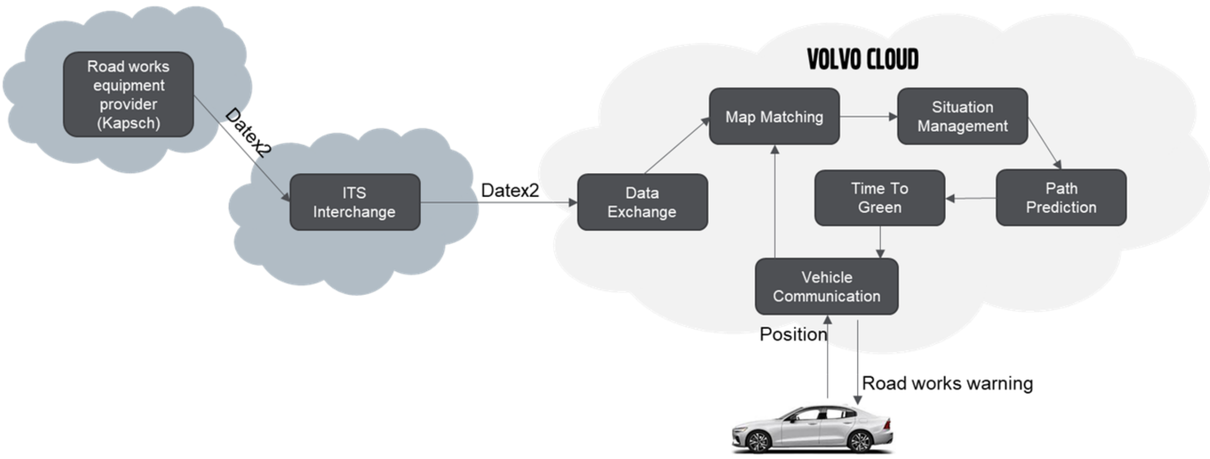

Figure 7. Schematic description of Volvo Cars' cloud application.

4.5.1.2 Messages

Volvo Cars are consuming DATEX II version 3.0, MaintenanceWorks situation with OpenLR LinearLocation as location reference from Kapsch, over the Swedish Interchange node.

4.5.1.3 In-vehicle HMI

An HMI concept was developed for the NordicWay 2 project. The position of the ego vehicle was shown on a map in the driver information module.

Real time information about active road works are received through the cloud and are displayed to the driver at a suitable time before the start of a road work, so that the driver has time to adjust and plan the driving in accordance with rules and regulations that applies when driving at a road work.

The solution for Volvo Cars' test vehicle was to install a screen that replaced the driver information module, DIM, which was moved to the glove box. The computer and other needed equipment were stored in the luggage compartment in the test vehicle. Figure 8 shows an HMI screenshot.

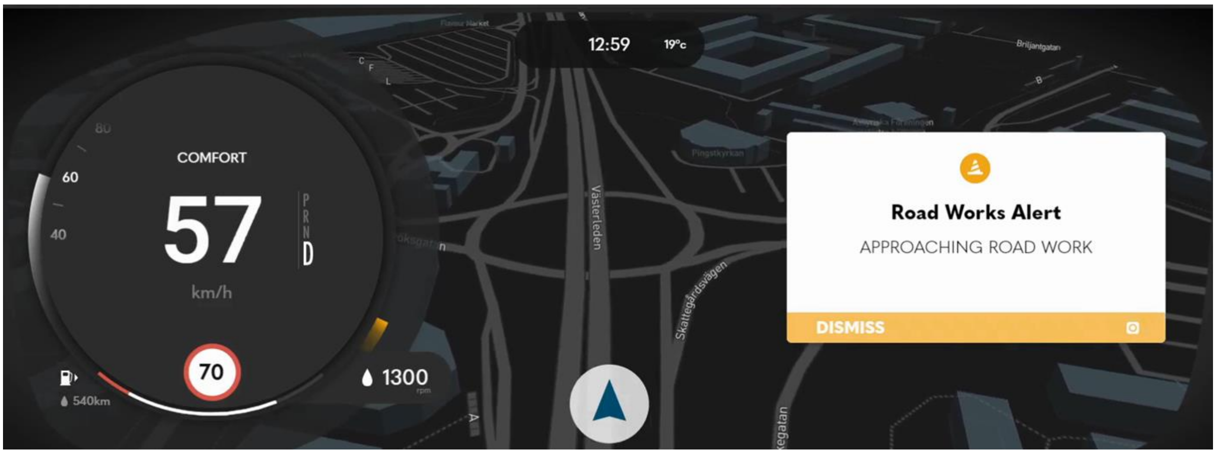

Figure 8. Protype HMI from Volvo Cars displaying RWW warning message. This HMI prototype is for research projects, not intended for production.

4.6 RWW Service over ITS-G5

Figure 9 shows the message flow of a DENM from the RWW unit to receiving vehicles.

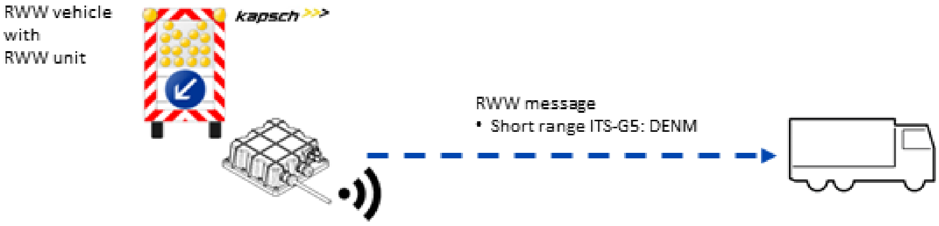

Figure 9. Short-range RWW DENM message flow.

Details of the DENM profiling (syntax and semantics) can be found in the NordicWay 2 deliverable *"D9.9.4 Data exchange interface specifications for RWW*".

This functionality was implemented on the RWW unit and on the AB Volvo truck, but due to of Corona lock-down of AB Volvo there were no short-range live-measurement towards trucks performed.

4.7 Road work status from STA to Interchange node

This interface and the data flow from STA to the Interchange node will be investigated further and integrated in the upcoming NordicWay 3 project.

5 Evaluation Results

5.1 Service ecosystem

5.1.1 Method

The service ecosystem has been constructed during the Service Workshop at January 21, 2020. The method is described in detail in the *"NordicWay 2 Evaluation Report"*.

The objective of the workshop was to describe the current ecosystem of this pilot, its actors and their roles, and to better understand the business potential and what is needed for implementation of the service. The workshop were divided into two sections. The first section was introduced by a discussion about lessons learned during the formation and planning phase of the pilot. Thereafter a description of the current ecosystem, i.e. how the pilot is set up today and how the actors cooperate, was constructed. This involved drawing an ecosystem on the white board and thereafter a discussion followed about the pains, gains and commitment to be a part of the current ecosystem. In the second section of the workshop a scaled-up version of the ecosystem was constructed. This was done by discussing the view of future business potential of the service and needed changes to reach the business potential was added to the ecosystem on the whiteboard.

5.1.2 Results

5.1.2.1 Current service ecosystem

Description of challenges encountered, and lessons learned in:

Forming the ecosystem (consortium, others)	It has been proven that the technical solution works in general, but we also need to “fine tune” the concept for when to start messages, quality of the position, validity time etc.
The service formulation and provision phases	Some issues were encountered, e.g. to have a stable distribution from STA to the interchange node. There need to be monitoring tools for those interfaces in a production system.
Access to data and right to use the data within the pilot (within the consortium, with public actors, with commercial actors)	No actual issues for this domain
Any other issues/challenges	It was realised that the Interchange is one single point of failure. How to build a robust system? To get this function to scale there need to be functional requirements in the public tenders, e.g. the contractor must have C-ITS equipped trucks and they deliver data to a certain standard

Figure 10 describes the current status of the RWW ecosystem. The actual service is created in the OEM actors’ cloud when receiving position data from the end user. Via the Kapsch hardware it is also possible to send RWW message to Volvo AB trucks using ITS-G5. No sub-contractors, owning or operating the TMA vehicles, are partners in the project. However, in order to test in real situations, the hardware created by Kapsch needs to be installed on a TMA vehicle and therefore communication regarding this installation is needed with the sub-contractor.

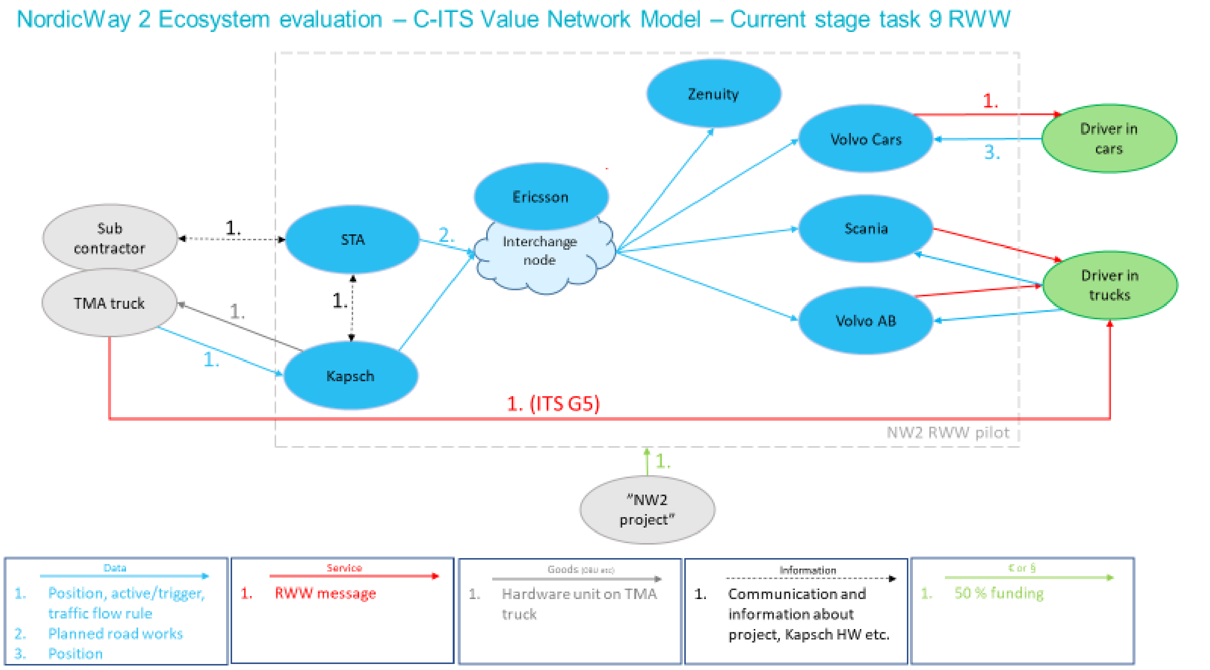

Figure 10. Current status ecosystem for RWW.

Pains, gains and commitment to be involved in this current ecosystem:

Actor	Pain	Gain	Commitment
STA	• Regulation is not STA's responsibility • No contractors involved	• Learning how STA should act	• Interested
Ericsson	• Running a multiyear research project • EU-project bureaucracy	• Creating an ecosystem with a future business potential	• Service level on the cloud infrastructure
Volvo Cars	• Development in the VCC-cloud and in vehicle	• Cooperation with other partners to get Road Workers information. • Influence to enable an implementation of RWW by demonstrating the ecosystem & service	• Involved in related R&D activities • Active actor in the market
Kapsch	• Overall: installation of the RWW-unit (planning, effort)	• Overall: RWW is triggered automatically (nobody has to put manually data in the system) • New business opportunity • New customers	• Active actor in the market • Involved in related R&D activities • Supports strategic objectives
Task lead input (supporting Kapsch)	• Who should run a C-ITS system? State/private company? • Procurement/legislation	• Network • New business • Insight in hybrid solution	• System supplier of C-ITS services • Hybrid solution is rather new for this area

5.1.2.2 Scaling up the service ecosystem

How should this service look/work in 5 years from now?

The geographical coverage should be whole Europe which is what is being developed in C-ROADS. The users should be all vehicles enabled and all drivers who have signed the GDPR-messages.

Maybe the RWW service is not a business case itself. In order to be valuable for the user other forms of works along the road, such as service work (e.g. change of tires) or accident zones are also important to inform the driver about. The Swedish Transport Agency (Transportstyrelsen) has a new obligation assigned by the government to investigate the situation for road workers in order to increase safety for them. This could potentially be an enabler for scaling up the RWW and similar services.

What is required to reach this vision?

To increase the number of users the information needs to also be accessible in smart phones and not only integrated in the vehicles HMI. Therefore, app providers are a new group of actors needed. OEMs could also create their own apps, like a "Safety app" which they provide to their customers.

One role for STA could be to include standardised requirements of what type of data that is needed to be delivered for their sub-contractors as procurements. This could be the C-ROADS specification for instance. If the sub-contractor knows that this comes up in every procurement, they will know how to price it. STA could also support with standards of procedures for other road operators, such as the municipalities, to make it easier for them to connect to the ecosystem.

Another important role for the public sector could be to secure the quality of the data.

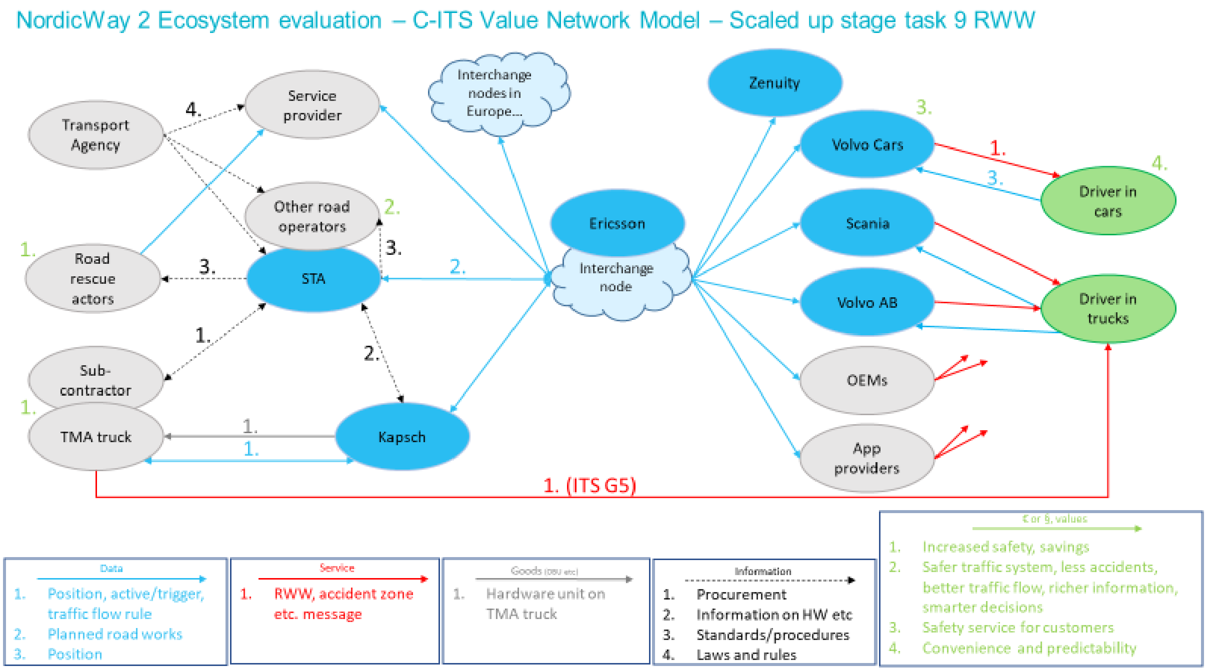

Figure 11. Scaling up ecosystem for RWW.

Figure 11 captures the discussion on how to scale up RWW. In the ecosystem STA is one public actor but there are also other actors owning and managing roads in the transport system and therefore "other road authorities" was added. The actor group "other road operators" include road transport operators (e.g. cities and municipalities), road transport authorities and motorway companies in other countries. Additionally, road rescue actors (fire departments, towing vehicles etc.) is also added to the ecosystem. STA could be the responsible part to inform the road operators and road rescue actors about standards and procedures for the RWW and similar services. As previously mentioned, the Transport Agency could potentially steer the development with new laws and rules regarding safety for different road workers.

If the service is to be scaled up on European level the interchange node needs to be connected to other interchange nodes in Europe. It is unclear who the owner of the interchange node should be in a future system but probably STA or another governmental body.

The RWW service is mainly for the common good, i.e. the drivers will probably not pay for this service. In this stage it is hard to point out who should pay for the service. However, there are several actors that would benefit from it. Values are not equal to money, but the values are also important to highlight. For the whole system the main values are less accidents, less severe accidents and better traffic flow. The sub-contractors, TMA vehicle owners and road rescue actors will experience increased safety for their personnel and also savings since their vehicles won't be damaged as much as today. The contractor can also follow up on the TMA if this system is implemented. For STA and other road operators this service will contribute to richer information about the transport situation which contribute to smarter decisions and traffic management. For the OEMs the values are convenience for the driver and to be competitive on the market. For the drivers the main value is predictability.

6 Other results

Other results of this pilot.

- Report: *"D 9.9.1 Overview of requirements and frameworks on RWW in C-ROADS and Nordic-Way countries"*
- Report: *"D9.9.4 Data exchange interface specifications for RWW"*
-

7 Dissemination

Main dissemination activities performed, in order of appearance.

7.1 Workshop in enhanced positioning May 2019

One of the goals for the RWW NordicWay 2 pilot was to look into how enhanced positioning could sharpen the use case. With current GNSS code base technology the absolute position could be determined within 5-10 m.

A modern vehicle could with all onboard sensors position itself in relative to other object's with very high accuracy but still it needs to have support to get the absolute position.

With this level of accuracy, it is hard for the vehicle to decide in which lane it is driving in.

At the workshop several radio based positioning technologies were presented, GNSS RTK, ITS-G5 triangulation, LIDAR, Cellular 5G positioning.

At this workshop Kapsch also gave an overview of current work item with "RTCM correction broadcasted over ITS-G5 radio". Figure 12 shows the system overview of this solution.

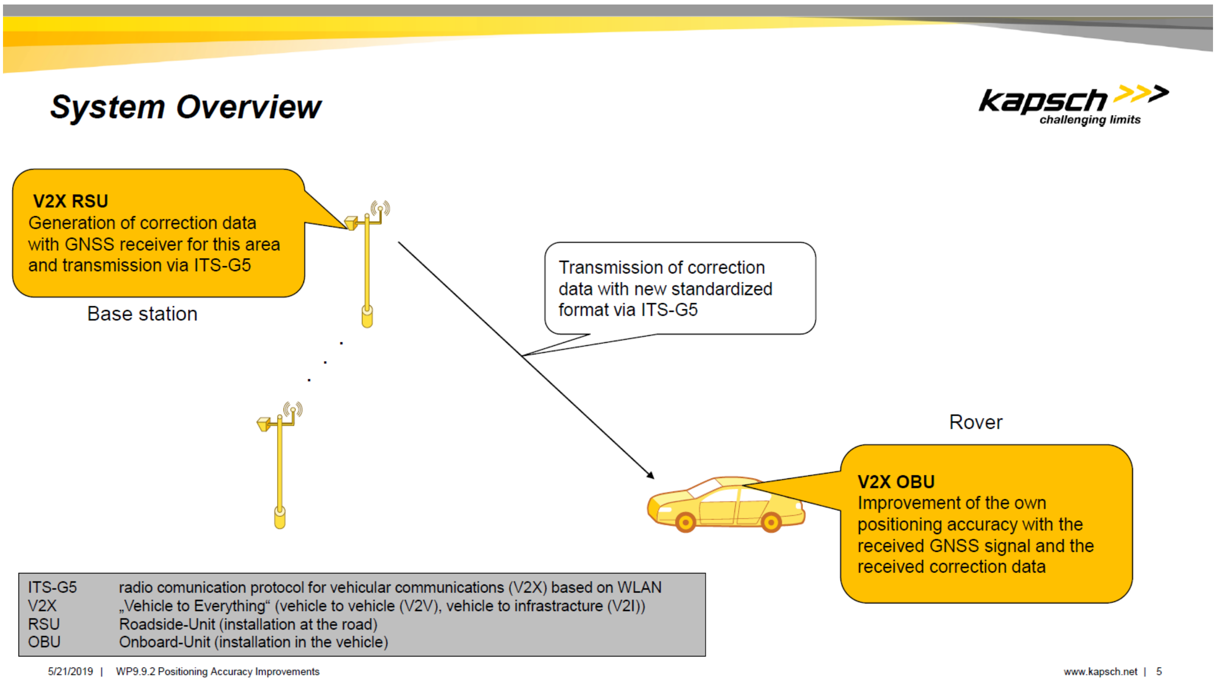

Figure 12. Positioning accuracy improvement with RTK via ITS-G5.

7.2 Filming and movie release summer 2020

The aim of the RWW movie was to describe for a wider audience how a Road Work Warning message could be used to support the driver when approaching a road work.

The film is available on the official NordicWay webpage

https://www.nordicway.net/demonstrationsites/road-works-warning

7.3 Swedish Showcase

The RWW movie complemented with a RWW presentation will be part of the Swedish Showcase in October 2020.

8 Conclusions

As already shown in the previous project NordicWay 1, the RWW and production chain from TMA vehicle via cellular communication to the cloud is really feasible and possible to put in production.

The service is not a time critical service in terms of latency. The driver could be informed well in advance already before the driver has line of sight.

There are still several open questions if you go to deployment, which is more related to work flow at a road works area. When should you activate the message? Should the pre-warning trailer and the TMA vehicle both be equipped with RWW units sending RWW messages?

So, there is still work for a full deployment operating RWW system. The most important is that such a system will save lives of road workers and drivers.

References

“D22 NordicWay Service Definitions Services and Use Cases”

“D 9.9.1 Overview of requirements and frameworks on RWW in C-ROADS and NordicWay countries”

“D9.9.4 Data exchange interface specifications for RWW”

“Final Report – Activity 9 Swedish Pilot, Appendix 1; NordicWay 2 Data Interchange Node Architecture”

“NordicWay 2 Evaluation Report”