Activity 5 Norwegian Pilot 1
C-ITS evaluation and final report.

NordicWay 2

Version 1.1

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Document Information

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Content

LIST OF ABBREVIATIONS

ADAS - Advanced driver-assistance systems
AGC : Automatic gain control
API: Application programming interface
CAM: cooperative awareness messages
C-ITS : Cooperative Intelligent Transport Systems and Services
DENM: Decentralized environmental notification message
FAM : Speed adjustment system
GNSS : Global navigation satellite systems
GPS : Global positioning system
IVI: Infrastructure to Vehicle Information
KPI : Key performance indicator
MQTT: Message queuing telemetry transport
NB-IOT: Narrow Band – Internet of things
NPRA : Norwegian public road administration
OEM: Original equipment manufacturer (car maker)
OBU: On board unit
PMB : Project management board
RSRP – Reference Signal Received Power
RSRQ – Reference Signal Received Quality
RSU: Roadside unit
TMC: Traffic management centre
UI : User interface
VMS : Variable message sign
VPN: Virtual private network

1 Introduction

The contribution of the Norwegian Pilot 1 is to explore the feasibility of a set of services, Day-1 and Day-1.5, on rural roads with poor cellular connectivity and without access to power mains. It may seem unusual to test under these conditions, but rural roads make up an important part of the transportation network. Roads with challenging topography and tight curves are not unique to Norway, but having goods producing industry at the end of such roads is typical Norwegian.

In the Norwegian Pilot 1 the feasibility of the services under the challenging prevailing conditions in the subarctic areas will be explored. Therefore, the use cases for the C-ITS services sometimes need to be adjusted to fit with the conditions at the location where the demonstrations are held. But the Norwegian Pilot 1 builds on the C-ITS Platform – even it takes a slightly different approach by focusing mainly on the rural road network.

Norway at glance:

- Goods producing industries are located along the coast in remote areas:
- Fisheries, fish farming and fish slaughterhouses.
- Ship building yards.
- Furniture production.
- Factories are cornerstones of the local villages.

Long trunk road network mostly 2 lanes:

- Oslo Kirkenes 2494 km and 34 hours of driving

Weather:

- From a sea level fjord to a mountain pass in as little as 45 minutes (E8).
- Normal winter weather would be extreme weather in mainland Europe.

Freight transport and getting the goods to the markets in:

- Mainland Europe.
- Russia.
- Asia.

How can European C ITS services be adapted to solve our problems?

NordicWay 2, Norwegian Pilot1 have piloted many services and tried to make them useful for the Norwegian Public Roads Administration.

The list of piloted services are:

- In vehicle speed limits
- Weather and road condition
- Slow and stationary vehicle
- Traffic ahead warning
- Emergency brake light
- Cooperative collision warning / Alert wrong way driving
- Road and lane closure
- Mobile road works
- Signal violation / Green light optimal speed advisory
- Single vehicle data
- Traffic information and smart routing
- On street parking information and management
- Information on fueling & charging stations for alternative fuel vehicles

2 NordicWay 2 Interchange Node Architecture

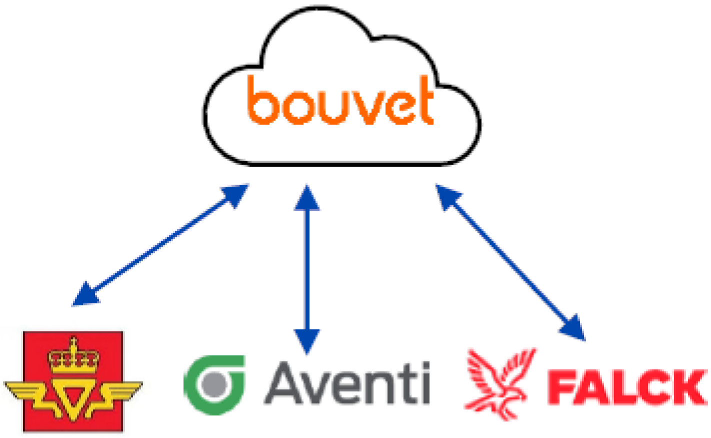


Figure 1 Norwegian interchange.

The interchange networks.

- It works by having several message brokers called interchanges, that can gather data from different service providers. These could be either run by governmental organization or the private sector.
- Each interchange keeps track of all the datasets that are available from the service providers that are connected to the interchange and its -stores meta data about the datasets (e.g. Geographic coverage, types of data, data format, who provided the data etc.)
- The information about the available data is then shared between all the interchanges so that each interchange knows what data is available, and where to find it.

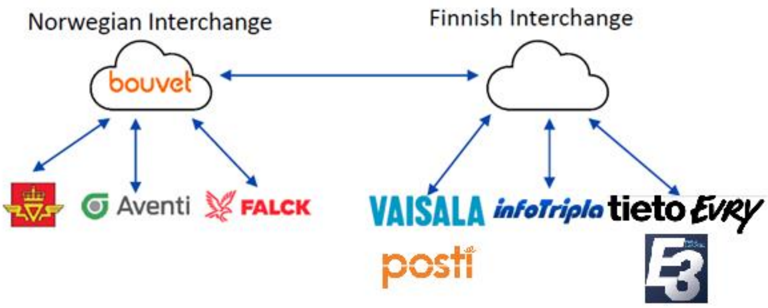


Figure 2 Interchange network federation.

- Service providers can now just tell the interchange what data it is interested in (e.g. "I want information about traffic accidents in Oslo")
- The interchange knows where to find that information and creates a data stream that fits those criteria available to the service provider.
- The provider of the data does not need to do anything to facilitate the data exchange, and if a new provider starts sharing data that also fits the criteria, that data is added to the data stream automatically.

During the main pilot operation phase of the project there were 6 interchange nodes in operation, where 5 of them were interconnected and shared data between actors in the different pilots. Norway operated 2 nodes, one main node and one test node. Finland operated 3 nodes, and Sweden operated one internal node for the Swedish pilots. In addition to data from the pilots, data from the national access points for all the nations were shared through the Norwegian Node.

Additional documents, protocols, and specifications

- Federation Use Cases [1] – This document describes the overall concepts and message sequence diagrams for the federated network of interchanges

- Federation Protocol [2] – This document defines the messages that is passed between the interchange nodes to facilitate the federated exchange of messages. Main parts of these messages are Capability exchange – messages used to advertise the datasets available on each node in the network, and Subscription exchange – messages used to initiate sharing of data between nodes.

- Client specification [3] – this document describes the relevant information that is required for a new client/service provider to connect to the system.

- The documentation and source code for the open-source implementation used by the Norwegian and Finnish nodes is available at: https://github.com/NordicWayInterchange/interchange

3 NordicWay 2 Norwegian test sites.

This chapter briefly describes equipment and infrastructure installed at the Norwegian demonstration sites, that were established in connection with NordicWay 2 project. For more details see the document Core Technical Equipment Deployed [4].

The Norwegian demonstration sites in NordicWay 2 are located

- on the E8 in Troms County, between Skibotn and the Finnish border
- on the E6 in Østfold County, at Patterød between Oslo and Swedish border at Svinesund

The geographical location is shown in Figure 3.

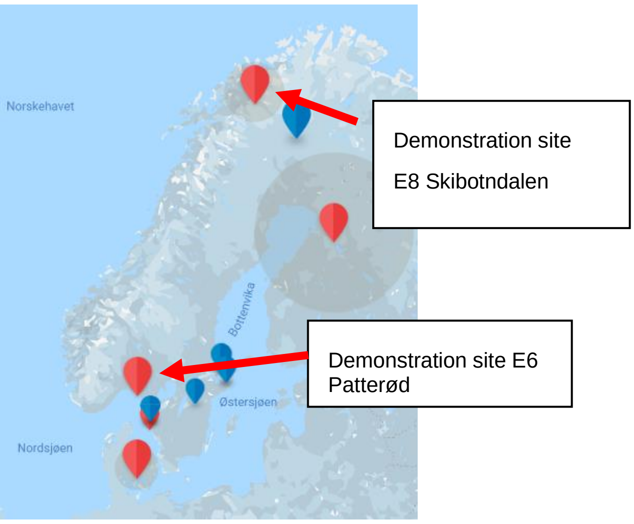


Figure 3 NordicWay 2 test sites locations.

3.1 E8 Skibotndalen

The demonstration site on E8 from Skibotn to the Finnish border is part of the transport route from northern Norway to Finland. It is particularly important for salmon traveling to Asian markets. This stretch of road has several problem areas for heavy trucks. Weather and driving conditions change significantly from the fjord in Skibotn to the mountain areas by the border.

The main problem areas on the Norwegian side of the border are shown in Figure 4. Halsebakken and Gardeborgbakken are hills with challenging gradient and curvature. On the section from Perskogen to the Finnish border the problems are mainly due to drifting snow.

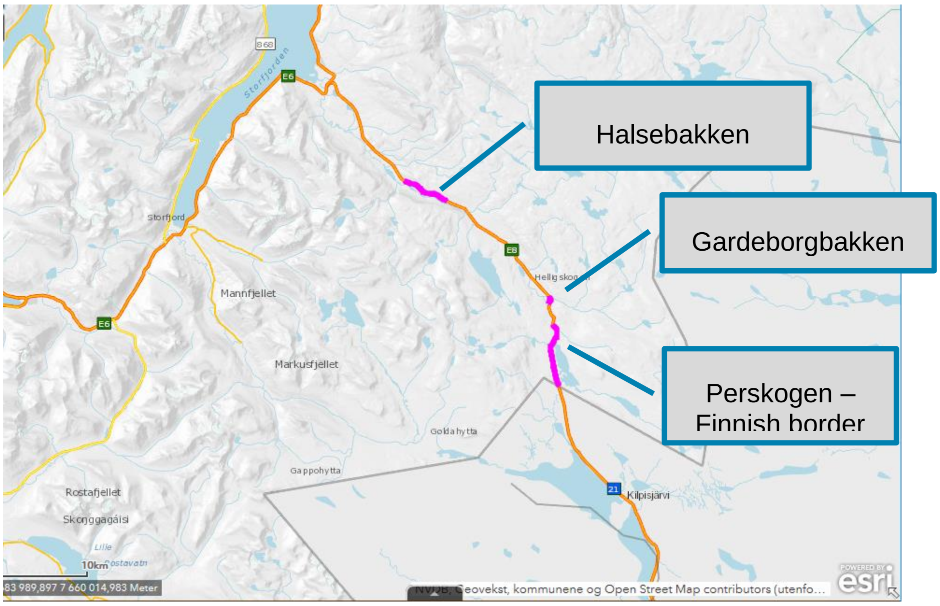


Figure 4 E8 Borealis - Main problem areas on the Norwegian side of the border

On the 38 km long road section a number of sites for technical installations have been completed. A total of 10 main sites (Figure 5) are equipped with power and network for communication, as well as cabinets, technical buildings or masts for mounting of sensors and other equipment. These locations are chosen to cover the main problem areas where traffic flow disruptions occur, and sites suitable for detecting, warning or stopping oncoming vehicles.

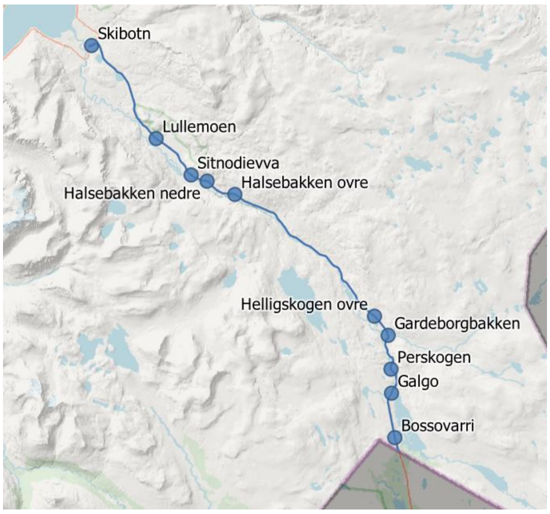


Figure 5 E8 Skibotn - Finland, main sites.

The following services were tested in Skibotn valley.

- Weather and road condition
- Slow and stationary vehicle
- Road and lane closure
- Traffic information and smart routing

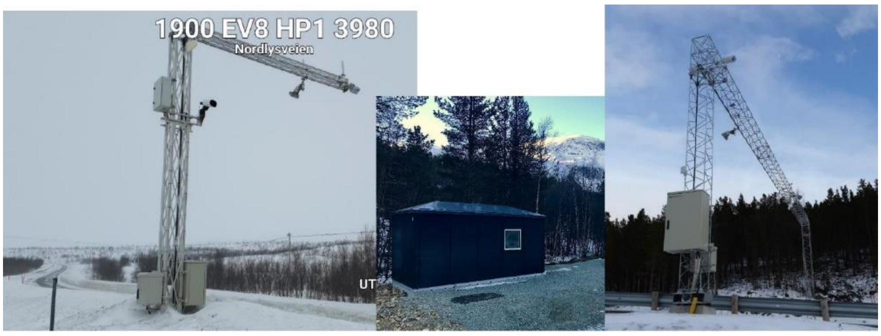


Figure 6 Installations at E8 Skibotn valley.

All cabinets, masts and technical buildings along the route are connected to 230V power. To achieve this, approximately 4750 m of underground power cable has been installed in ditches with transformers from the existing 400V cable. Also, 260 m of overhead power cables have been installed.

Figure 7 Installation of electrical power

Fibre network cable is installed along the entire valley, from Skibotn to the Finnish border, 38 km. The main sites are connected to the network with access points, and the fibre network is prepared for additional connections with cable coils every 500 meters.

VLAN solution is offered to the companies involved in test activities along the demonstration site.

When the project started there was poor cellular coverage in the Skiboten valley. Telenor upgraded their network in the Skibotn valley to 4G for the whole stretch. In addition, Telenor has enabled NB-IOT in the 4G network as well as Lora Wan.

At Sitnodievva, a new 600-meter-long road section was built in order to create suitable conditions for traffic monitoring with various technologies – also in-ground sensors such as weigh-in-motion, inductive loops and distributed acoustic sensors (acoustic fibre).

Figure 8 Sensors for traffic registration has been installed, such as inductive loops at four locations, travel time antennas and weigh-in-motion sensors.

3.2 Patterød

Patterød is an intersection on E6 between Oslo and Svinesund with high speed and heavy traffic. A common situation is spillback queue on E6 from the ramp in the northbound direction. The slow-moving queue on the highway can be up to approximately 1 km long, and the speed limit on the site is 110 km/h. This leads to potentially dangerous situations.

Another problem at this intersection is wrong-way (ghost) drivers, entering the highway on the exit ramp from north.

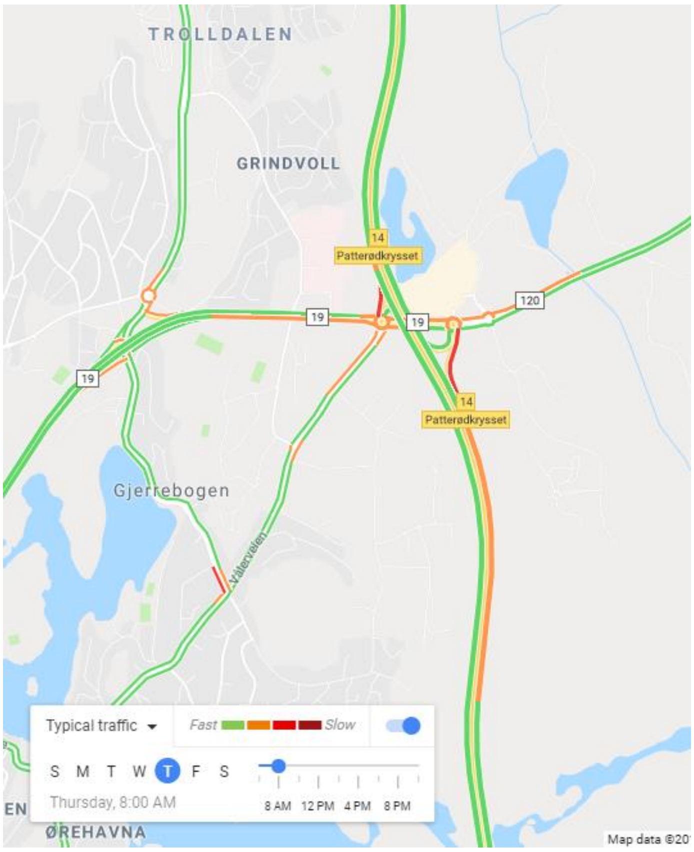


Figure 9 Patterød intersection.

A system for queue detection is based on inductive loops installed on the ramp from south, and variable message signs is installed on E6 south of the intersection. These are commonly used technologies that are ready for use and were used as a reference for new technical solutions being tested on this site.

Two cameras are mounted in the intersection to facilitate testing.

The test site is equipped with a technical building. Four locations have cabinets and masts for mounting of RSUs and other equipment. The fixed RSUs are mounted about 7 meter over the road surface. The testing has also included two mobile RSUs. Power and fibre communication have been made available in the intersection.

New technology for queue detection or other applications can be tested on this demonstration site, including ITS-stations with G5 radios. The first tests with mobile roadside units (RSU) were performed in April 2019. Fixed RSUs were mounted in masts in the intersection during summer 2019.

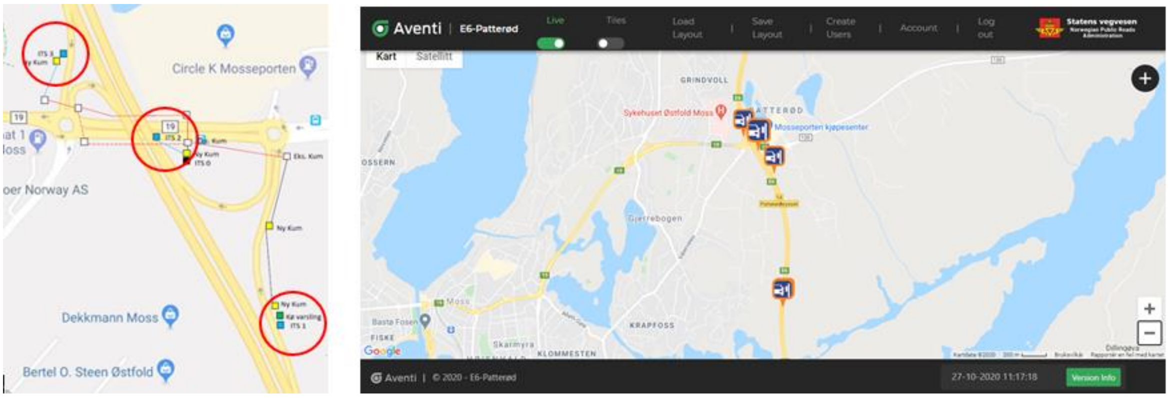


Figure 10 Patterød intersection, technical installations and G5 technology (right).

Figure 11 Equipment used at Patterød intersection, includes G5 OBU and RSU.

The following services were tested in Patterød intersection

- In vehicle speed limits
- Emergency brake light
- Cooperative collision warning (wrong way driving)

3.3 Jonsvatnet and Fv866.

Jonsvatnet

Due to Covid19 some tests had to be moved from E8 Skibotn Valley to Jonsvatnet, close to NPRA office in Trondheim.

The following services were tested around Jonsvatnet

- Traffic ahead warning
- Mobile road works

FV866

The Takting project was limited to a section of FV866 from E6 on mainland Troms and out to the island of Skjervøy, where there are two bottleneck sections One was on the Skattørsundet bridge (0.8 km long). This is a one-lane bridge over Skattørsund between Kågen and Skjervøy

The other was the Maursund tunnel (2.1 km long). This is an undersea tunnel that connects Kågen to the mainland below Maursund. The tunnel is categorized by poor fire safety, a narrow profile and 10% incline. Due to the narrow profile two trucks cannot meet in the tunnel and if this occurs one of the trucks must back out.

Figure 12 Bottlenecks at Fv866.

The following services were tested at Fv866

- Signal violation
- Green light optimal speed advisory

4 Norwegian Pilots

C-ITS services can improve traffic safety and efficiency, but to achieve this there is the need for communication between vehicles and the infrastructure. The problem with vehicle to infrastructure is the need for a backend system and possible roadside equipment. Another challenge is the physical equipment for communication which is one part of the equation and the equipment to sense and generate information that can be passed on to the vehicles.

Norwegian Pilot 1 explores the interaction between systems sensing challenging conditions that the vehicles and drivers that need to beware of these conditions. The NordicWay interchange is a core part of the system for passing on information between the systems involved in sensing and communication. Both ITS G5 communication and cellular communication have been tested in the different pilots. The aim of the pilots has been to explore the data chain from sensing, information generation and dissemination of information. Every service does not test the full data chain, but the part of the chain where road authorities need to build knowledge in order to deploy C-ITS services successfully.

Services have been adapted to Norwegian conditions to make them useful for road authorities and road users. Cost is a major issue for road authorities, hence finding ways to make C-ITS generate additional have been explored, especially for freight transport on rural roads in arctic climate. Another dimension is utilizing the C-ITS G5 technology as a sensor to monitor road traffic and intersection conditions.

This part of the report details each service that is piloted in the Norwegian Pilot 1.

For each service the report has the following structure:

- An introduction that briefly describes why this service is important
- Description of the pilot
- Technical setup, with all the involved actors.
- Use case/messages as defined in C-Roads specifications and adopted to the Norwegian Pilot 1

4.1 In vehicle signage (IVS)

4.1.1 In vehicle speed limits

4.1.1.1 Introduction

The "In vehicle speed limits" service explored how ITS G5 data on queue build-up on ramps can be used for generation of the information needed for the in-vehicle speed limits service.

The cross-border route between Sweden and Norway, E6 Svinesund-Oslo, has a recurrent problem with queue spillbacks from the off-ramps onto the main road. This can lead to serious incidents including rear end collisions.

4.1.1.2 Description of the pilot

Static road signs messages sent to the vehicle's internal display may help drivers notice road signs as they pass by. However, more intelligent and adaptive solutions can bring even more benefit to the drivers. Examples could be:

- Adaptive speed limits (ASL)
- Speed reduction recommendation based on traffic situation

The Norwegian public roads administration has systems to control dynamic road signs from their traffic management center (TMC). But the main challenge for the TMC is to decide when to increase or decrease the speed limits. The biggest problem seen from the actors in the Patterød region is that sensors sometimes makes system unstable and unreliable. When unstable systems are in operation the road users lose trust in the system and will no longer follow the advice given.

From a road operator perspective C-ITS based in ITS G5 holds a potential to provide an elegant solution for monitoring of roadways and intersections. The Cooperative Awareness Message (CAM) messages from the ITS G5 radios provide information on vehicle speed and direction among other elements. The Patterød IVI test was set up to test if ITS G5 CAM messages can be used as an upstream source for IVI messages.

The first element that was tested in the Patterød intersection was the coverage of ITS G5 radios. In this intersection there are 3 permanent RSUs and in addition there are 2 mobile RSUs. Debug information was extracted from the radios to log received signal strength. The second element that was tested was an algorithm for detecting the back of the queue. The algorithm extracts the location and vehicle speed. Then this information is processed to find the speed along different segments of the road.

The biggest advantage of using ITS G5 CAM messages is the area of coverage. A typical radar sensor or system based on inductive loops will only cover a small area, typically a detection zone where speed is measured. And this data is used to infer if there is a queue and if the back of the queue is upstream or downstream of the detection zone. Using ITS G5 CAM messages has the benefit of covering a large area if one looks at the problem a bit differently. Now the question is not if the queue upstream or downstream of a point, but rather where is the back of the queue. Being able to “track” the end of the queue is believed to give much more detailed information to the TMC, and they can regulate the variable speed limit signs with greater precision. This reduces the instability of the system that makes road users distrust the system.

A simpler solution was also tested where detection zones are created and if the average speed in a detection zone is lower than a threshold then a Decentralized Environmental Notification Message (DENM) message is set to warn drivers about the queue. For testing a threshold of 80 kph was set (100 kph speed limit).

At present the advent of a queue would have to be sent to the traffic management center who would then reduce the speed. However, the impacts of Covid-19 resulted in a severe reduction in traffic volumes and the problem with queues has disappeared for the time being.

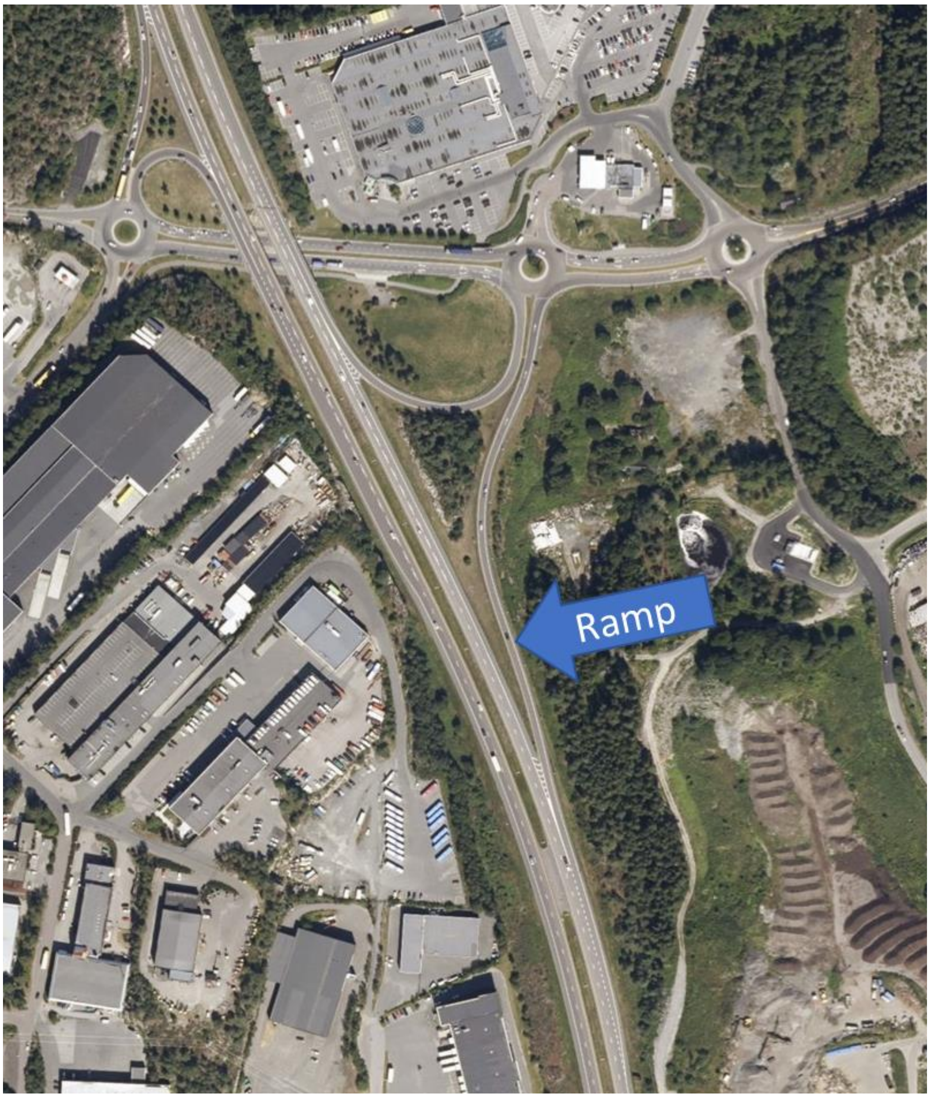


Figure 13 Aerial photo of Patterød test site with problematic ramp.

Figure 13 shows photo of the area, and the problematic ramp is indicated by the blue arrow. The problem occurs when the queue spills back from the roundabout and onto the main road (E6). Figure 14 show the view from a test vehicle in the queue and driving on the hard shoulder a long way back from the ramp. This is the situation that needed to be detected using contents from the CAM messages.

Figure 14 also show the vehicles on the hard shoulder before the ramp, and that the queue tries to split into two lanes to double the storage capacity of the ramp.

Figure 14 Vehicles on shoulder.

4.1.1.3 Technical setup

The main goal of testing this service was to explore how ITS G5 CAM messages can be used to locate the backend of the traffic queue. Data from ITS G5 OBUs was picked up, and location, timestamp and speed were extracted. The analysis explored which algorithms to use to identify the back of the queue. The goal was to use simple algorithms that could subside in the RSU, hence not forwarding the ITS G5 CAM messages. There were two primary reasons for this setup, with the first being privacy. A centralized storage of ITS G5 CAM messages can be used to extract single vehicle routes if there is enough coverage of ITS G5 in the area. This was demonstrated in 2016 (Lykkja, Evensen, Søråsen) where travel time calculations were done after a de-anonymization routine had been run. The other reason for processing the information at the edge is cost of data communication. The NPRA was more interested the speed on different road segments then the speed of each vehicle.

The developed algorithms are simple and robust, with the roads and lanes are divided into segments of equal size. Each segment has a point representing its location with data mapped to the closest point. Each point is given an attribute that gives its location as a linear reference along a specific road section. For example, offramp 1, 100 meters. This would mean a point 100 meters upstream (from the end of the specific road section). For each location simple percentile calculations are completed to establish the 25%, 50% and 75% percentile. These form the basis of a boxplot as seen later. The location with the greatest difference between the 75% and 25% percentile is the rear end of the queue. From a traffic engineering perspective this show the location where the change in speed is greatest over the segment.

This was seen as a good alternative to a simple assessment of the speed, i.e. if speed is under 30 kph then there is a que on the spot.

When the back of the queue exceeds a specific length upstream from the intersection an event is triggered, and an IVI message warning of congestion is created for the road section upstream from the off ramp.

Having a large detection area will enable smoother regulation of speed limits on the motorway. Depending on the queue length one can drop 10 kilometers per hour in increments as the queue drops. This gives more granularity to the operation. This could also potentially mitigate congestion effects that may occur due to a sudden drop in the speed limit.

Having more granularity also raises some interesting regulator aspects. At present speed limits are given in steps of 10, but does this increment make sense in a fully digital world with variable speed signs and IVI messages passed over G5? The benefit of smaller increments is smoother regulation of traffic, possibly reducing shockwave effects.

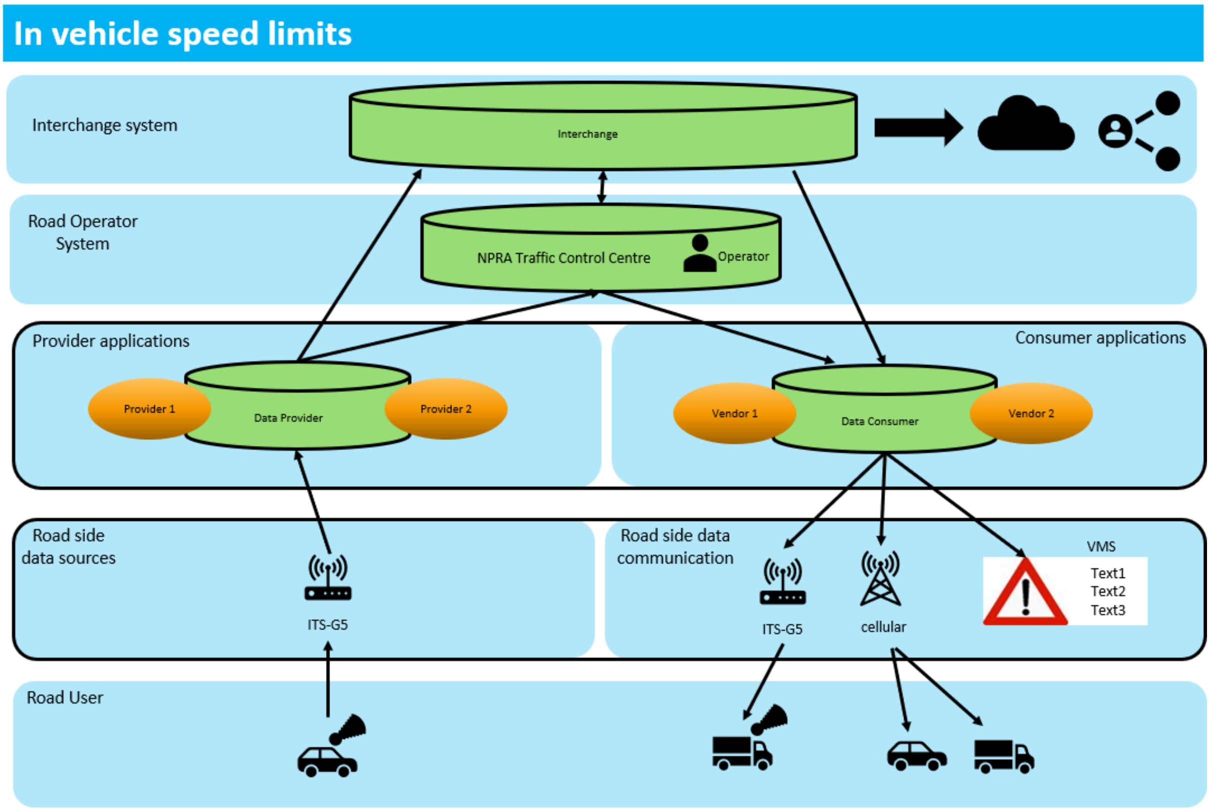


Figure 15 NPRA Pilot Data System for in vehicle speed limits.

Figure 16 shows the detection of queue on the ramp. The ramp and hard shoulder on the main road are divided into segments of 100 meters in length and calculation of the 25%, 50% and 75% percentiles are calculated. The dotted blue lines show expected speed when there is no congestion.

The figure below shows quite clearly that using speed and location and simple statistics is all that is needed to find the end of the queue. The ramp ends at about 350 meters from the roundabout. In the left graph one can see that the queue is far beyond the ramp, 750 meters. While 13 minutes later the backend of the queue is at where the off ramp starts.

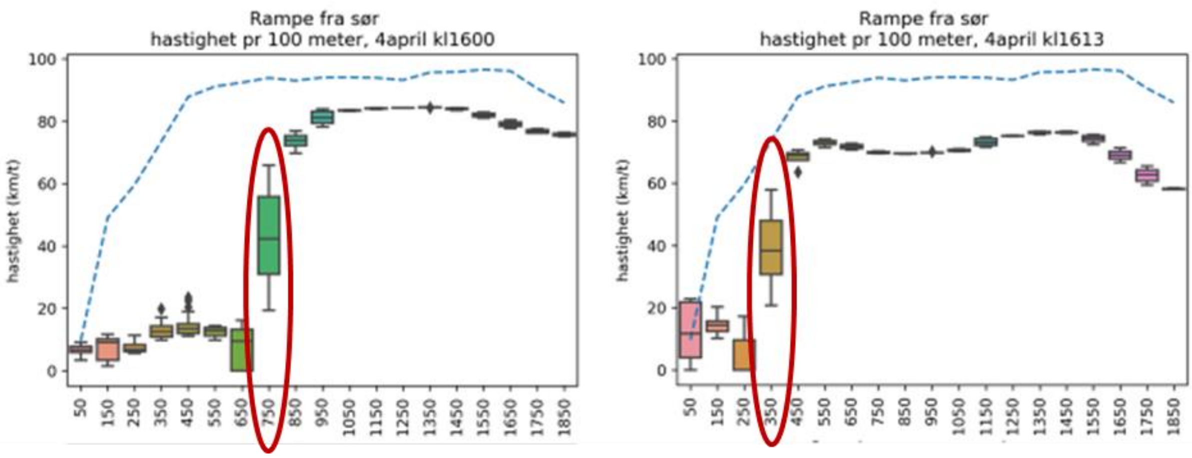


Figure 16 Detection of queue in ramp.

4.1.1.4 Use case/messages

Use Case Description	
Summary	Drivers receive notifications via in-vehicle systems about the dynamic speed limits displayed on roadside VMS systems.
C-Roads Use Cases	Dynamic Speed Limit Information (IVS-DSLI) [TF2-SD].
Actors and relations	The main actors are: Road-Side System (displays and sends speed limit information) Road Operations System, Content Provisioning System (sets speed limits, receives and distributes speed limit information); Interchange System, Application Backend System (distributes speed limit information) Vehicle (receives speed limit information and displays it to driver);
Logic of transmission	One-way (V2I) and two-way (I2V, V2I) communication.
Triggers	Speed limits are implemented, initiated or changed by the road operator.
Constraints/dependencies	Speed limits are displayed on VMS systems.

Table 1 Service description of in vehicle speed limits.

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	VMS message	SituationPublication	v2.3 (Level B)	None

Table 2 DATEX II message representation.

Use Case	Deployment	Message Type	Standard
In Vehicle Speed Limits	Norway	DENM	ETSI EN 302 637-3 [ETSI-BS2]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]

Table 3 ETSI Standard message representation.

4.2 Hazardous location notification (HLN)

4.2.1 Weather and road conditions

4.2.1.1 Introduction

Weather and road conditions can have a substantial influence on driving conditions and is one of the prioritized C-ITS services demonstrated in the Norwegian Pilot 1. The “weather and road condition” service piloted several systems to get current and expected weather and road conditions on a challenging route under arctic conditions. This report contains the service definition, the pilot description, technical and architectural setup, results and lessons learned.

4.2.1.2 Description of the pilot

E8 in the Skibotn valley is ideal corridor for testing applications related to driving conditions in winter-time. It must however be emphasized that the peripheral road network as of today has some limitations with regards to demonstrate all actual scenarios for weather and road conditions. One of the main challenges is to monitor the road network with good coverage in real time and to calculate reliable prognoses for the expected change in driving conditions.

In addition to a previously existing weather station at Galgo, three weather stations were installed with Norwegian national standard specifications along the E8 test site at *Halsebakken nedre*, *Gardeborgbakken* and *Bossovarri*.

The three new weather stations measure

- Humidity
- Air temperature
- Road condition
- Friction (estimated)
- Water layer
- Ice layer
- Snow layer
- Precipitation
- Visibility in precipitation
- Visibility
- Road surface temperature
- Road surface state
- Wind speed
- Wind direction

Variable message signs are mounted in three locations. The signs at Lullemoen and Helligskogen are connected to low-cost weather stations, enabling them to show wind and temperature information, as well as other types of information from other sources. The purpose of these signs is to inform drivers of heavy vehicles when difficult driving conditions are likely to occur.

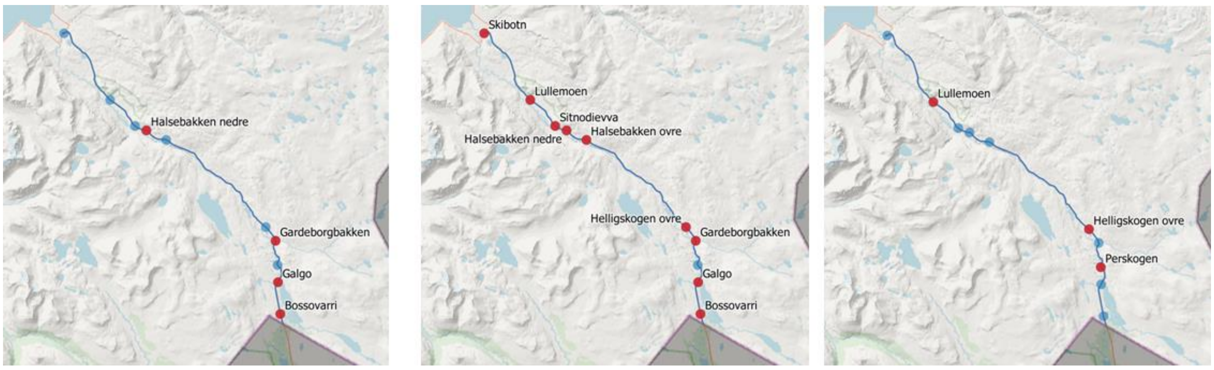


Figure 17 Locations with weather stations (left), cameras (middle) and Variable message signs (right) on E8 in Skibotn Valley.

Figure 18 Smart road sign with weather station.

Smart electronic road signs with an integrated weather station and ITS station (Figure 18) may function autonomously, always displaying the most relevant and important information to the drivers. For the Norwegian Pilot 1, signs may also be equipped with an RSU that transmits weather information to passing vehicles for in-vehicle display.

By combining data sources (weather sensors, weather forecasts, data from winter maintenance vehicles, data from probe vehicles and from mobile road condition monitors) more reliable information on weather and road conditions may be obtained. Weather data from the Datex Node is distributed through the NordicWay Interchange and displayed to drivers by the use of smart electronic road signs and in-vehicle signage. Data from the low-cost weather stations has been distributed both to the VMS and to the Interchange.

Furthermore, this pilot has explored the possibility to utilize weather forecasts and information on winter maintenance actions, along with artificial intelligence, to generate precise travel time forecasts with a long horizon. The project named “Multi-criteria travel time forecast on road sections” has been carried out by the German company PSI Group.

The user can choose between 12-hour and 36-hour prediction period, see Figure 19. Travel time forecasts are validated using speed data from "salmon trucks" equipped with optical sensors.

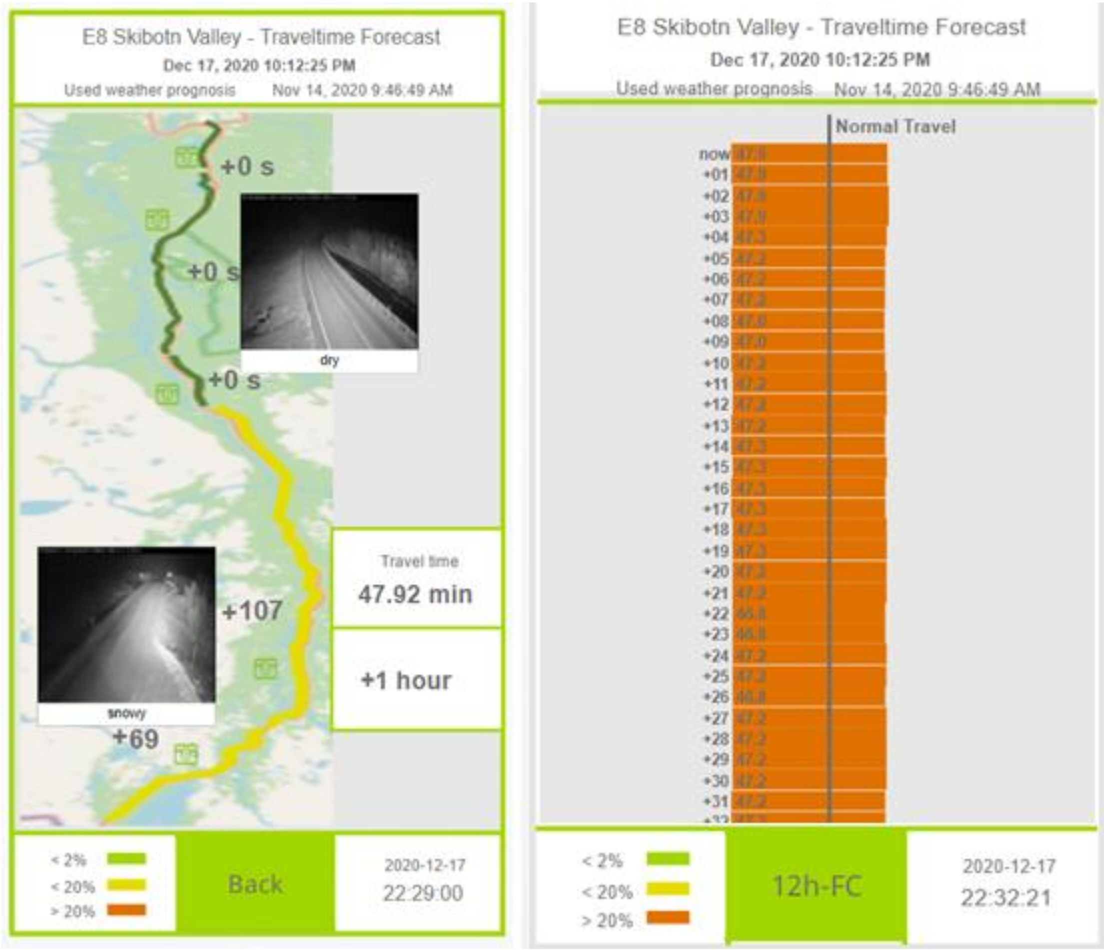


Figure 19 Travel time prediction – PSI Web application.

The on-site pilots for the weather data were scheduled for spring 2020, but because of the COVID pandemic the project was unable to finish the test. The system-flow, however, has been tested so the data can be delivered to road users, both for user from the operator display available on the NPRA Pilot data system, and by sending information to the variable message signs. Data can also be sent to the interchange so that any system listening for them can make use of the messages.

The project planned to test different messages on the signs and to stop selected drivers from passing down the road and to conduct an interview covering topics like:

- Did the driver see the message displayed on the VMS?
- Did he/she take notice?
- Does he/she think the system is useful?

It is uncertain if or when the project will be able to complete these interviews.

4.2.1.3 Technical setup

Official weather data is available from several nearby NPRA installed weather stations and that can be collected in real-time using a pilot developed REST-API or directly on the NPRA “vegvær”-webpage for historic data. Real-time data is stored in the NPRA Pilot Data System using a NoSQL database for future reference and comparison. Key values for weather conditions are also sent to a user interface for interpretation by a human operator for pilot tests.

The Triona company provided the project with sensors measuring weather data, and data from these sensors are available for the NPRA Pilot Data system using MQTT. The data can also be download from their ITS Platform. Key values from these sensors are continuously displayed on the variable message sign at Lullemoen in the form of air temperature and wind speed data. The data also contains information that can be relevant for warning drivers about adverse conditions, but the quality of the data for the sensors is not yet known and was therefore not used for this purpose. Part of the pilot included evaluating of the relatively low-cost Ortana sensors result compare to the data from the more expensive NPRA stations.

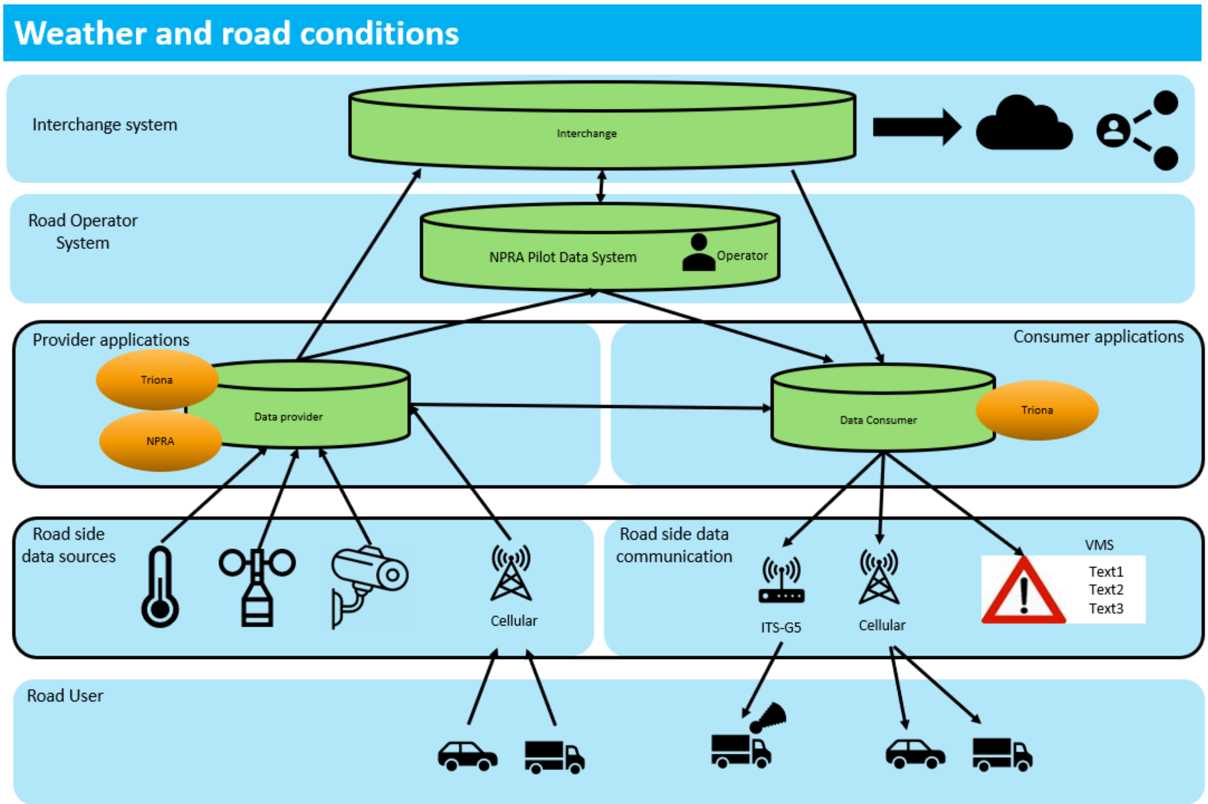


Figure 20 NPRA Pilot data system for weather and road conditions.

Figure 20 shows the eco system for weather condition and temporarily slippery road warnings. The service consists of the following components:

- Road operator system
- Interchange system
- Application backend system
- Roadside system
- User interface

Data from the NPRA stations are shown to the operator who needs to assess them and notify road users as necessary. The information is displayed in an intuitive user interface with the values shown as gauges with color coding to indicate which values are in ranges which may cause problems for road users(Figure 21). The operator can set a few predefined messages to the variable message signs in the area to warn drivers about certain conditions. These are:

- Warning of strong wind
- Put snow chains on tires.

The third option is to set the default sign message, this is the message being displayed when pilot tests are not being performed. For Helligskogen this is the message “drive carefully” and for Lullemoen this is a display of the current air temperature and windspeed. Other values can be set on the VMS’ through Triona’s ITS Platform but this part of the pilot was not set up.

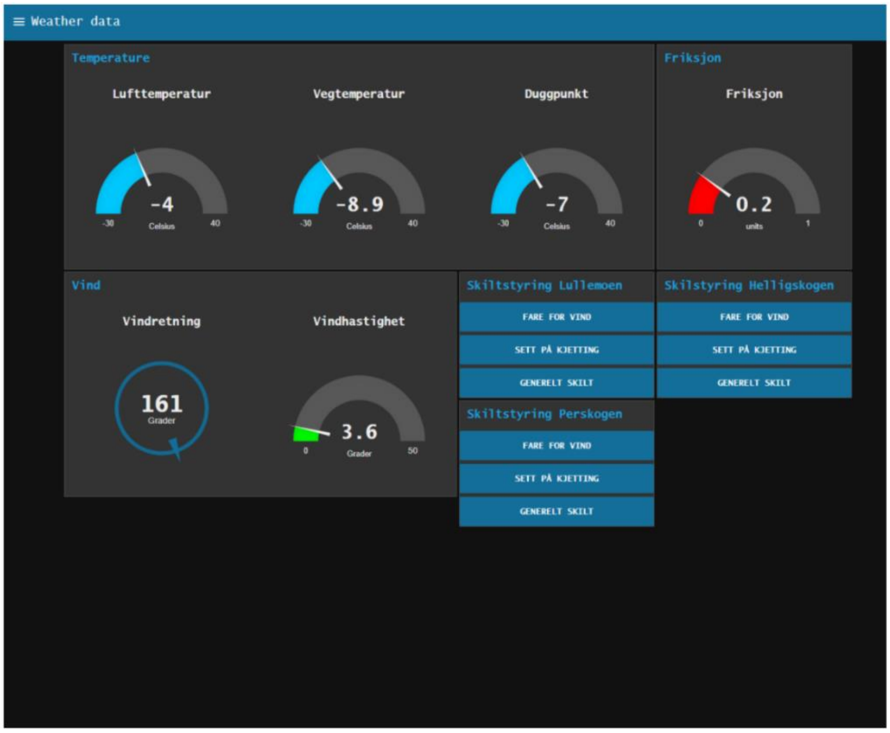


Figure 21 User Interface for road operator.

Since data was collected using both the more costly NPRA weather stations and more affordable sensors from Ortana/ Triona, the project did an analysis to compare how the Ortana sensors performed against the NPRA stations. The NPRA stations were used as a reference and as a measure of the relative accuracy of the Ortana stations.

The data is collected at different time intervals, so data from both the NPRA stations and Triona's stations had to be aggregated in order to make meaningful comparisons. For the analysis data was aggregated into 15- and 60-minute intervals. Analysis and aggregation were completed in Microsoft Excel.

For a comparison of the Ortana sensors to the NPRA weather station, see Figure 22. Data for the month of November 2020 was analyzed using the following measurements:

- Air temperature
- Road temperature
- Dew point temperature

Nordic WAY 2

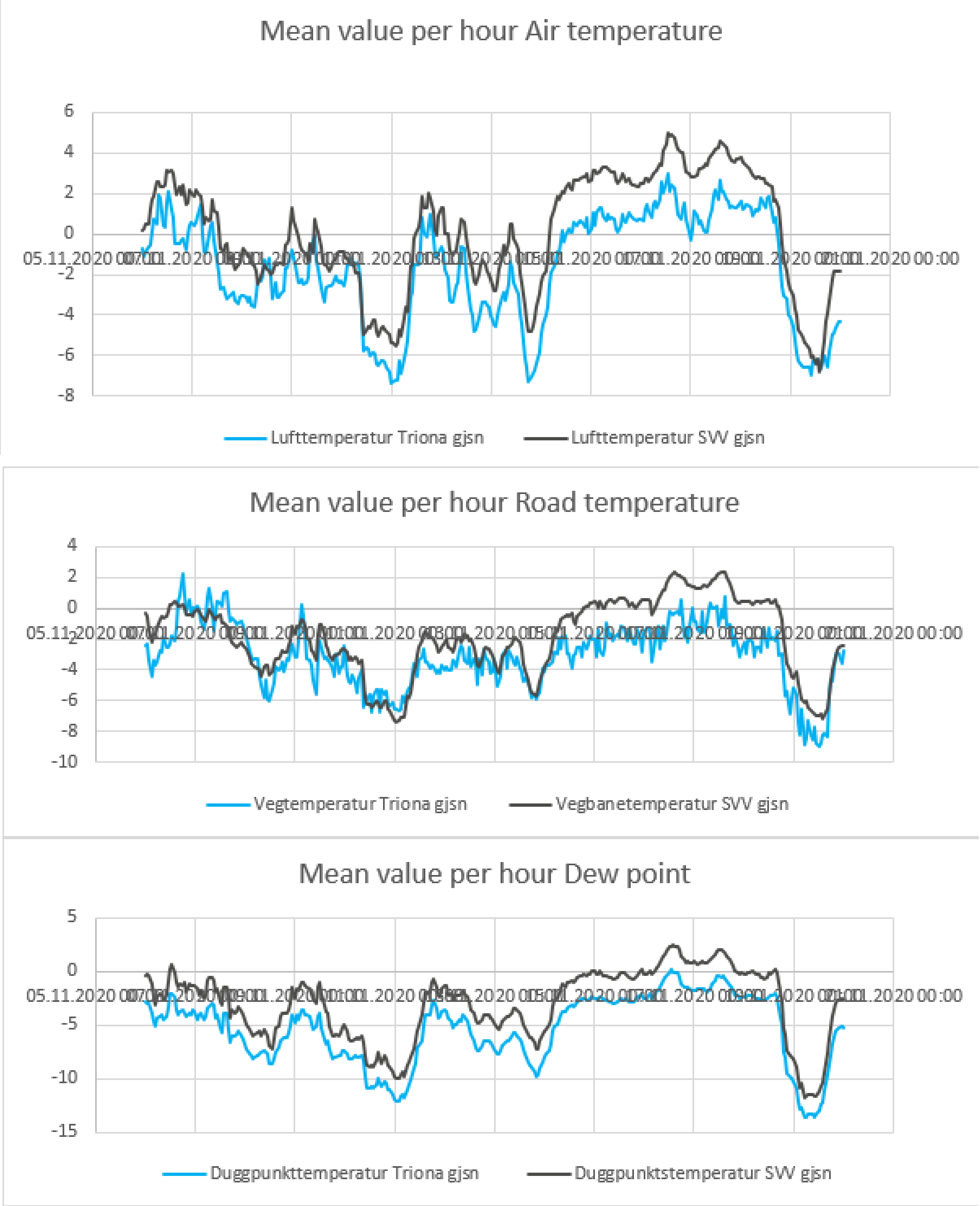


Figure 22 Triona sensor vis NPRA station for air temperature, road temperature and dew point.

4.2.1.4 Use case/messages

Use Case Description	
Summary	Drivers receive warnings about dangerous and changing weather and road conditions.
C-Roads Use Cases	HLN - Weather Condition Warning (HLN-WCW) [TF2-SD], HLN - Temporarily slippery road (HLN-TSR) [TF2-SD].
Actors and relations	The main actors are: Interchange System, Application Backend System (distributes warnings); Road Operations System, Content Provisioning System (receives and distributes warnings) Vehicle, Personal Device (may detect and report dangerous and changing conditions, receives warnings and displays them to the driver);
Logic of transmission	One-way and two-way communication (V2I, I2V)
Triggers	Information about weather and road conditions are available to actors responsible for issuing and distributing warnings to drivers.
Constraints/dependencies	Constraints and dependencies include: Warnings are valid and up to date (i.e. they reflect current weather and road conditions). Warnings include information about the location and type of the conditions, and driving behaviour advice, where appropriate. Warnings are cancelled if the conditions cease to exist, or they shall be updated if the conditions change.

Table 4 Service description of weather and road conditions

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Weather and road condition	SituationPublication	v2.3 (Level A)	None

Table 5 DATEX II message representation.

4.2.2 Slow and stationary vehicle

4.2.2.1 Introduction

On low volume roads, slow and stationary vehicles do not create traffic jams in the traditional sense. Slow and stationary vehicles frequently occurred on inclines in wintertime and this increases the risk for accidents and for delays for other traffic. It is therefore natural addressing the problem of slow and stationary vehicles is one of the C-ITS services piloted in the Norwegian Pilot 1.

The “slow and stationary vehicle” service shows how vehicles downstream from a maintenance vehicle that drives slowly can be notified about this and dangerous situations can be avoided. This report contains the service definition, the pilot description, technical and architectural setup, results and lessons learned.

This pilot includes also the basic functions for the service Road and Lane closure.

4.2.2.2 Description of the pilot

On the E8 between Skibotn and Kilpisjärvi there is a road section at the Garderborgbakken with a challenging uphill situation. If some vehicles (normal heavy vehicles) stop on this uphill section, it will be valuable to inform other vehicles about the situation. This will ensure that the situation will not get worse and to provide information that is useful if a driver needs to decide whether to continue to drive or wait until the road is fully operational again.

Figure 23 Truck stopped uphill in Gardeborgbakken.

Figure 23 illustrate a typical weather-related incident with a stopped truck resulting from snow and low friction for tires.

Two detection systems have been investigated:

- Lidar system
- Magnetic sensors in the road surface

Both solutions should use the NordicWay interchange as the means of distribution of messages, allowing other actors to utilize the data.

4.2.2.3 Technical setup

For detecting slow or stationary vehicles in Gardeborgbakken the project used systems from ITS Perception and Q-Free. The two vendors utilize different technologies for detection and provide both sensors and software to detect and report events.

ITS Perception's system consists of six lidars sensor, three observing the lane bound for Finland, and three observing the lane coming from Finland. The system uses machine learning and image recognition technology to detect vehicles and their speeds. Events, i.e. vehicles detected, are reported to a NPRA developed back system using a message queue, described later.

Q-Free's system consists of 120 parking sensors installed in centre of the road, covering a length of about 600 meters in the lane bound for Finland. The sensors detect vehicles situated right above the sensors and will detect speed using the sequence in which the sensors pick up the vehicles. Q-Free provided both the sensors and a software for reporting events to the NPRA back system.

Both ITS Perception and Q-Free have developed algorithms for detecting vehicles travelling through the area and report three different scenarios, normal where vehicles drive at or close to the speed limit, slow speeds when speed is well below the speed limit and where vehicles that have stopped. All these events are available for the project as notifications over MQTT. This enables the user to subscribe to the correct events. The project logged all three event types.

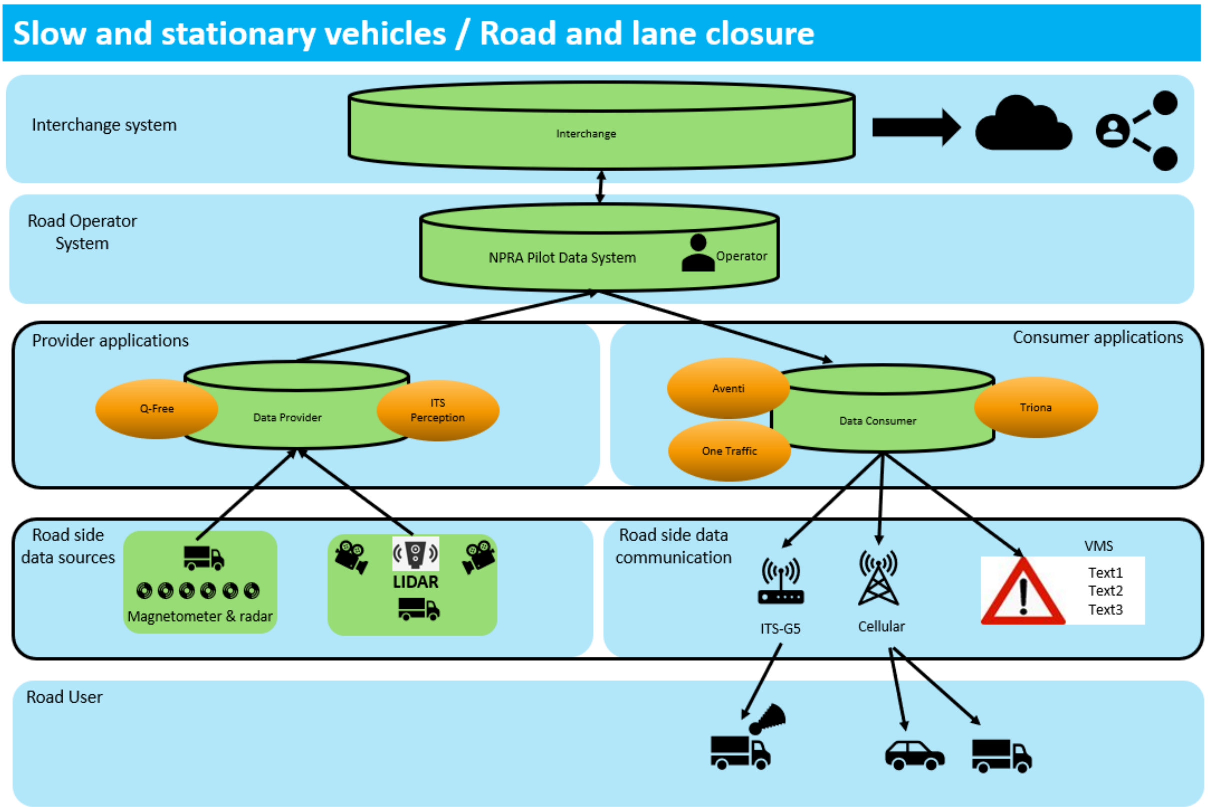


Figure 24 NPRA Pilot data system for slow and stationary vehicles and road and lane closure.

The systems are running and recording data even if no tests are being conducted. All events are logged for the entire pilot study period from mid-2019 to mid-2020.

The data flow starts with either system detecting a vehicle on the stretch of road being monitored, this detection event is sent in form of a message on the MQTT server for each vendor. The messages are secured using a dedicated network that can be accessed using a VPN or by being physically connected to the actual network.

The message is sent to the NPRA Pilot Data system, a server running the necessary application to collect, store and evaluate the data. A MQTT client listens for notifications from the systems, and all messages received are stored in a NoSQL database for traceability and later analysis. When an event, either for slow and stationary vehicle is received, the data is sent to the appropriate applications for analysis and handling. This includes an application storing images to disk from the surrounding road cameras for evaluating whether or not the event was a false positive, and to a user interface so that an operator can evaluate and take necessary actions during the tests (Figure 25). All applications have been developed using a Node-Red framework, enabling the project to quickly develop and adapt prototype software.

Images are stored using two systems, one system storing images collected every ten seconds from four surrounding cameras throughout the pilot period. These images can be used later to analyze false negatives, where a situation occur but was not detected. As described above, images from the same cameras where stored with a link to all slow and stationary events, to evaluate if the detected event actually occurred or not.

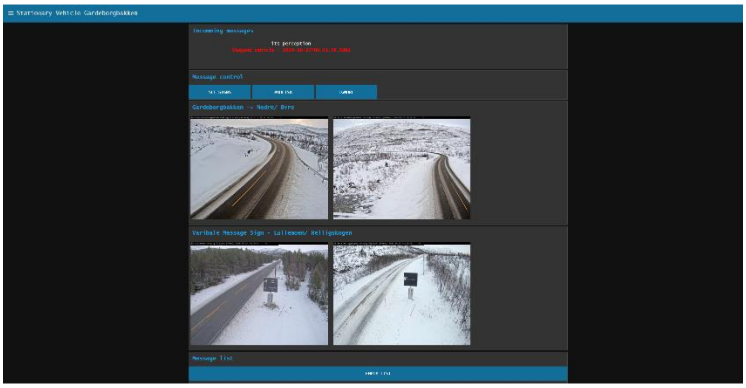


Figure 25 User Interface for stationary vehicles.

The user interface shows the last unhandled message, if there is one, on the top of the screen. The message is displayed in red to attract the user's attention. On the bottom half of the screen the last 100 messages are displayed. The images seen in the user interface are updated approximately every 10 seconds. Using these messages, the operator can evaluate whether a detected slow or stopped vehicle event is a valid one and can accordingly initiate notifications to road users. This includes pushing data out to users or setting an appropriate message for one or more of the variable message signs in the area.

None of the vendors in the project currently support using Datex 2 messages as input to their systems, so the project team had to make adaptations to address this issue. This was done using the NPRA Data system as a proxy for the Interchange and pushing messages directly to the vendors. In this case this involved writing messages to a REST API in Aventi's ITS platform using JSON-messages. These messages are displayed in the platforms map interface and are also pushed to One Traffic and displayed in their mobile application. This functionality was demonstrated in the trials performed in October of 2019. Notifications were also available to vehicles using G5 radios in the area.

The variable message signs were delivered from Triona and controlled using their ITS Platform. The process of setting the message on the variable message signs is controlled using the platforms REST API. To avoid confusing drivers and reducing the confidence in the messages displayed on variable message sign in general, the new sign messages was only available for a minute before it was reset to the initial value. Changing the message was not fully automated during the trials and always hard to be initiated by an operator.

The project has verified that both technologies do indeed detect situations where the vehicles are driving slowly or has stopped. During the pilots, detected events for stopped vehicles have used an app an variable message signs to warn drivers. A preliminary study of the data provided by ITS Perception was delivered for Milestone 21 “first trial of data processing for freight industry”.

The systems have been running for more than twelve months and have provided the project with data and insight. There are two main take-aways. One is the systems and infrastructure are quite vulnerable to problems. During the pilot the project experienced distributed denial of service (DDoS) attacks on one of the cloud providers, broken network equipment and adverse weather conditions. Due to these issues there have been several periods of down-time.

Another take-away is data quality. These systems generate a lot of events, especially for slow vehicles, and there were dozens every day. Very few of these notifications are actually relevant, and mechanisms for filtering and validating the data needs to be developed. A further study regarding the quality of detections is therefore needed. The project has gathered the data for this in form of the images and all the stored events.

This highlight an issue that affects other of the services piloted - there is a lack of mechanisms and procedures for validating data before acting upon the data. From project discussions and from the pilots it became apparent that data and technology is not the biggest factor preventing roll-out of this technology, it is a lack of mechanisms and procedures for the road operator handling the data.

4.2.2.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use Case Description	
Summary	Drivers receive information about nearby slow or stationary vehicles.
C-Roads Use Cases	HLN - Stationary Vehicle (HLN-SV) [TF2-SD].
Actors and relations	The main actors are: • Road Operations System, Content Provisioning System (receives and distributes information); • Interchange System, Application Backend System (distributes information); • Vehicle, Personal Device (may detect and report slow moving and stationary vehicle, receives warnings and displays them to the driver);
Logic of transmission	Two-way communication (I2V, V2I)
Triggers	Information about a slow or stationary vehicle (position, speed, etc.) is available to actors responsible for issuing information/warnings about such vehicles.
Constraints/dependencies	Constraints and dependencies include: • Information/warnings are available to road users for which they are relevant (i.e. road users approaching the slow or stationary vehicles). • Information/warnings are valid and up to date (i.e. the slow and stationary vehicles are on the road at the specified locations). • Information/warnings are timely (i.e. they should allow road users to undertake timely adaptation of driving behaviour). • Information/warnings are cancelled if the hazards cease to exist or be updated if the state of the vehicles change.

Table 6 Service description of slow and stationary vehicles

Use Case	Deployment	Message Type	Standard
Slow and Stationary Vehicle	Norway	DENM	ETSI EN 302 637-3 [ETSI-BS2]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]

Table 7 ETSI Standard message representation.

4.2.3 Traffic ahead warning

4.2.3.1 Introduction

The "traffic ahead warning" service shows how information about vehicles ahead can be sent to vehicles downstream. Under rural conditions, the traffic ahead is typically traffic that is not moving at expected speed, due, for example, to traveling up a steep hill.

This pilot also includes the basic functions for the service Mobile Road Works.

4.2.3.2 Description of the pilot

On low volume roads, slow and stationary vehicles do not create traffic jams in the traditional sense. A typical example of a slow vehicle on a peripheral road may be maintenance vehicles, often operating at speeds of around 30 km/h. Currently the location and the status of the maintenance vehicles (if they are doing maintenance, gritting, plowing etc.) is unknown. Providing information on location and the vehicles status can provide good value to freight transports, freight transport service providers and to road operators. By exchanging real time data through the NordicWay Interchange node, all interested parties can obtain machine generated information on these slow-moving vehicles. Two solutions have been investigated:

- Utilizing the backend systems of the maintenance operator.
- Linking a device to the yellow warning lights mounted to the maintenance vehicle exterior, transmitting when the warning light are switched on.

Both solutions should use the NordicWay interchange as the means of distribution of messages, allowing other actors to utilize the data. This service should be tested on real maintenance trucks. Cooperation with the maintenance contractor has been initiated and the maintenance trucks in the E8 contract area has been set up to deliver data.

The pilot on traffic ahead warning was originally planned to be carried out on E8 in Skibotn Valley, but due to the COVID pandemic it was necessary to change the location to keep with the project's time schedule. It was found appropriate to use the road around Jonsvatnet on the outskirt of Trondheim as test area (Figure 26).

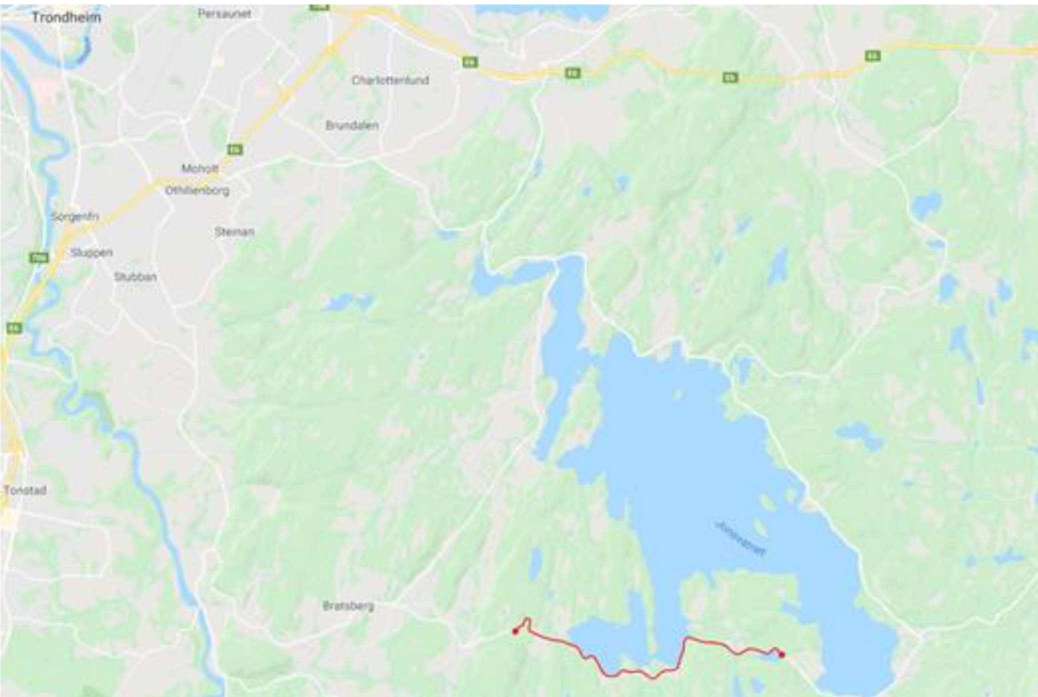


Figure 26 Test area used for the pilot on Traffic ahead warning.

The road around Jonsvatnet is a municipal road with low traffic volume and variable cellular network connectivity

4.2.3.3 Technical setup

The pilot on Traffic Ahead Warning was limited to the solution with yellow warning light. In the demonstration car A acted as slow-moving traffic by driving considerable below the speed limit. Car A had the warning light switched on and send out its position. Car B was the approaching car. After turning on the warning light in Car A, a signal was sent via the cellular network to a cell phone in the following car (car B). Car B moved at the speed limit and the driver could see where the slow-moving traffic was on his smartphone. The driver of car B was then able to reduce his speed before he saw car A on the road and could approach in a much safer speed than possible without this information. See Figure 27.

The technical implementation used a GPS and a narrow band IoT modem to communicate the warning light status with the backend system. The physical device was integrated into an existing warning light, so the function of the system required no additional interaction from the operator of the car besides just turning on the light.

Figure 27 Car A (left) Car A and following car B (middle), position of traffic ahead displayed on map (right).

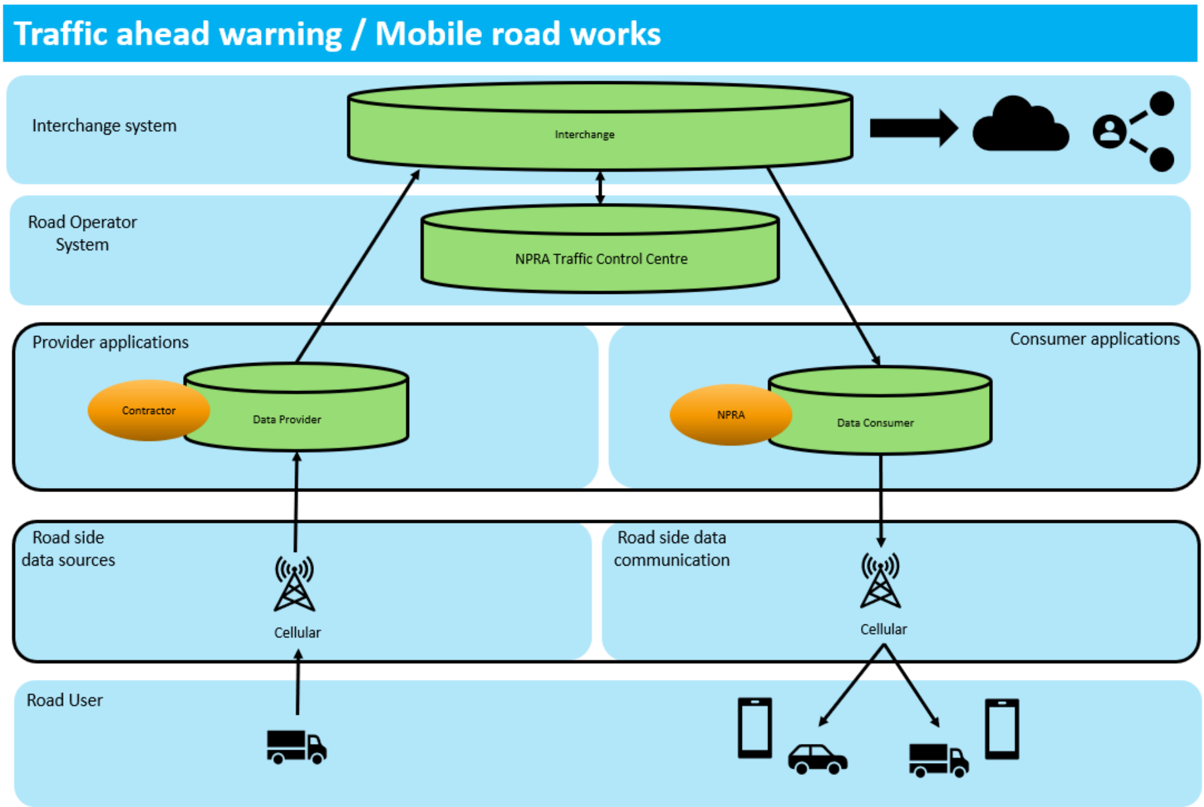


Figure 28 NPRA Pilot data system for traffic ahead warning and mobile road works.

4.2.3.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use Case Description	
Summary	Drivers receive warnings about traffic jams ahead.
C-Roads Use Cases	HLN - Traffic Jam Ahead (HLN – TJA) [TF2-SD].
Actors and relations	The main actors are: Road Operations System, Content Provisioning System (receives information about traffic ahead, distributes traffic ahead warning); Interchange System, Application Backend System (distributes warnings); Vehicle, Personal Device (may report traffic ahead, receives warning and displays them to the driver).
Logic of transmission	Two-way communication (V2I, I2V)
Triggers	Information about traffic jams are available to actors responsible for issuing warnings.
Constraints/dependencies	Constraints and dependencies include: Warnings are available to road users for which they are relevant (i.e. road users approaching the traffic jams).

	Warnings are valid and up to date (i.e. the traffic jams are ongoing). Ideally, warnings should be based on end-of-queue information. Warnings are timely (i.e. it should allow drivers to undertake timely adaptation of driving behaviour). Among others, warnings should provide information on distance to the traffic jams. Warnings are cancelled if the traffic jams cease to exist or be updated if the characteristics of the traffic jams change.

Table 8 Service description of traffic ahead warning

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Traffic ahead	SituationPublication	v2.3 (Level A)	None

Table 9 DATEX II message representation.

4.2.4 Emergency brake light

4.2.4.1 Introduction

The service emergency brake light will reduce the risk of dangerous situations when hard braking occurs. The emergency braking system of vehicle is activated and then a backend application system sends a warning to other connected vehicles approaching the vehicle.

The "emergency brake light" service explored the generation of G5 radio emergency brake DENM messages, and challenge that would occur if the ITS G5 radio was not connected with the vehicle systems.

4.2.4.2 Description of the pilot

One of the benefits of having onboard units is the possibility to generate data on vehicle behavior. The Coda on board units bought for the Patterød test site can generate DENM messages for emergency / hard braking. The Patterød test site consists of a multilevel high-volume intersection that joins Moss and a regional road to the E6 arterial road.

There are 3 permanent roadside units operating in the intersection as well as 2 mobile RSUs. The reasons for having this much equipment is that knowledge about range and coverage of the RSUs and OBUs was unknown. A separate research project is underway to study the coverage of ITS G5 and cellular equipment. The results expected from this research project is the development of a coverage calculation tool for ITS G5 and Cellular links so that the optimum location of the RSUs can be found. Since the tool is expected to be completed in 2022, the project team had to make guesses on the locations of the roadside equipment and supplement those mobile units if complete enough coverage was not achieved.

The experiment for extracting hard braking messages is quite simple. The RSUs are linked into an on-site fiber network that relay the CAM and DENM messages to a backend system built by Aventi. The mobile RSUs have a cellular uplink to the same backend system. There is a storage functionality on the backend system so that JSON representation of the ITS G5 messages can be downloaded for further analysis by the NPRA.

Several tests were performed by NPRA staff driving through the various segments of the intersection. Data was later extracted and placed on maps using available GIS software. In addition, a "simpler" area was added on the side roads to the E6, with little traffic and very few physical obstructions. At this location the braking test were performed under controlled conditions to see if emergency braking messages could be extracted. Here it should be noted that this was tested with OBUs that were not plugged into the vehicle, i.e. receiving data from the vehicle by the CAN-bus or similar networks. Thus, the data on braking was calculated from the GNSS functionality of the box.

In addition to the explicit braking tests, normal driving test in the Patterød intersection were performed.

The focus on this pilot was data generation, hence not all parts shown in the technical setup picture were tested. In the total NordicWay 2 pilot all parts have been tested. Even if not every part of the eco system has been tested in each pilot activity, the Norwegian pilot 1 has tested all Parts of the eco system.

Figure 30 Picture from unobstructed area.

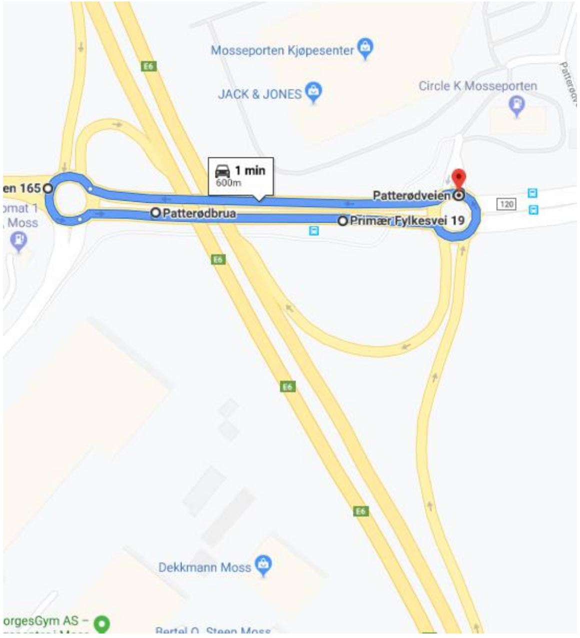


Figure 29 Drive path for drive tests in the Patterød intersection.

4.2.4.3 Technical setup

The RSUs have been set up to dump received CAM and DENM messages into a back-end system operated by Aventi. From there the messages were downloaded to the NPRA for analysis. No security was used in the pilot, but in future projects there would be a need to deploy a security model. The OBUs were placed in the vehicles and connected to the standard 12V power plug. The ecosystem shown in Figure 31is the envisioned system. If there is a lot of braking, the systems also include sending DENM messages warning incoming traffic. In addition, messages would be sent to the interchange for statistical purposes so that data can be stored and used to locate areas with high levels of hard braking. These are locations that infrastructure improvements maybe needed.

Emergency break light

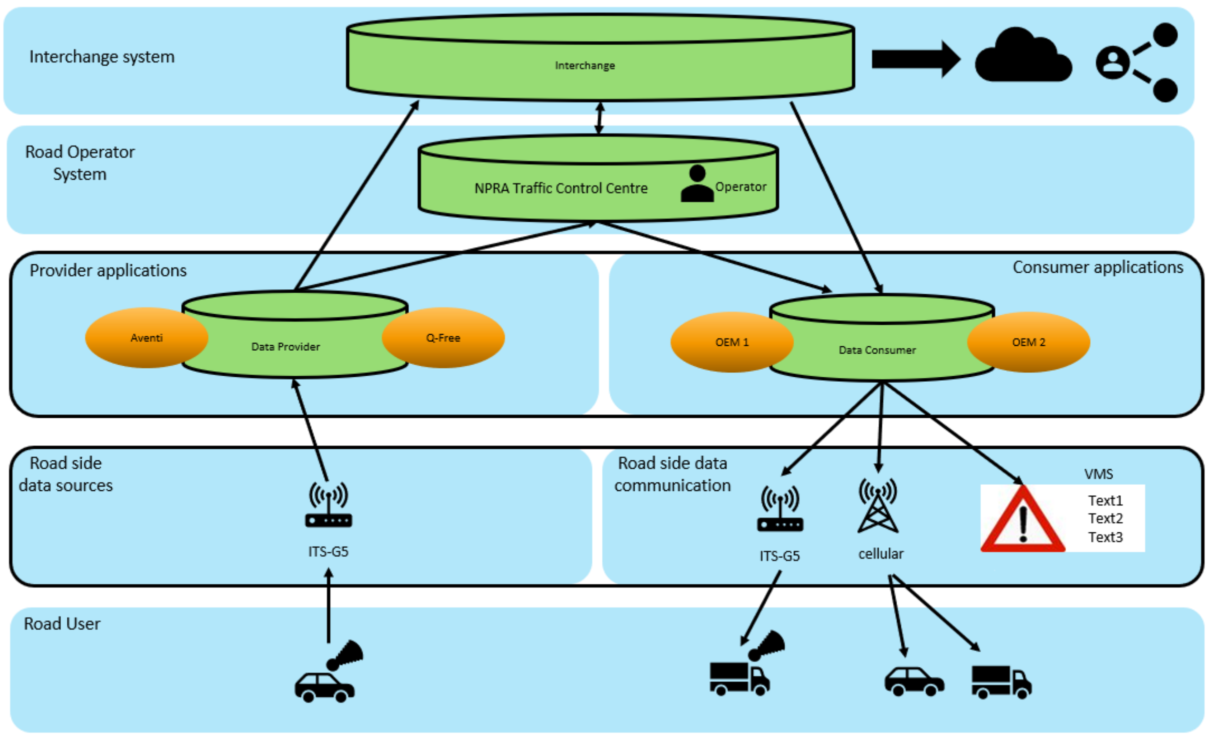


Figure 31 NPRA Pilot data system as implemented for emergency break light

A testing of braking showed that the OBUs correctly identified hard braking, see Figure 32. The left part of the figure shows CAM messages, while the right part of the figure shows the emergency braking messages. Because the CAM messages are sent out at a fixed frequency, it is also possible to see that the vehicle slows down in the left part of the figure as the green dots are close together where the speed is low.

Figure 32 CAM and DENM messages (E18 Ski).

This shows that an OBU that only has GNSS input can identify areas of hard braking and can issue emergency braking DENM messages. These messages can then be passed on to the road authorities.

During testing at Patterød it was discovered that emergency braking messages where triggered when the vehicle was moving in a normal traffic flow (with normal braking and acceleration). In addition, tests were performed when the vehicle was traveling at a constant speed. The plotting of the data clearly shows that the issue is linked to an overhead blockage (Figure 33) as the vehicle drives under two bridges and temporarily lost satellite reception.

Figure 33 False DENM messages produced.

This also demonstrates that the OBU is heavily dependent on GNSS availability. Without GNSS availability the system will have reduced value. Thus, there is a need for a combination of inertial navigation and GNSS to produce consistent and robust messages. Systems that provide too many false positives often cause loss in trust. As a result, there is a need for a focus on the external data sources the OBU uses, and what quality these have, to ensure a robust operation with minimal false positives.

4.2.4.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use Case Description	
Summary	Drivers receive information about nearby vehicles with emergency brake lights switched-on.
C-Roads Use Cases	No use case is defined.
Actors and relations	The main actors are: • Road Operations System, Content Provisioning System (receives and distributes warning) • Interchange System, Application Backend System (distributes warning); • Vehicle (reports that emergency brake lights are switched-on, receives warning and displays it to the driver).
Logic of transmission	Two-way communication (V2I, I2V)
Triggers	Emergency brake lights of vehicles are turned on.
Constraints/dependencies	Constraints and dependencies include: • Information/warnings are available to all road users for which they are relevant (i.e. road users approaching the hazards). The information/warnings should be issued repeatedly as long as the hazards exist. • Information/warnings are valid and up to date (i.e. they should relate to vehicles with emergency brake lights turned on). • Information/warnings are timely (i.e. it should allow drivers to undertake timely adaptation of driving behaviour). • Information/warnings are cancelled if the hazards cease to exist.

Table 10 Service description of emergency brake lights

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Emergency brake warning	SituationPublication	v2.3 (Level A)	None

Table 11 DATEX II message representation.

Use Case	Deployment	Message Type	Standard
Emergency Brake Lights	Norway	DENM	ETSI EN 302 637-3 [ETSI-BS2]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]

Table 12 ETSI standard message representation.

4.2.5 Cooperative collision warning / Alert wrong way driving

4.2.5.1 Introduction

The “cooperative collision warning/alert wrong way driving” pilot has explored how ITS G5 data can be used to detect wrong way driving and generate information on drivers entering the motorway in the wrong direction.

4.2.5.2 Description of the pilot

Vehicle driving the wrong way on a motorway ramp or motorway is critical situation. There have been a number of wrong way crashes accidents of this type, several with lethal consequences. One ramp in in particular on the Patterød intersection worries the local authorities. There are two challenges in stopping this type of accidents. The first is detection of the wrong way vehicle and the second is resolving the situation. Both issues were part of this pilot. The main focus was on detection, but the setup of the Patterød intersection also includes the possibility to send out messages over ITS G5 using the standard DENM message (CauseCode=14 and SubCauseCode=2).

Figure 34 shows both the ramp that has issues with wrong way driving and the ramp used for testing.

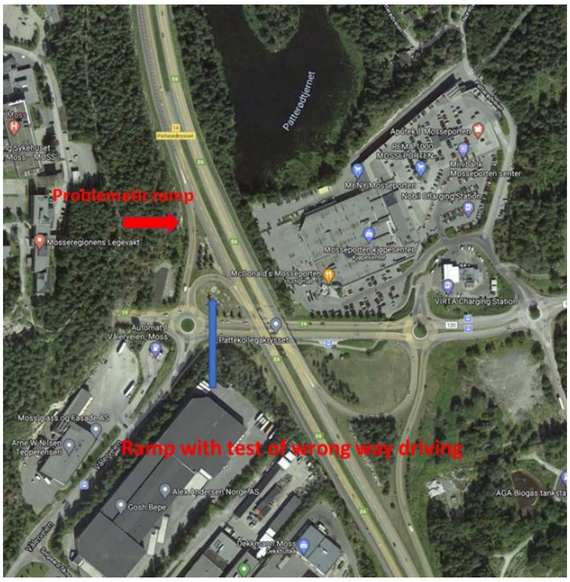


Figure 34 Ramp for piloting wrong way driving detection.

The hardware setup is exactly like in pilot 4.1.1 used for vehicle speed limits. The difference is the type of algorithm and the message sent out via the roadside units. The key here is the processing of CAM messages on the roadside unit. A detection zone is drawn in a web tool that shows a map covering the area. The direction of flow is set, so if a unit passes in wrong direction a warning will be triggered. If traffic passes in the normal direction, then no message will be generated, and the cam messages are not stored or communicated to a back-end system. This is a key part of the concept, with data minimization supported by local processing. The zones drawn in the web interface are downloaded to the RSUs and all processing is also done in the RSU. The only information passed upwards in the chain is the event of a wrong way driver. The RSU could also operate in autonomous mode, where the DENM messages is sent immediately when a wrong way incident is detected. This is a desirable feature because the system will not depend on a backend. But until there are enough vehicles with ITS G5 on the road then it is not possible to have stringent enough tests of his system. Hence, we foresee operating the system in cooperative mode, where it will transmit the event to the interchange. The NPRA will then subscribe to all wrong way driving events and receive them when they are issued. The NPRA system will then decide whether or not to instruct the RSU to send out a DENM message. The event will also be available for all other subscribers on the interchange – for example OEMs. Having events on the interchange is useful for the TMC who can reduce the speed on the motorway.

As it is not possible to test wrong way driving in a safe manner, so a physical simulation was conducted in Oslo. The driving direction was reversed in the digital world, but not in the real world. Hence an ITS G5 equipped vehicle should trigger the wrong way event. A video from the test is published on youtube: https://www.youtube.com/watch?v=d6SWVVsGGo4&feature=youtu.be (1.feb 2020)

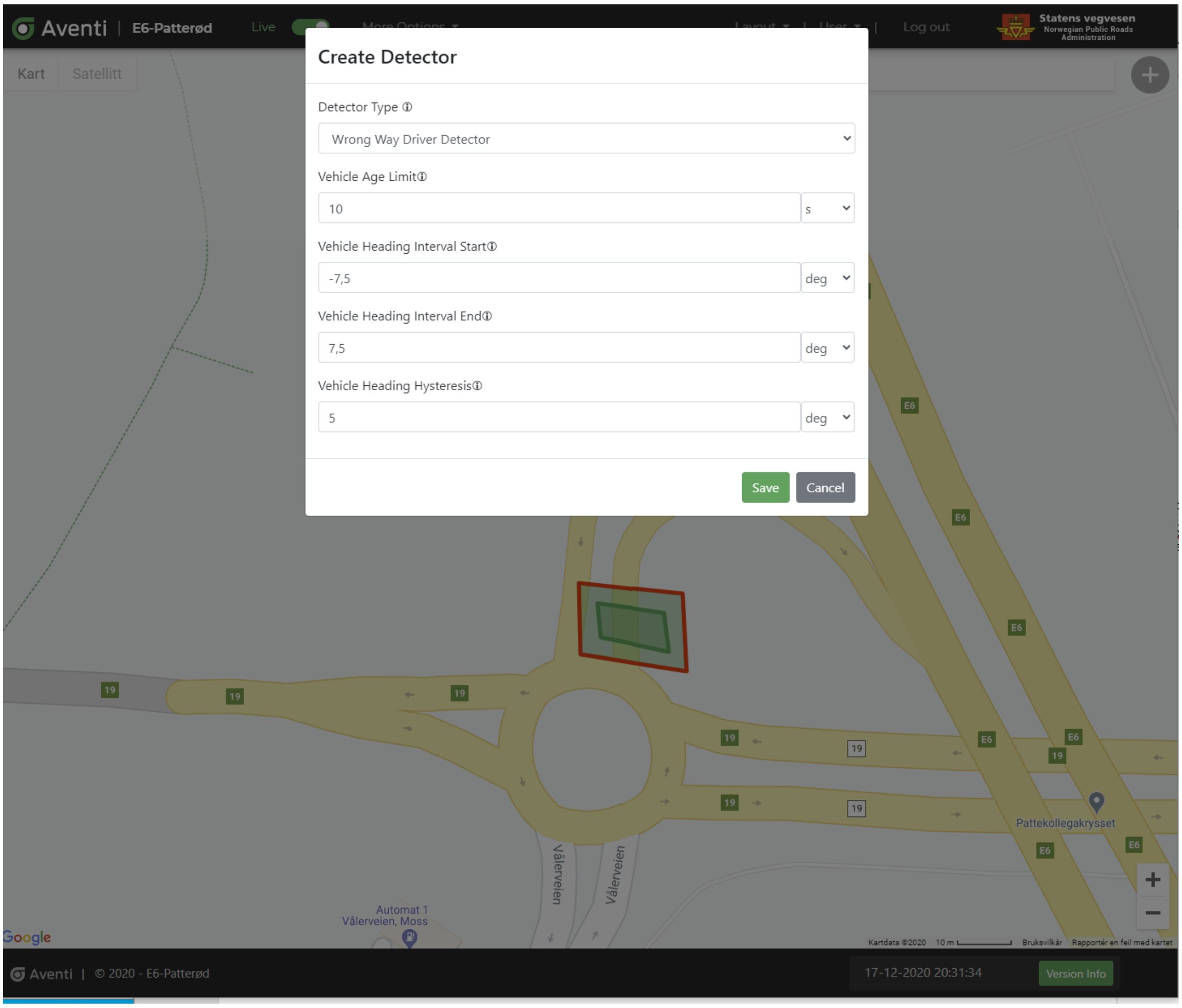


Figure 35 Wrong way driver detector drawn for an RSU

4.2.5.3 Technical setup

RSUs have been set up to dump received CAM and DENM messages to a backend system operated by Aventi. From there the messages were downloaded to the NPRA for analysis. No security was used in the pilot, but in future projects there is a need to deploy a security model. The OBUs were placed in the vehicles and connected to the standard 12V power plug. The ecosystem shown below shows the envisioned system, that also includes sending of DENM messages warning other drivers.

A core part of the system is the backend that supports the RSUs. The backend system has two-way communication with the RSUs, CAM and DENM messages are received and sent. In addition, the backend sends, and updates zones used by the algorithm to detect wrong way drivers.

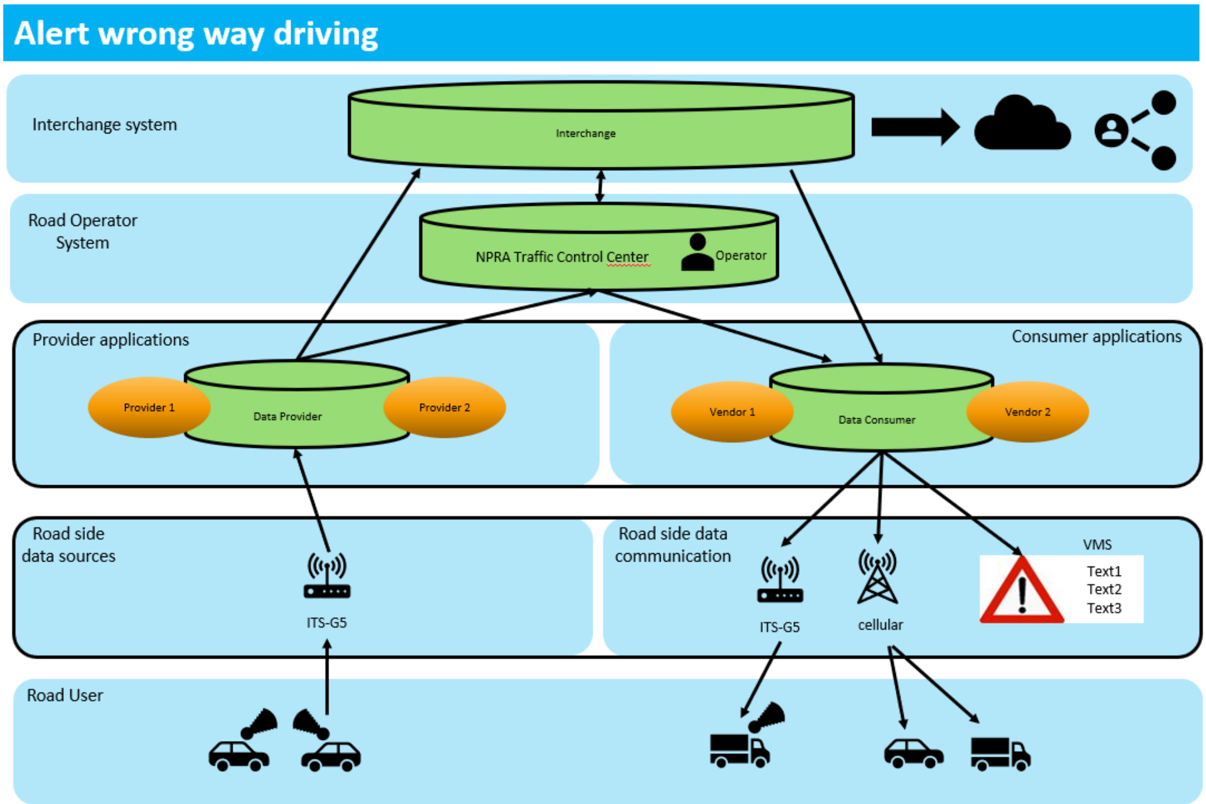


Figure 36 NPRA Pilot data system as implemented for alert wrong way driving.

4.2.5.4 Use case/messages

Use Case Description	
Summary	This use case is to warn a driver that he could encounter a vehicle that is driving in the wrong way. It is not the primary aim of this use case to alert the wrong-way driver that he is on the wrong way. Valid for roads with separate carriageways (non-urban) including entrance and exit segments. This use case could be added in the future to the warning sequence if detection quality and confirmed status of information is improved.
C-Roads Use Cases	HLN - Alert Wrong Way Driving (HLN-AWWD) [TF2-SD].

Actors and relations	The main actors are:
	• Road Operations System: the operator of the TCC/TMC detects a wrong-way-driving incident and issues a warning message. Incidents are detected using various types of detection sources, e.g.
	  • Road-side Systems (automated wrong-way detectors, cameras);
	  • Personal devices of field operators, police, drivers, etc. (phone, mobile apps, radio)
	  • Other connected vehicles.
	• Interchange System, Application Backend Systems: distributes message to the involved vehicles and to the involved road operators (and the public). May distribute information from vehicles for use by the involved road operators (and to the public).
	• Vehicle: receives message and displays it to the driver, may provide further information related to the incident.

Logic of transmission	I2V, I2I
Triggers	There are two main display possibilities: • A moderately intrusive alert to encourage the driver to adapt his behaviour (change lane to right as precaution) without risk of an overreaction. • An intrusive alert to encourage the driver to adapt his behaviour in case of urgency.
Constraints/dependencies	Constraints and dependencies include: • Warnings are available to road users for which they are relevant (i.e. road users approaching the hazards). • Warnings are valid (i.e. the hazards are ongoing). • Warnings are timely (i.e. they should allow road user to undertake timely adaptation of driving behaviour). • Warnings are cancelled if the hazards cease to exist or be updated if the characteristics of the hazards change.

Table 13 Service description of cooperative collision warning/Alert wrong way driving.

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	VehicleObstruction	SituationPublication	v2.3 (Level A)	None

Table 14 DATEX II message representation.

Use Case	Deployment	Message Type	Standard
Cooperative Collision Warning/Alert Wrong Way Driving	Norway	DENM	ETSI EN 302 637-3 [ETSI-BS2]
		CAM	ETSI EN 302 637-2 [ETSI-BS3]

Table 15 ETSI standard message representation.

4.3 Road works warning

4.3.1 Road and lane closure

4.3.1.1 Introduction

On the E8 between Skibotn and Kilpisjärvi at Gardeborgbakken there is a road section with a challenging uphill. If some vehicles (normal heavy vehicles) stop on the uphill, it will be valuable to inform other vehicles about the situation. This will ensure that the situation will not get worse and also provide information that is useful if drive need to decide whether to continue to drive or wait until the road is fully operational again.

This pilot is included in the pilot Slow and Stationary vehicles, se chapter 4.2.2

4.3.1.2 Description of the pilot

See chapter 4.2.2.2

4.3.1.3 Technical setup

See chapter 4.2.2.3

4.3.1.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use Case Description	
Summary	Drivers receive information about nearby road and lane closures. The information may include advice on adaptive behaviour such as alternative routes.
C-Roads Use Cases	RWW - Road Closure (RWW-RC), RWW - Lane Closure (and other restrictions) (RW-LC) [TF2-SD].
Actors and relations	The main actors are: • Road Operations System, Content Provisioning System • (distributes information); • Interchange System, Application Backend System (distributes information); • Vehicle, Personal Device (may report road and lane closure, receives information and displays it to the driver).
Logic of transmission	One-way communication (I2V) and two-way communication (V2I, I2V)
Triggers	Road and lane closures are planned, started, stopped or terminated.
Constraints/dependencies	Constraints and dependencies include: • Information about road and lane closures is available to road users for which it is relevant (i.e. road users approaching ongoing road and lane closures, road users planning trips which may be affected by planned or ongoing road and lane closures). • Information is valid and up to date (i.e. the reported road and lane closure characteristics (time, location, state, etc.) are correct). • Information is timely (i.e. it should allow road users to undertake timely adaptation of driving behaviour). • Information is cancelled if the road and lane closures are terminated) or be updated if the characteristics of the road and lane closures change.

Table 16 Description of road and lane closure.

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Road and lane closure	SituationPublication	v2.3 (Level A)	None

Table 17 DATEX II message representation.

4.3.2 Mobile road works

4.3.2.1 Introduction

The “mobile road work” service demonstrates how information about vehicles ahead can passed as warning be downstream. Mobile road works are typically maintenance vehicles doing work, either ploughing, sanding or trimming vegetation. These services are conducted at a maximum speed of 30 kilometers per hour in Norway.

4.3.2.2 Description of the pilot

Mobile road works are mostly related to operational activities with slow moving or short-term stopping of maintenance vehicles. Convoy driving on mountain passes in wintertime can also be regarded as mobile road works but are more controllable.

Maintenance vehicles operate at low speeds and this can lead to queues of vehicles forming behind the maintenance vehicle, often resulting in dangerous overtaking’s maneuvers performed by impatient drivers. This situation occurs both in summer and in winter.

In the winter season there are sometimes a need for convoy driving on mountains passes. To help the front vehicle to control the vehicles in the convoy, a solution has been developed to inform the front vehicle leading the convoy about the situation (the position) of the following vehicles.

The use cases for the NordicWay 2 Pilot on mobile road works have been chosen to demonstrate two use cases:

1. Communication between maintenance vehicles and the vehicles queueing behind them
2. Investigate the possibility for notifying the queueing vehicles in a convoy about the other follower's position and support safe convoy transport.

The pilot on mobile road works was originally planned to be carried out on E8 in Skibotn Valley, but due to the Corona pandemic it was necessary to change the location for use case number 1 to keep the time schedule.

<u>Use case: Maintenance vehicles and the vehicles queueing behind them</u>

It was found appropriate to use the road around Jonsvatnet on the outskirt of Trondheim as test area for the use case on communication between maintenance vehicles and the vehicles queueing behind them (Figure 37).

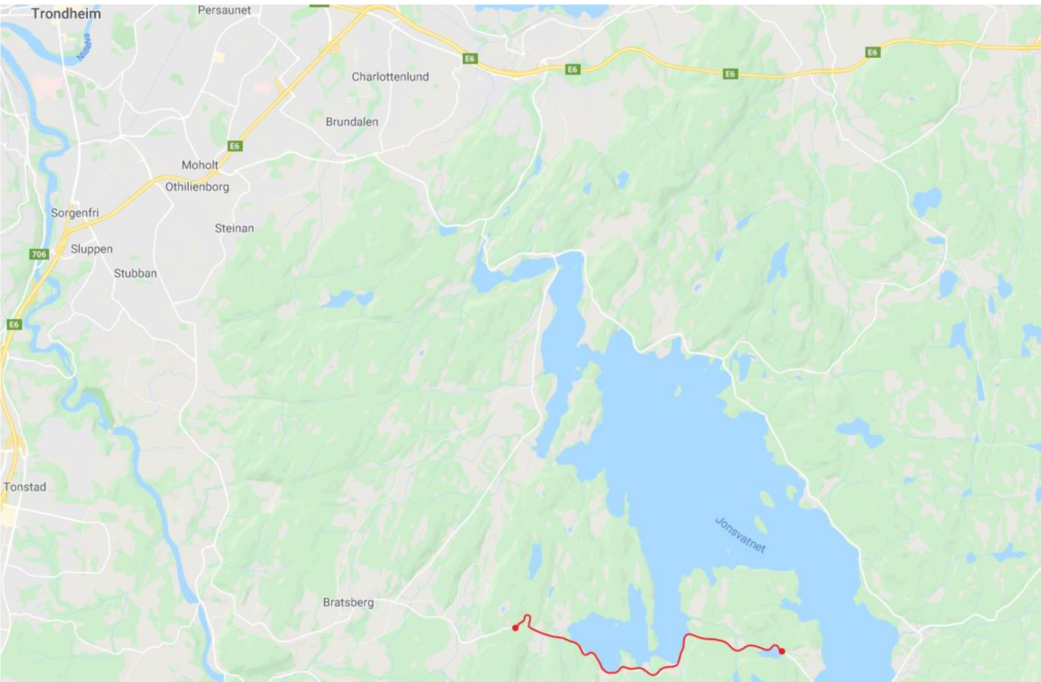


Figure 37 Test area used for the use case maintenance vehicles and the vehicles queueing behind them.

The road around Jonsvatnet is a municipal road with low traffic volume and variable cellular network connectivity.

<u>Use case: How to secure a safe convoy transport</u>

On some roads in Norway during periods with harsh winter weather, it is necessary to drive in convoys. These are roads where it can be dangerous to drive alone due to very challenging weather and driving conditions. Convoy driving is performed by a convoy leader driving first, a limited number of participants who want to cross the stretch following in a convoy, with an accompanying car at the end that can communicate with the leader car. Multiple problems can occur in a convoy and this can lead to evacuation of the convoy. This may be due to poor visibility, people driving off the road or getting stuck, or that some of the participants do not have a vehicle that is properly equipped to handle the weather conditions on the roadway.

The convoy execution app will help to make convoy execution clearer so that any problems that occur can be detected early or averted. The goal is to lead a safer convoy driving and more efficient implementation of convoys. This is completed by making a digital twin of the convoy, by collect data from all the cars in the convoy and using it to display a visualization of the condition of the convoy. In addition to this, the app can be used to send messages from the leader car as well as from the participants so that they can report problems.

The testing of the convoy execution app was performed on the research section along the E8 in addition to parts of the E6. The stretch that was used for testing can be seen in Figure 38.

Figure 38 Test area used for the use case how to secure a safe convoy transport.

4.3.2.3 Technical setup

<u>Use case: Maintenance vehicles and the vehicles queueing behind them</u>

To test the mobile road works, a car A with a warning light on the roof and technology to send out information about speed, location and other parameters was used. The driver in car B had a smartphone where he could receive the message sent from the warning light on car A.

In this demonstration, car A was placed on the side of the road to act as a mobile road work vehicle and car B was placed on the road 500 meters behind car A to act as the approaching vehicle. On a given signal, car A switched on the warning light, and car B started driving towards the location where car A was standing. After turning on the warning light, a signal was sent from car A via the cellular network to the cell phone in car B. This message was displayed as a road warning sign on the map on the driver's smartphone in car B. This road warning sign was at the exact location where car A was standing. Car B could then approach car A in a safe speed because the driver knew where car A was located. See the process in Figure 39.

The technical implementation used a GPS and a narrow band IoT modem to communicate the warning light status with the backend system. The physical device was integrated into an existing warning light, so the function of the system required no additional interaction from the operator of the car beyond switching on the light.

Figure 39 Warning light switched on (left), position of mobile road work displayed on map (middle) and safe approach to mobile road work (right).

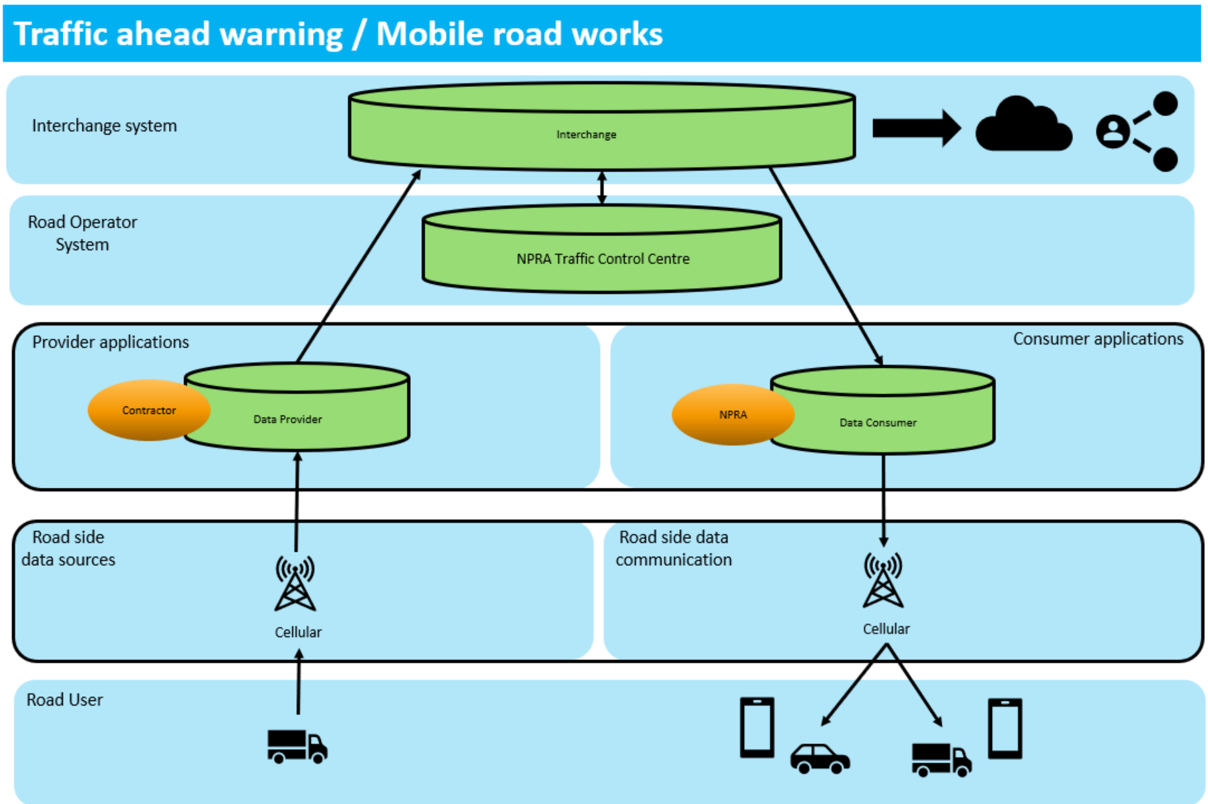


Figure 40 NPRA Pilot data system as implemented for mobile road works.

Use case: How to secure a safe convoy transport

Figure 41 shows the architecture for the application on convoy transport.

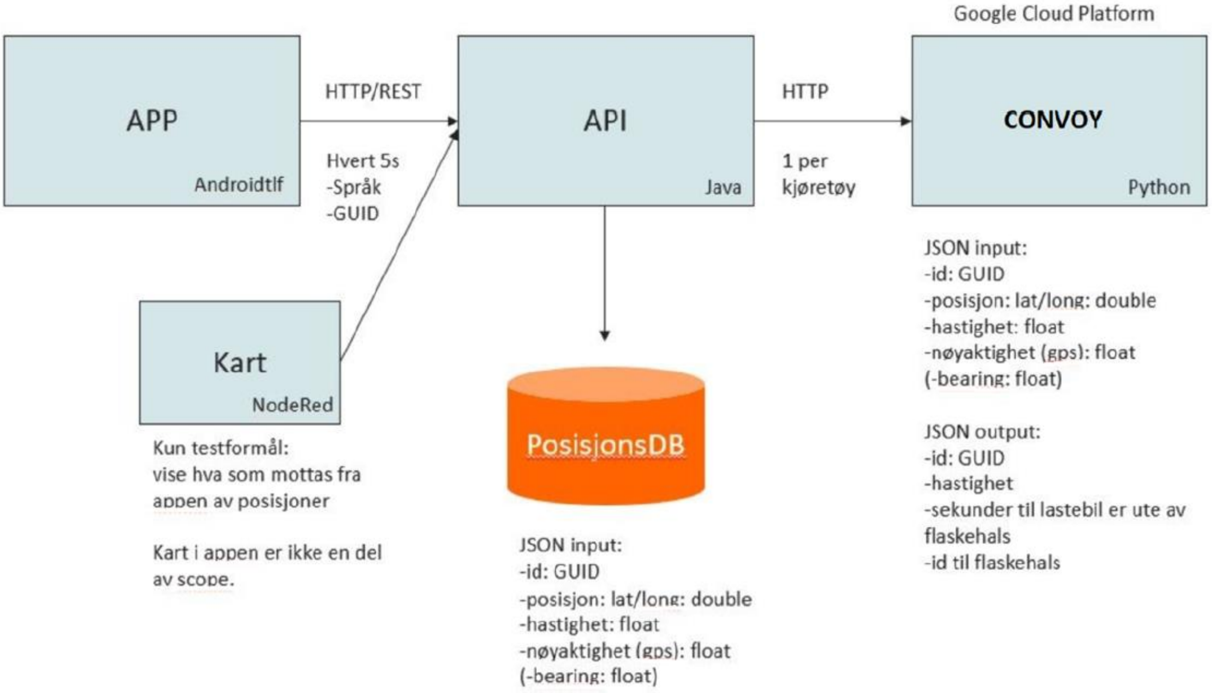


Figure 41 Architecture for the use case on convoy transport.

The convoy application system is divided into several components.

1. CONVOY
Developed in Python 3 with a Flask REST API and uWSGI application server. The application deployed to Google Kubernetes Engine with Nginx http server and Redis to share car state between labor processes. It keeps track of convoy condition and helps positioning using road data.

2. API (Java API)
An API that receives data from CONVOY and forwards it to clients and vice versa. It is written in Java and uses Spring and stores data in Google Cloud SQL database.

3. Android app
Android is used as a platform to create the app (client).
The app has two modes, leader mode and participant mode. There can be only one convoy leader typically the plough truck and there can be many participant cars.

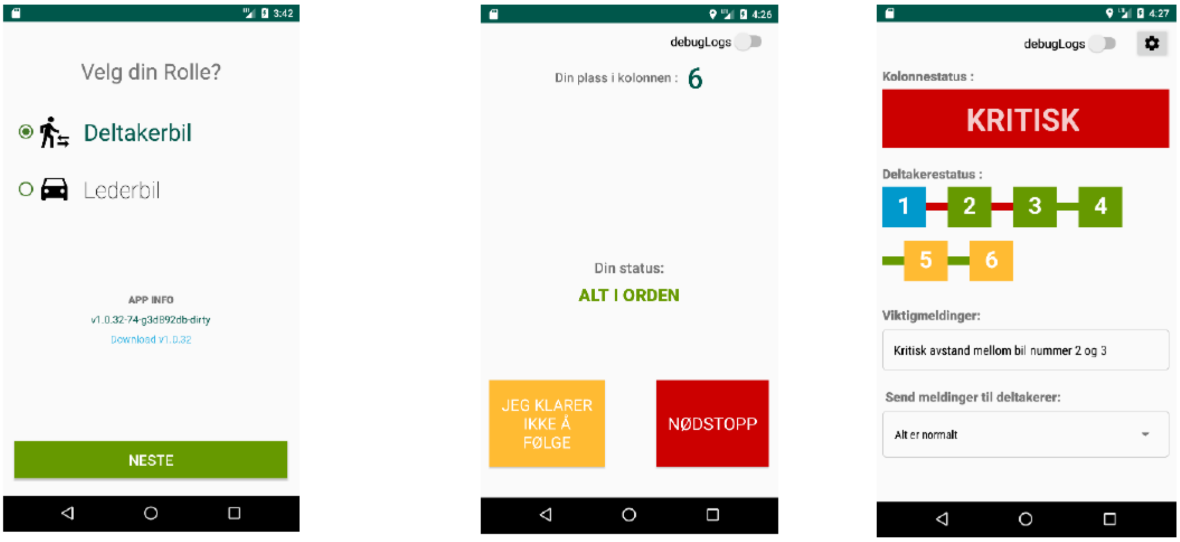


Figure 42 Convoy app, Startup page (left), participant mode (middle) and Convoy leader mode (right).

In participant mode, the participant's number which is their order in the convoy and current status are displayed. Messages can be sent to the convoy leader by pressing buttons (warning or emergency stop). If there is any message from the manager, it is clearly displayed on the participant's screen.

In leader mode, the current status on the convoy is displayed, the status of distances between each of the vehicles and the status of each participant / vehicle in the convoy. Using the information, a manager can efficiently implement convoy driving. There are also options for messages that a manager can send to all participants as needed. Important messages such as the general status of the convoy are displayed on the screen, and the messages are read aloud so that the driver is not disturbed and can concentrate on driving.

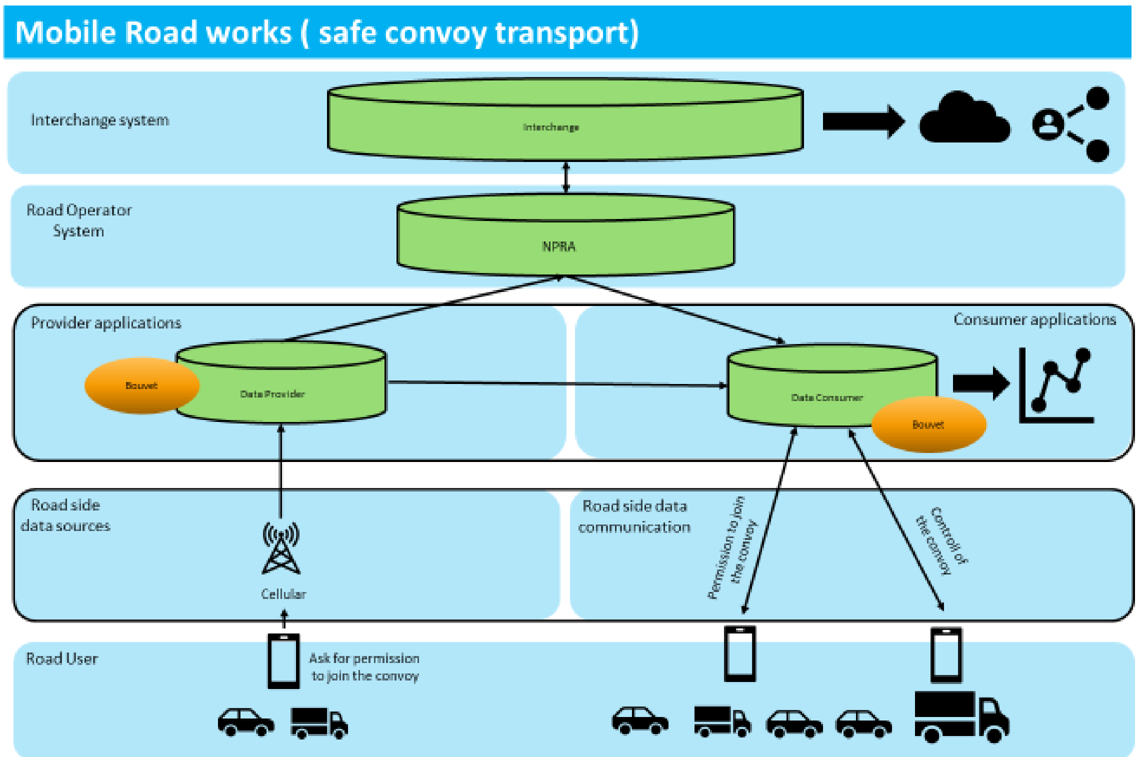


Figure 43 NPRA Pilot data system as implemented for use case how to secure a safe convoy transport.

4.3.2.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use Case Description	
Summary	Drivers receive information about nearby mobile road works such as slow-moving maintenance vehicles.
C-Roads Use Cases	RWW - Road Works – Mobile (RWW-RM), RWW - Winter Maintenance (RWW-WM) [TF2-SD].
Actors and relations	The main actors are: • Designated Vehicle (reports its location) • Road Operations System, Content Provisioning System (distributes information); • Interchange System, Application Backend System (distributes information); • Vehicle, Personal Device (receives information and displays it to the driver).
Logic of transmission	Two-way communication (V2I, I2V)
Triggers	Mobile road works are planned, started, stopped or terminated.
Constraints/dependencies	Constraints and dependencies include: • Mobile road works information is available to road users for which they are relevant (i.e. road users approaching ongoing mobile road works, road users planning trips which may be affected by the roadworks). • Information is valid and up to date (i.e. the road works is ongoing, the reported characteristics (time location, speed, direction, etc) are correct). • Information is timely (i.e. it should allow road users to undertake timely adaptation of driving behaviour). • Information is cancelled if the road works are terminated) or be updated if the characteristics of the road works change.

Table 18 Description of Mobile road works.

Deployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Mobile road works	SituationPublication	v2.3 (Level A)	None

Table 19 DATEX II message representation.

4.4 Signalized intersection

4.4.1 Signal violation/ Green light optimal speed advisory

4.4.1.1 Introduction

The “takting” project presented in this report is a proof-of-concept for conducting virtual traffic signaling in rural areas via an app. The takting server is supposed to give speed advice to drivers of heavy vehicles driving about hot spots and bottle necks where it is difficult to pass on rural road. The speed advice is given to minimize meeting situations between heavy vehicles.

4.4.1.2 Description of the pilot

Signalized intersections are uncommon on the rural road network in Norway. However, the service is still interesting with regards to facilitating safe and efficient passing of narrow road sections, such as 1-lane bridges or narrow and steep tunnels.

The road infrastructure in Norway has "bottlenecks" in various locations, some in areas with high volumes of traffic that lead to queues and delays for those traveling by car. In low-traffic areas, there are other challenges. An example is tunnels with an unfavorable profile where it is very difficult or impossible for two large vehicles to pass each other. Roads where this happens typically have low traffic, around 250 - 1000 vehicles a day. By adjusting the speed before a problem area (such as a tunnel or a single-lane bridge) it is possible to avoid having vehicles meet.

This project was limited to a section of FV866 from E6 on mainland Troms and out to the island of Skjervøy, where there are two problematic sections. The current stretch is about 34km and has two bottlenecks;

The Skattørsundet bridge (0.8 km long). This is a one-lane bridge over Skattørsund between Kågen and Skjervøy

The Maursund tunnel (2.1 km long). This is a tunnel under the sea that connect Kågen to the mainland below Maursund. The tunnel is categorized as having poor fire safety, a narrow profile and 10% incline. Two trucks cannot meet in the tunnel so when a meeting situation occurs one of the trucks has to back out of the tunnel.

On this roadway there are approximately 60 trucks a day in both directions.

Figure 44 Scenario for GLOSA.

By utilizing “Virtual Traffic Lights”, drivers can receive in-vehicle messages to avoid meeting situations at bottle necks. In addition the red-light violation warning can warn drivers if an oncoming vehicle has passed a virtual red light. Last, but not least, the green light optimal speed advisory (GLOSA) technology may allow heavy goods vehicles to keep an optimal speed when approaching a virtual traffic light and reduce their number of stops. The back end should allow for several different strategies for giving priority.

The goal with this pilot was to develop a concept and system that prevents meeting situations for heavy trucks.

During the project period, Bouvet has developed a system that can prevent meeting situations on the defined roadway sections where lorries cannot meet (bottlenecks), by giving speed advice to the drivers of the lorries that operate in the area. We have analyzed the problem and developed a micro-simulation model of the traffic situation, visualization tools and a speed adjustment system (FAM) including the App and server infrastructure.

FAM contains the algorithm that gets an overview of vehicles in the "roofing area" and which provides speed advice to the vehicles, so that they can drive through bottlenecks without encountering oncoming vehicles. FAM provides its driving advice via an App, which reports the vehicle's position and speed regularly via GPS information. Based on this information, FAM tries to predict which cars may end up in meeting situations, and then gives speed advice to one of the vehicles to prevent this.

The takting project is a proof-of-concept for virtual traffic signaling via an app in rural areas. The takting server is to give speed advice to drivers of heavy vehicles driving on a rural road with hot spots where it is difficult to pass. The speed advice is given to minimize meeting situations between heavy vehicles.

The Swarco Utopia server component are used in Trondheim to give buses priority at intersection with traffic lights. The algorithm chooses a signal phase that gives the lowest cost of traffic when different vehicle types are given different cost.

The idea here is to use the Utopia server to calculate the speed advice given to the driver in the takting project. The hot spots will be modeled in Utopia as a traffic light intersection, but no physical traffic lights will need to be set up on the road.

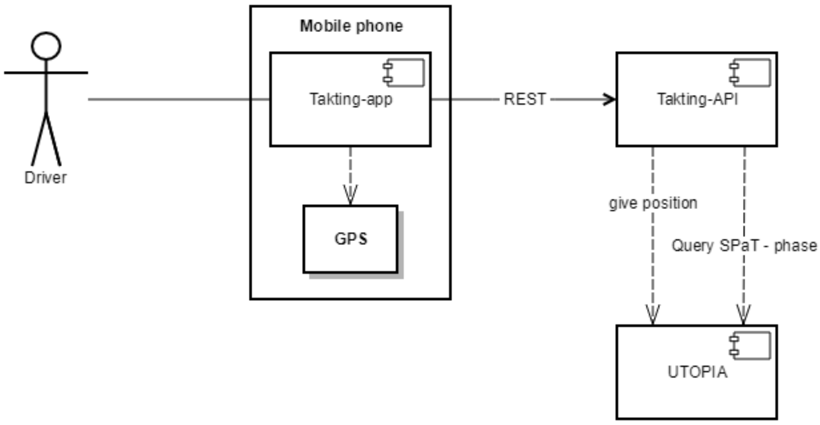


Figure 45 Architecture for Takting application.

4.4.1.3 Technical setup

The solution consists of an Android App, a REST API and a Speed Adjustment Engine (FAM). The back-end systems are put into production in a cluster on Google Kubernetes Engine (GKE) with an environments for staging and production, which gives us the opportunity to prepare and test the entire value chain in a separate environment before changes are lifted into production. Jenkins X has been chosen for construction and production due to good integration with Git and Kubernetes, as well as good tool support for developers.

The app is developed with Kotlin and consists of a user interface and a background service. The user interface consists of a button to turn the pacing on and off, and offers driving advice in the form of colour, text and sound. The background service sends GPS data to the rear systems on a regular basis and updates the user interface based on driving advice from FAM.

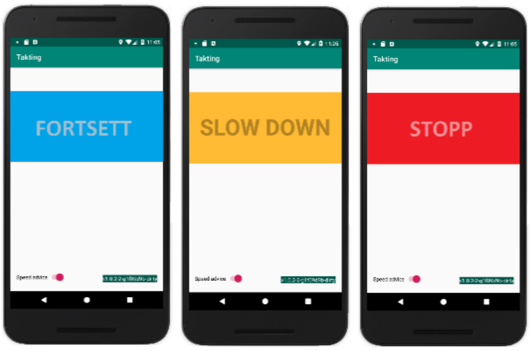


Figure 46 Interface for Takting application.

There is a mechanism in the App to offer the user a download of any new version via a website in the cluster. Since this mechanism was only tested internally in the development team, we decided to avoid rolling out new updates before the test on FV866. We recommend that a production-ready solution updates the App using Google Play, as it will be easier for the user.

The API is a Java application that receives GPS data from the App, stores it in a database and sends GPS data to FAM for the preparation of driving advice. The application receives and delivers data in JSON format, and has the logic to handle any noise in the interactions between the app and FAM.

During the test on Skjervøy, it was discovered there was a need to filter out GPS data with poor precision around the tunnel openings, as these created a lot of noise for FAM. This filtering will be implemented in the app, but to minimize risk and fix the problem quickly on the test day, this issues were solved in the API. The change was tested in a staging environment and lifted into production before the tunnel tests started and did not create problems for the testing.

In a future solution with several tempo ranges, it will be logical that the API also uses geohashing to distribute requests from the app to site-specific instances of FAM and rejects GPS data from outside the tempo ranges.

FAM is a Python application that has been described in detail earlier in the report. In the cluster, this is set up with an application server that can be scaled up horizontally and divides the state of the tempo area between process instances by means of a key-value store.

The roof area is configured externally, but some key parameters are defined in the application, and must be changed in code if necessary. After the first long-distance tunnel test, we wanted to increase the safety margin around the bottleneck, as the outcome of GPS data in the Kågentunnelen created problems for FAM. This led to us having to make code changes in FAM and launch a new version into the production environment.

In a future solution with several beat areas, we will be able to put into production several instances of FAM with different configurations. We will then refine the current FAM application as a common module used by area-specific applications, with configuration for tempo area with bottlenecks and orchestration in the cluster. This model will also make it possible to implement area-specific logic when needed.

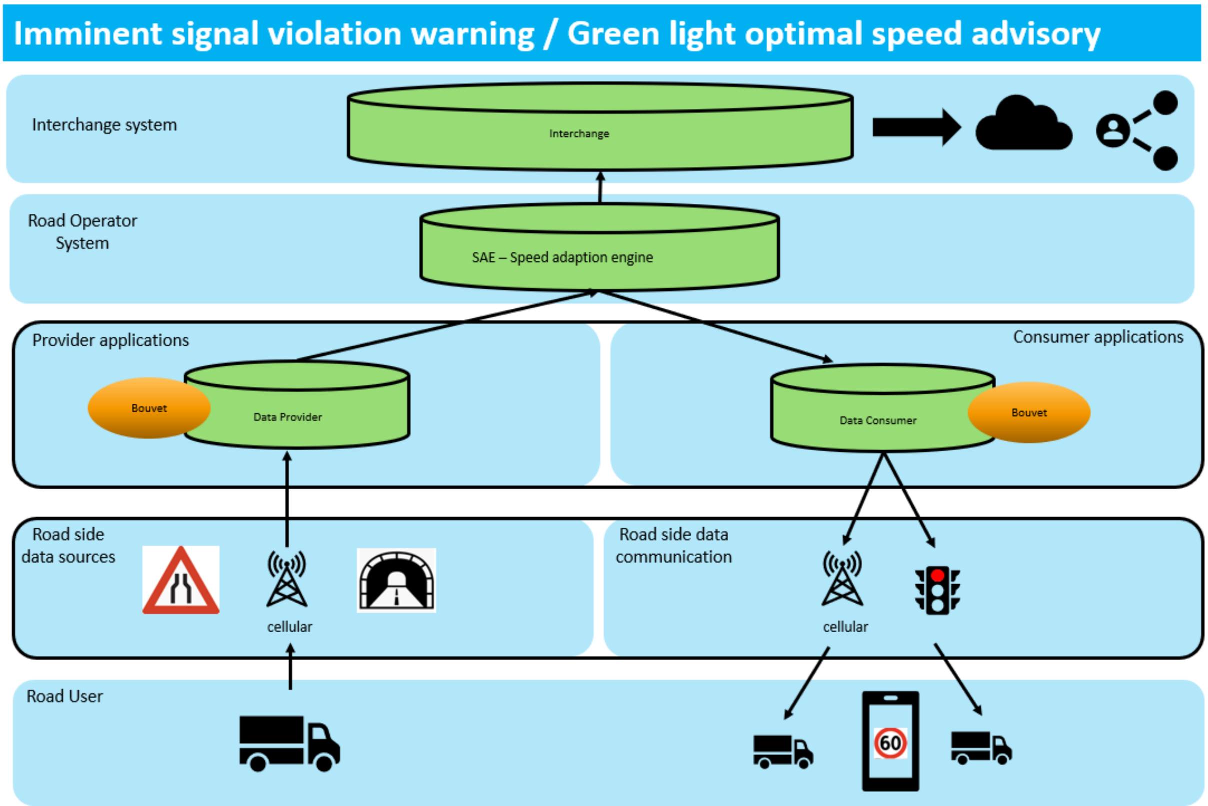


Figure 47 NPRA Pilot data system for imminent signal violation warning / green light optimal speed advisory.

The system has been tested using simulation, local walking tests, local driving tests, as well as a full-day test performed by NPRA on the Skjervøy section using four cars.

Sixteen tests were performed on the Skjervøy section: 9 on the Maursund tunnel, 7 on Skattørsundet. In summary, 29 of 31 meeting situations were averted on both the Maursund tunnel and the Skattør-sundet. The two unsuccessful meeting situations were on a long-distance test and in the Maursund tunnel. The reason was difficulties in following the speed advice (for example, no possibility of making an emergency stop), GPS drops in both tunnels, and too little margin around the bottleneck. During long-distance test number 2, the margins were expanded, and this solved many of the problems, but there was also a meeting situation there. It was reported as possible to avert, but ignored due to traffic behind, and that the other car was visible on its way out of the tunnel.

In summary, the feedback from the NPRA drivers was positive, and the system was perceived as working. This also shows data collected from the tests. GPS signal and telephone coverage are good on the test section, except where the two tunnels were close to each other (so the GPS signal is disturbed and eventually disappears). The drivers usually managed to follow the speed advice that was given, and no meeting situations arose without any kind of emergency stop or signal.

4.4.1.4 Use case/messages

The description below is from the NordicWay 2 report on services and use cases (NordicWay 2, 2020).

Use case Introduction	
Summary	Drivers receive warnings about potential signal violations at nearby signalized intersections. Drivers are warned when they are in danger of violating a red light, or when it is possible that another vehicle is going to make a red-light violation.
C-Roads Use Cases	SI - Imminent Signal Violation Warning (SI-ISVW) [TF2-SD].
Actors and relations	The main actors are: • Road-Side System (distributes information about the current phase state and predicted timing of the traffic lights); • Application Backend System (distributes information and warnings, may generate red light warnings warnings); • Interchange System (distributes information and warnings); • Vehicle (detects possible signal violations and generates warnings, receives information and warnings, displays warnings to the driver).
Logic of transmission	Two-way communication (V2I, I2V)
Triggers	A signal violation is detected, i.e. a vehicle passing or about to pass a red light.
Constraints/dependencies	Constraints and dependencies include: • Facilities are available for detecting possible signal violations based on phase and timing information from the signalized intersection. • The information from the signalized intersection shall be sufficiently accurate and reliable to ensure high-quality red-light violation warnings. • Warnings are timely (i.e. they should allow drivers to adapt their behaviour to avoid signal violations). This requires a sufficiently low latency system implementation. • The signal state as indicated by the physical signal heads always take precedence over the information provided in the vehicle.

Table 20 Description of Signal violation.

The communication channel was cellular and integration to the interchange was not included, so no Datex or ETSI messages were generated in this pilot.

4.5 Probe vehicle data

4.5.1 Single vehicle data

4.5.1.1 Introduction

The “Single vehicle data” service show how the NPRA can receive data from an OEM about the status of the road. One of the more challenging tasks for a road operator is to know the state of the road network in relation to parameters that change quickly with estimates of road friction being one such a case. The service collects friction events from all modern Volvo vehicles produced after week 47 in 2017. This should indicate that many more than 1000 vehicles deliver data. That there are more than 68 million observations in a year with coverage in every city in Norway is proofs of this. The exact number of vehicles reporting data at any time is not available as this number is protected by the privacy laws.

4.5.1.2 Description of the pilot

The service is to provide vehicle-generated data about how vehicles experience current road conditions. The road condition is used in a broad sense, the data type that the road operators are interested in is what friction can a normal vehicle achieve on the roads. Road friction is used by the road operators as a measure to see if road maintenance has been adequate. But a friction estimate is challenging as it is a combination of the vehicle tires and the state of the road surface. The measurements are also dependent on driver behavior and road layout. The core of the friction estimation is the Kamm-circle which show the forces exerted by the vehicle on the road surface in longitudinal and lateral directions. If no force is exerted, then it is not possible to use Kamm-circle to get estimates of road friction. Hence one should expect more data on roads with turns that make the driver accelerate and decelerate.

In this pilot a parallel interchange to the operational interchange was set up. The main purpose for this was the need for a private data channel. At the beginning of NordicWay 2 this was not part of the interchange specification. The messages passed through the parallel system were encoded as Datex messages.

Due to privacy regulation, it is hard to estimate the total number of cars participating. But vehicles manufactured after week 47 in 2018 had a specific system that would contribute with data. And in one year more than 68 million events where detected. According to official sales statistics for Norway a total of 5279[1] vehicles that had the system were sold in 2019. This was just for two specific models, in addition there are other models, but they were not on the top 15 selling list. Thus, we can assume more than 5000 vehicles have the system and are able to report data. Looking at the data received we found that both big cities with100 000+ inhabitants and smaller cities down to 10 000 inhabitants have registered events. A separate work analyzing the data and understanding the data's value and limitations has been undertaken and reported in the Gothenburg PMB.

4.5.1.3 Technical setup

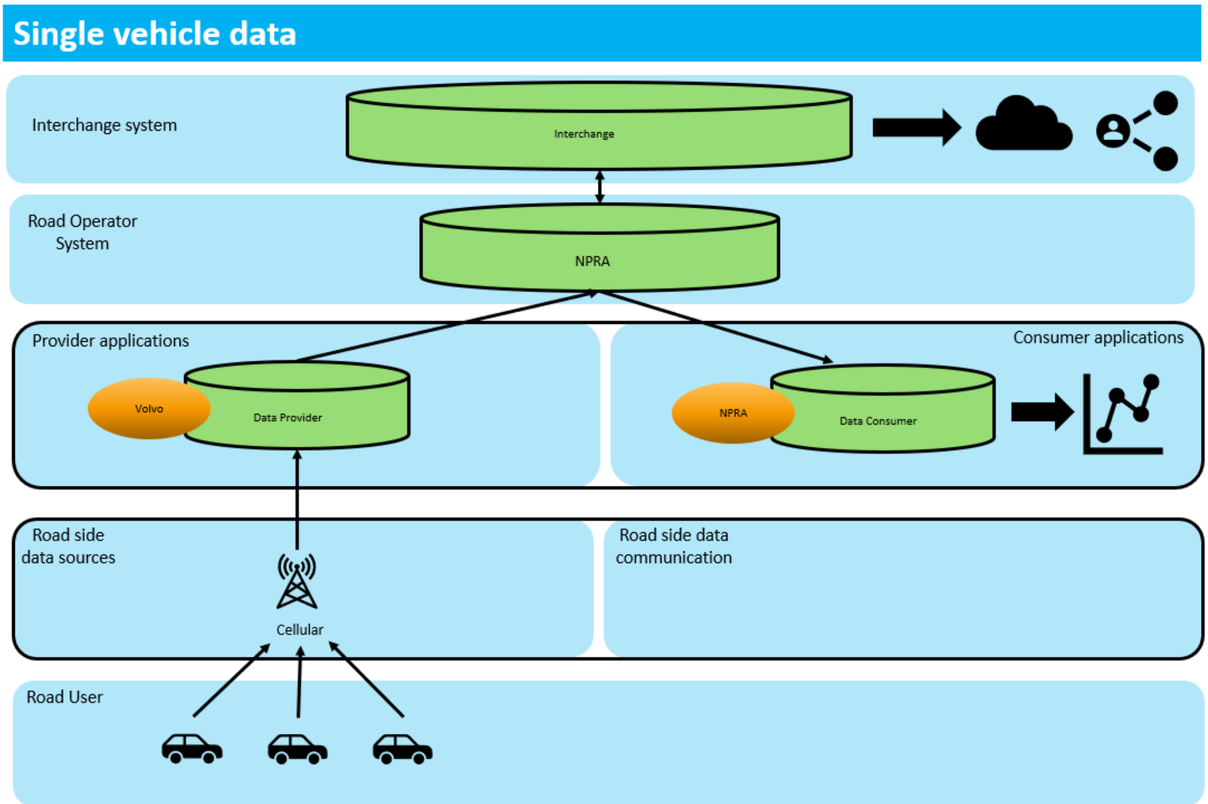


Figure 48 NPRA Pilot data system for Single vehicle data.

[1] https://e24.no/privatoekonomi/i/wPpLe1/bilsalget-falt-med-38-prosent-i-2019-tesla-model-3-ble-toppselgeren

The system uses an OEM developed slipperiness alert system. The existing sensors in the vehicle are combined to produce an estimate of how slippery the road is. Data is produced for both high and low friction. These events are then transmitted back to the OEM where it is processed and anonymized. Then the events, including a quality parameter, are sent to a parallel interchange setup and received by the NPRA. On the NPRA side the events are stored in a PostgreSQL database where they can be accessed for analysis. In addition to storage of the data a live dashboard has been up and running which shows friction events in the Trondheim area.

4.5.1.4 Use case/messages

Service definition

Use case Introduction	
Summary	Collects data from individual vehicles.
C-Roads Use Cases	PVD - Vehicle Data Collection (PVD-VDC), PVD - Event Data Collection (PVD-EDC) [TF2-SD].
Actors and relations	The main actors include: • Vehicle (collects and distributes data); • Application Backend System, Interchange System (distributes data); • Road Operations System, Content Provisioning System (receives data).
Logic of transmission	One-way communication (V2I).
Triggers	Data collection requires the consent of the driver/owner of the vehicle.
Constraints/dependencies	Constraints and dependencies include: • Data collection, processing and distribution must be compliant with GDPR and local legislation (e.g. concerning data retention time). • Actors must agree on sharing data (Selling vehicle data can be part of a business model, vehicle data may be sensitive business info for service providers, since it can give insight into number of clients, etc.).

Table 21 Service description of Single vehicle data.

Scenario for use case: Single Vehicle Data (PVD-EDC) (
A vehicle (V1) reports the occurrence of an event (slippery road condition) to its application backend system (V) which publishes a report to the interchange system. The report is received by a road operations system (DK) and a content provisioning system (C) subscribing to messages on hazards.

Table 22 Scenario for Single vehicle data.

4.6 Traffic management

4.6.1 Traffic information and smart routing

Smart routing is dependent on having three central pieces of information available. The first is a road network that is topologically correct. The second is having traffic information available and the third is information on the vehicle. In the NordicWay 2 project we explored how the national road routing service could be extended to include Finland. The routing service already includes the Swedish network since the original developer of the routing service was a Swedish company. But within the NordicWay project the NPRA explored how Finish data could be acquired and included in the routing service. There has been considerable research in this area including, PReVENT/MAPS&ADAS (2004/2007), SpeedAlert (2004/2005) and ROSATTE project (Road Safety Attributes Exchange Infrastructure in Europe; 2008-2010). This meant that the NPRA had access to data already exchanged by our Finnish colleagues. This data was then implemented in the routings service.

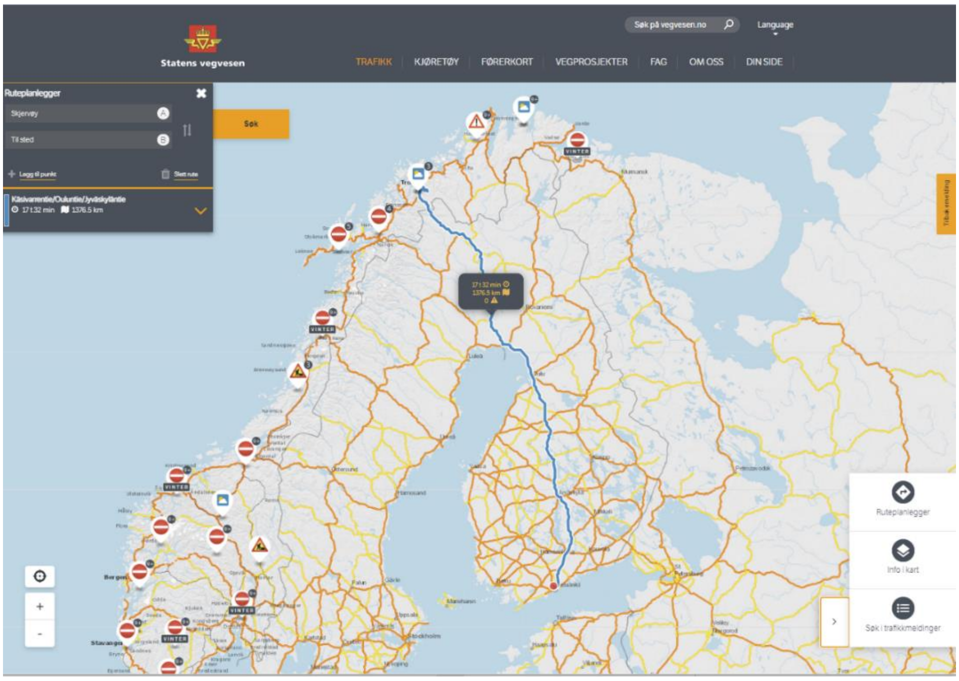


Figure 49 Smart routing service, route from Skjervøy to Helsinki.

Figure 49 shows the main freight route from Skjervøy (using the E8 to cross the Norwegian Finnish border). The map also shows how Datex messages are included on the Norwegian side and used for the routing. At present no Datex messages are used in Sweden or Finland. The reason for this is that access to Datex messages and filtering of them are quite cumbersome. When the NordicWay interchange becomes operational, then the interchange could serve as the supplier of messages for all the Nordic countries without extra effort. The last part of a smart routing application is routing based on the vehicle. In the case of Norway not all routes are good choices for heavy trucks. Thus, effort was put into the route calculations so that it is possible to choose routes that are truck friendly. Height restrictions and road width, vehicle length and vehicle weight are not put into the routing engine. In practice this means that routes with steep hills and sharp turns are not selected as good routes for heavy duty trucks. It is quite an improvement over other routing services on the market, such as Google. Access to the route planning service is free of charge and available through an API: https://www.vegvesen.no/ws/no/vegvesen/ruteplan/routingservice_v2_0/open/routingservice. While the routing service is free to use, registration is needed to ensure that the NPRA has the capacity to provide a good service and also to support a dialogue with the users.

The work in the NordicWay project has led to the NPRA giving priority to truck routing and that Finland now have been included on a permanent basis. But it should also be noted some of the experiences with from the Nordic Tour where data quality of the Datex messages was commented. More work needs to be put into providing Datex messages with higher quality, otherwise services like the Norwegian rout plan service will suffer.

4.6.2 On street parking information and management.

4.6.2.1 Introduction

This service shall provide road users with up-to-date information about on street and road parking accessibility and availability.

A sensor system records the status (on/off) for a parking lot. The status information is sent to the sensor backend system, and it is distributed to vehicles by a third-party application system via the interchange system and connected vehicle backend systems.

4.6.2.2 Description of the pilot

Sensors from Q-Free, see Figure 50, were mounted on parking spots to reveal how the they are being used, and to collect usage statistics and status for available parking spots. Each parking spot was equipped with a parking sensor placed in a drilled hole. The battery capacity of the sensor is expected to be approximately 10 years. A nearby antenna registered the activity of the sensors.

Figure 50 Sensors from Q-Free.

A webpage and an app were developed to show status information about the parking spots and an expected usage forecast for the next 12 hours (Figure 52).

Users could check the webpage or the app to find an available parking spot, and this would help manage and plan their trips.

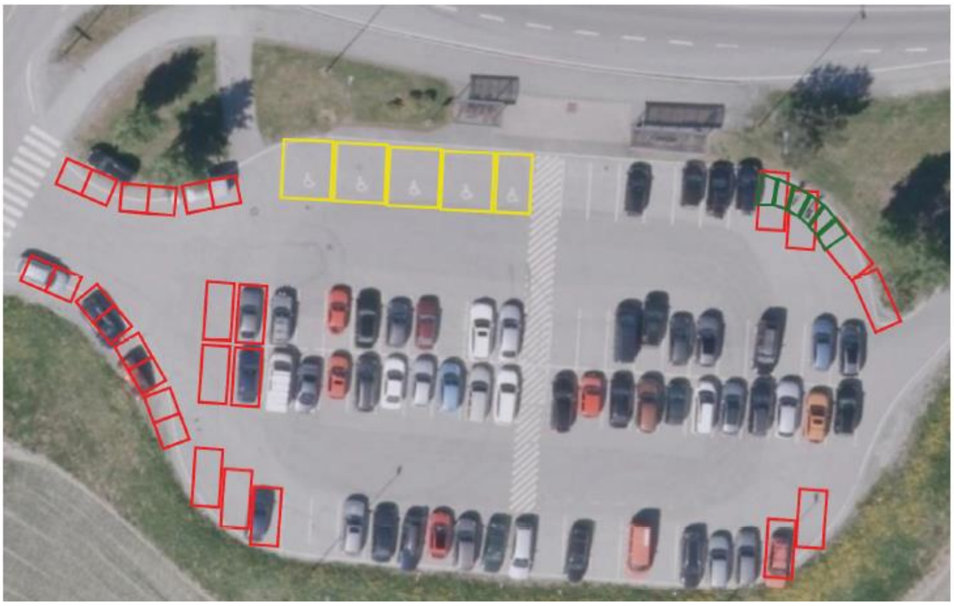


Figure 51 Parking slot situation.

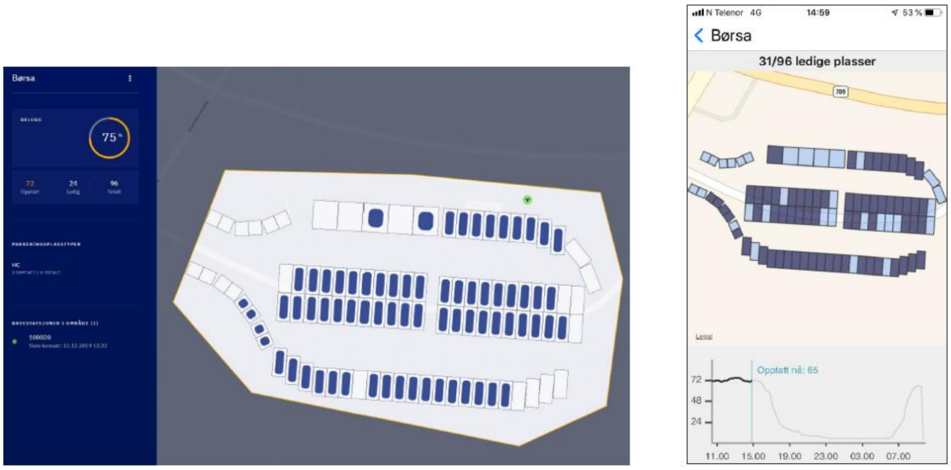


Figure 52 Parking slot situation on web page and mobile app.

4.6.2.3 Technical setup

The parking sensor is a small and robust unit that is easily installed in the ground at each parking space. The sensor uses radar-based technology to sense with 99% accuracy, whether a vehicle is present at space or not. The sensor then transmits the information regarding parking space availability using NB IoT communications, which can be sent on to a variety of outputs, such as Variable Message Signs located near the parking site, or straight to end-users through websites or mobile phone applications.

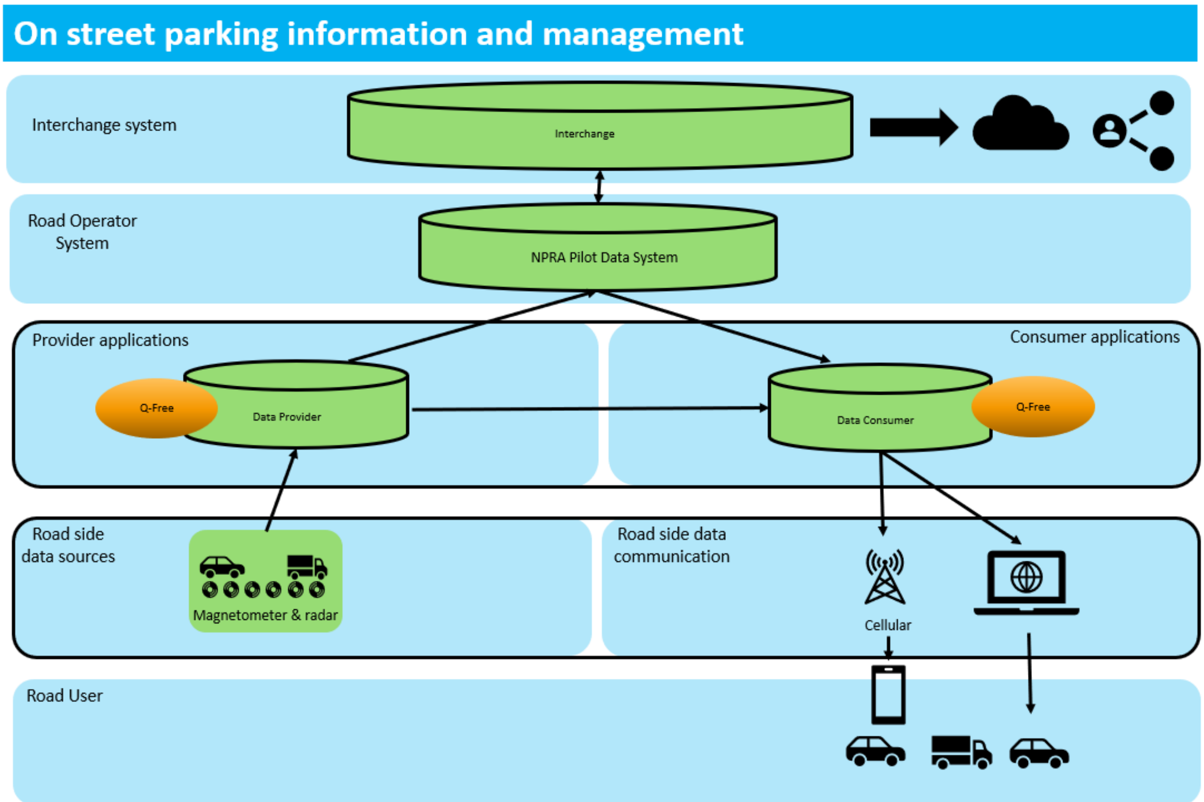


Figure 53 NPRA Pilot data system for on street parking information and management.

During the test, weather conditions such as snow and ice partially hide the markings on the parking lot. Consequentially, several of the parked cars were not registered by the sensors. It was also discovered that two parking spots were displayed as occupied because the sensors were covered in snow. One of the sensors changed its status from occupied to available when the snow was removed from the sensors. Several other parking spots that were covered in snow had the correct status in the app, therefore it is uncertain how much the sensors are affected by snow and ice. The main source of errors in the app seems to be hidden markings on the parking lot. The reliability of the app will depend on the presence of snow or ice on the ground.

Cars parked on top of the markings will also affect the status information in the app. In some cases, one parked car can be displayed as two occupied parking spots because of this. In other cases, only one of the parking spots were displayed as occupied. This is probably due to the sensors' sensitivity, and this can vary between sensors.

Functional (user perspective):

Users that took part in the test at E6 Ranheim were more positive about the pilot project than at E134 Børsa. The reason was mainly because the users at E134 Børsa rarely has trouble finding a parking spot, while the users at E6 Ranheim often found that all the spots are occupied. The usage and capacity of the parking lot is therefore essential for how useful the users find the information in the app. Some people also commented that they were annoyed because of cars that are parked over many days and take up parking spots that daily commuters wanted to use.

4.6.2.4 Use case/messages

Service definition

Use Case Description	
Summary	Provide road users with up to date information about on street and road parking accessibility and availability via communication with vehicles. Additional inputs about the possibility to adapt this use case for urban use could result into a broadening of the use case in the future.
C-Roads Use Cases	IVS - Embedded VMS “Free Text” (IVS-EVFT) [TF2-SD].
Actors and relations	The main actors are: • Road Operations System, Content Provisioning System (provides and distributes parking information); • Interchange System, Application Backend System (distributes parking information); • Vehicle (receives parking information).
Logic of transmission	I2I, I2V
Triggers	Up-to-date information about on street and road parking accessibility and availability is available for communication to vehicles.
Constraints/dependencies	Constraints and dependencies include: • Facilities are available for proper display of parking information. • Parking Information is valid and up to date.

Table 23 Service description of on street parking information and management.

Scenario for use case
A sensor system records the status (on/off) for a parking lot. The status information is sent to the sensor backend system, and it is distributed to vehicles by a third-party application system via the interchange system and connected vehicle backend systems.

Table 24 Scenario for on street parking information and management.

eployment	Message	DATEX II Payload	Version and Level	Profiles and Extensions
Norway	Status and settings of VMS units	VMS Publication	v2.3 (Level A)	None

Table 25 DATEX II message representation.

4.6.3 Information on fueling & charging stations for alternative fuel vehicles

In the northern part of Norway, the distance between settlements is significant. The main road network has good coverage of fuel stations, but availability drops quite quickly when one start to use the regional road networks. At present, a common trait of electric vehicles and vehicles that run on alternative fuels is driving range limitation. Another issue is the time it takes to refuel. Both these issues are assumed to improve in the years to come particularly as electrification of the transport sector increases.

In the meantime, the best option is to provide information on the location of alternative fuels and charging stations. In this project we tried to explore the potential in existing databases and to see what role the NordicWay interchange could play.

According to the Nobil webpage (https://info.nobil.no/eng):

Cooperation between the governmental entity Enova and the Norwegian Electric Vehicle Association resulted in the development of an open, publicly owned database that allows everyone to build services using standardized data free of charge.

The most important part of the Nobil database is that is provides an API for use free of charge. This API gives access to the data in the database.

In the NordicWay 2 project we set up a service in NodeRed to extract data from the database via the API and then explored the data. The setup worked quite well, as we were able to extract data on the location of charger locations and place them on maps. This is mostly static data that and does not change very quickly. The use of the NordicWay Interchange does not make sense in this respect as it is built on queuing technology, that is best suited for dynamic data. But there are some datatypes in the database that change quickly, and that is the real time status of the chargers. As over December 2020 there were 1700 charging point delivering real time status. A total of 16829 publicly charging points are available in the database, so about 10% of the charging points have real time information. The Nobil data base also covers Sweden and Finland.

Bases on the data exploration it was concluded that it is simpler for travellers if the database is included by the OEMs in their infotainment system, rather than NRAs providing this as a service. And for the Norwegian authorities focus on making the data available to the public for free as is the case. The key messages is that the database is free to use to develop applications or services The contents of the license can be found at: https://creativecommons.org/licenses/by/4.0/legalcode

Use Case Description	
Summary	Provides information to road users on accessibility and availability of AFV fuelling and charging stations
Background	The increase in the number of alternative fuel vehicles on the European road network has increased the need for fuelling and charging stations for these vehicles and for informing users of the vehicles about the location and capabilities of these stations. This information allows road users to … The increase in the use of alternative fuel vehicles is supported by authorities for environmental purposes. Increasing the number of fuelling and charging facilities and information about these facilities may encourage transition to and use of alternative fuel vehicles.
Objective	To support the use of alternative fuel vehicles. The purpose is to reduce local emissions (air pollutants and noise) in urban dense areas. This will improve health and lower the risk for heart problems or other vascular diseases.
Expected benefits	Expected benefits include: • facilitating the use of alternative fuel vehicles; • increasing the comfort of users of alternative fuel vehicles.
C-Roads Use Cases	No use case is defined.
Actors and relations	The main actors are: • Road Operations System, Content Provisioning System (provides information); • Interchange System, Application Backend System (distributes information); • Vehicle (receives information and displays it to the user).
Logic of transmission	One-way communication (I2V)
Triggers	Information on AFV fuelling and charging stations is accessible to actors providing information to road users.
Constraints/descriptions	Constraints and dependencies include: • Information is relevant (i.e. it should help drivers in deciding to choose and use the stations). This includes information about the capabilities and service features – including safe and secure parking - offered by the stations as well as distance to the stations). • Information is valid and up to date (i.e. it reflects the current capacity and capabilities of the stations).

Table 26 Description of Information on AFV fuelling and charging stations.

5 Evaluation

This chapter presents a summary of the evaluation for the Norwegian Pilot 1 and its services/use cases.

Evaluation results for all pilots in NordicWay 2 are summed up in NordicWay 2 Evaluation report [5].

5.1 Quality of service

The table below shows which KPI's the NordicWay 2 project should analyze. The evaluation results are presented in detail in report Technical evaluation Input-Norway [6].

IMPACT AREA	RESEARCH QUESTION	INDICATOR/KPI	UNIT	WHERE STUDIED		
				FI	NO	SE
Quality of service	What is the impact (of NordicWay2) on the coverage of the service?	Physical coverage	-	x	x	-
		Number of vehicles equipped with • fully functional C-ITS in-vehicle device • partially functional C-ITS in-vehicle device	Number	x x	x x	-
		Change in number of external data sources per C-ITS service	Number	-	x	-
		Number of C-ITS service vehicles or users	Number	x	-	-
	What is the performance of the service?	Number of C-ITS messages distributed per service and node	Number	x	-	-
		Location accuracy	-	x	-	-
		Latency • end-to-end • between federated interchange nodes	s ms	x x	x -	x x
		Message success rate	%	x	-	-
	Is the continuity of services achieved cross-border?	Cross-border continuity of services	Yes/no	x	x	x
		Cross-organisational/cross-brands data sharing	Yes/no	x	x	-

Table 27 KPI's in technical evaluation.

5.1.1 Method

In Norway, the quality of services was studied by focusing on the overall functionality and documentation of the equipment used and deployed in the pilots.

5.1.1.1 Data logging from the Nodes

<u>Bouvet Interchange node</u>

The test scenarios were:

- Sending 2000 messages as soon as possible, from one client to the Interchange node
- Send 1 message, receive 1 message, 2000 times, from one client to the Interchange node

For the different scenarios the configuration of the Interchange was changed to see if the latency were affected. Memory size and number of validation processes were two important parameters.

<u>Aventi “Interchange” node</u>

The company Aventi did an end-to-end test, but the Interchange node was not included, instead the messages were distributed to the Norwegian Datex node. This setup is interesting because it measures latency in an ITS-G5 short-range communication set up with both on-board unit (OBU) and Road-Side Unit (RSU). Log files were used to track the transfer of each DENM message. An android phone was used just to trigger a DENM message from OBU and there was no logging in the Android. Time 1 is the time difference between the time OBU transmitted the DENM and RSU received the DENM. Time 2 represents the time it takes from RSU to C-ITS-S (C-ITS station/server). Time 3 is the time it takes to transfer and write the DENM to the Datex node, see Figure 58 in 5.1.2.2.

No additional steps were made to synchronize the clocks of OBU, RSU and C-ITS-S while performing the test. All records were logged in an universal timestamp.

5.1.1.2 Controlled field tests

The controlled field tests in Norway were focusing on verifying the main functionalities of the selected services and cross-organizational data sharing. Most of the field tests were Prove of Concept tests (POC).

<u>Bouvet test at Fv866, Skjervøy</u>

The following services were tested

- Signal violation
- Green light optimal speed advisory (virtual lights)

The aim of the field test on Skjervøy was to verify that the system can be used to take cars through bottlenecks on the Fv866 section.

Figure 54 Test area at Skjervøy, Norway.

<u>NPRA tests in Skibotndalen</u>

The following services were tested

- Weather and road conditions (interoperability)

- Slow or stationary vehicle(s) and Traffic ahead warning

The aim of the field tests in Skibotndalen were to verify the quality of the detection systems and to set up the service ecosystem. There were plans for more testing and logging during spring/summer 2020 but those tests had to be cancelled due to the COVID-19 pandemic situation.

<u>NPRA tests at Jonsvatnet, Trondheim</u>

The following services were tested

- Slow or stationary vehicle(s) and Traffic ahead warning
- Road works warning

Figure 55 Typical situation for slow or stationary vehicle.

The aim of the field tests at Jonsvatnet were to verify the POC of the services. The maintenance vehicle was sending messages to Norwegian Interchange node and these messages were distributed to a mobile app to the vehicles approaching the maintenance vehicle.

<u>Nordic Tour</u>

The Nordic Tour was planned together with all of the partners in NordicWay 2.

- 5000 km of real-world roads
- Comprehensive network – large variation in road geometry, traffic volume, topography, urban/rural
- Moderate difference in weather conditions – follow up logging during winter
- Gøteborg – Kilpisjarvi – Gøteborg
- 4 Countries
- 5 border crossings (2 by ferry – 3 road based)
- Always connected to the interchange

The aim of the NordicTour was to collect data on:

- Vehicle perception of infrastructure, focus on state-of-the art ADAS
    - To what extent can the vehicle understand the surroundings?
    - Camera with detection of lane markings and signs along complete route
- Connectivity measurement – RSRP, RSRQ and Ping times
    - On roof
    - In vehicle, worst-case (logging device in front passenger well on the left side)
    - In-vehicle not worst-case (In boot of the vehicle)
- Interference in LTE bands (data from spectrum analyzer)
- GNSS logging – accuracy, signal quality, potential CW-jamming, AGC shifts
- Cross border testing of service functionality, logging of connectivity when border crossing and logging of events available through the interchange when driving in all 4 countries.

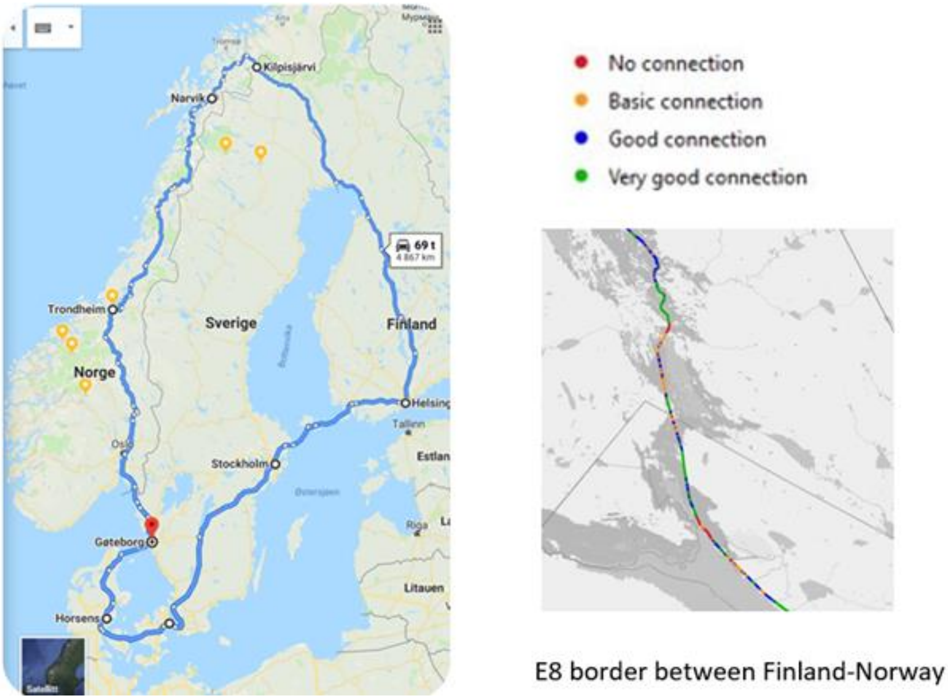


Figure 56 The Nordic Tour route and Cross border communication quality.

More information and evaluation results about the Nordic Tour is available in the report: NordicWay2 – Norwegian pilot 2 – Final report [9].

5.1.2 Results

5.1.2.1 Coverage of service KPIs

<u>Physical coverage - KPI_Q01</u>

The services piloted in Norway were based on hybrid communication, both cellular and short range. For cellular solutions, the physical coverage will be the whole road network and there are also some backoffice services that are accessible by web sides and will be distributed mainly by cellular technology. For short range services the coverage will be on small areas (spots).

As we have some “cellular services” located on special road segments it will not have any relevance all over the country, so it is not a problem that cellular solution cover all country. In Table 28 the coverage for all services and pilots have been estimated.

C-ITS service	**Network coverage**
	Pilot
Immediate collision risk warnings	
Slow or stationary vehicle(s) & traffic ahead warning	Skibotndalen=80km Jonsvatnet=45 km
Signal violation / intersection safety	Skjervøy
Cooperative collision risk warning	Patterød

Increased risk warnings	
Roadworks warning, mobile roads work	Skibotndalen=80km Jonsvatnet=45 km
Weather and road condition warning	Skibotndalen=80km
Improving traffic flow	
Time to green	Skjervøy
Green light optimal speed advisory (GLOSA)	Skjervøy
Traffic information & smart routing	Skjervøy-Grense=140km Tromsø-Grense=150 km County of Troms
Being informed	
On street parking information and management	Ranheim= Spot Børsa= Spot
Information on alternative fuel vehicle fuelling & charging stations	All of Norway
Other	
Collection of data mapping of infrastructure readiness for connected and automated driving	E8-E6=1850km

Table 28 Physical coverage estimations from Norway.

Number of vehicles equipped - KPI_Q02

In Norway we had about 40 OBU (ITS-G5) to collect, send and receive messages. The testing was done at Patterød junction and on a test lab in Oslo, conducted by the company Aventi. The plan was also to test out the ITS-G5 technology installed in next generation Volkswagen Golf, but the technology is at moment not operating in Norway, due to a special implementation by Volkswagen. The G5 technology testing at Patterød includes 40 OBU, 4 permanent RSU and 2 mobile RSU ITS stations from the company Aventi.

Figure 57 Aventi RSU (mobile ITS station).

Number of vehicles equipped with partially functional C-ITS in-vehicle-device - KPI_Q02b

Some vehicle equipment (cellular phones) was used to only collect data, i.e. the test vehicles. The number of the vehicles, which were installed with 'partially functional C-ITS' to collect data during the pilot testing was limited to 3-4 vehicles. In addition, some users had access to a mobile app from OneTraffic that collected messages from Aventi back office system. There were around 10 active users of this application.

Change in number of external data sources per service. - KPI_Q03

Before NordicWay2, a mobile service only used data coming from the Datex node where Vegvær (the Norwegian RWIS) and the traffic data counting system (point measurements) were central data sources. With the NordicWay2 several external data sources have been established. This has been demonstrated at the two main test sites on E8 in the Skibotn Valley and on E6 in the Patterød junction. The new data sources are coupled to the instrumentation established on the test sites and includes:

- Travel time
- In vehicle speed limits
- Speed (slow moving vehicles)
- Stopped vehicles

Quality KPI	KPI	Description	Unit	Results	Comment
KPI_Q01	Physical coverage	Change in length of the network covered by C-ITS services	%	See Table 28	All roads for some services Local roads for some services Spots for some services
KPI_Q02	Number of vehicles equipped	Change in number of vehicles equipped with fully functional C-ITS in-vehicle-device	Number	40 vehicles with OBU	Test vehicles

KPI_Q02b	Number of vehicles equipped with partially functional C-ITS in-vehicle-device	Change in number of vehicles equipped with partially functional (only receiving or sending messages) C-ITS in-vehicle-device	Number	10 vehicles with cellular applications.	Test vehicles
KPI_Q03	Change in number of external data sources per service.	Change in number of external data sources per service (via Federation/Interchange nodes) (comparing the situation before and after the NW2)	Number	There are different types of services with different numbers of external sources. It varies from 1-4	

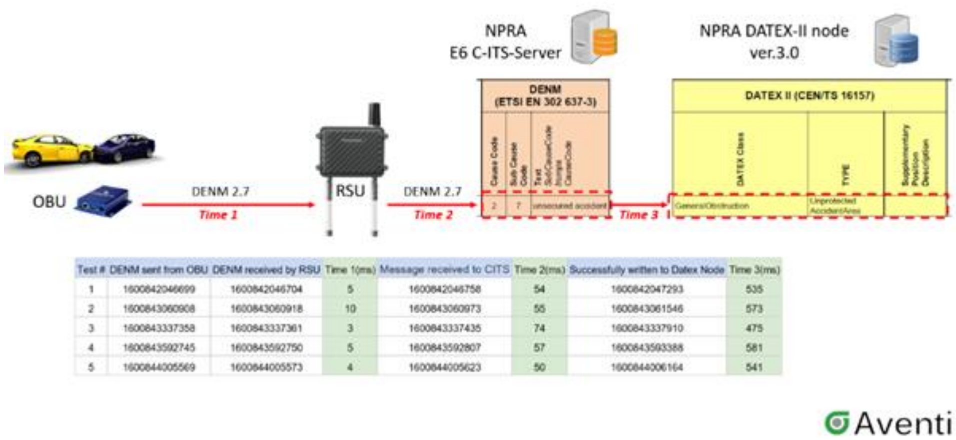
Table 29 Summary of the results of the coverage of service KPI's in Norway.

5.1.2.2 Service performance KPIs

Latency (end-to-end)- KPI_Q08

Aventi "Interchange node": Send 1 message, receive 1 message

Aventi did a limited test manually generating a DENM-message in the OBU and measured the latency between the different nodes, see time1, time2 and time3. However, the clocks of the clocks of OBU, RSU and C-ITS-S were not the synchronized accurately.



Test #	DENM sent from OBU	DENM received by RSU	Time 1(ms)	Message received to CITS	Time 2(ms)	Successfully written to Datex Node	Time 3(ms)
1	1600842046699	1600842046704	5	1600842046758	54	1600842047293	535
2	1600843060908	1600843060918	10	1600843060973	55	1600843061546	573
3	1600843337358	1600843337361	3	1600843337435	74	1600843337910	475
4	1600843592745	1600843592750	5	1600843592807	57	1600843593388	581
5	1600844005569	1600844005573	4	1600844005623	50	1600844006164	541

Figure 58 Aventi set up at test results for latency.

Cross-border continuity of services. - KPI_Q12

To verify continuity of connection when crossing a border, a logging set up was established. Border crossings has some issues since there is typically a loss of reception before re-establishing a connection. But same equipment may behave differently during the handover. For example two similar Samsung S9 phones were used in the test but they behaved quite differently.

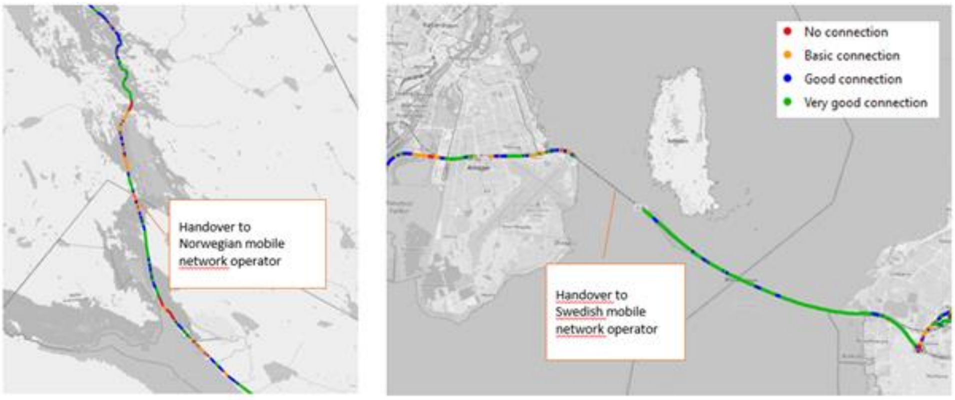


Figure 59 Quality of connection level when border crossing.

Cross border testing of the services also included the interchange node testing. This important test was done to verify that the interchange received events/messages from all countries /service providers and that the service applications were able to consume these messages. Logging of messages and visual observations from a map view of a mobile application verified that the ecosystem was working well in all four countries. When driving along the Nordic Tour route an application on the phone presented continuously messages from the interchange federation nodes (Figure 60). Therefore, it was verified that the cross-border continuity of services worked.

Figure 60 Messages shown on map under Nordic Tour.

From this test, it is quite clear that the interchange and delivery of messages works, but one needs to take great care when filtering the messages. There are also some issues with the roadworks. There was ghost roadworks, which exists in the digital world, but there is no trace of it in the real world. Also, there were missing roadworks, which exists in the real world but do not exist in the digital world. These issues were encountered in all countries, for details see [9].

<u>Cross-organizational/cross-brands data sharing.- KPI_Q13</u>

Figure 61 shows one example of the ecosystem in which different organizations (actors) are involved and represent different brands. The cross-organizational data sharing in the NordicWay 2 Norwegian pilot and the data sharing across Interchange system was confirmed. Messages were distributed and received by all actors and their end-users.

Weather and road conditions

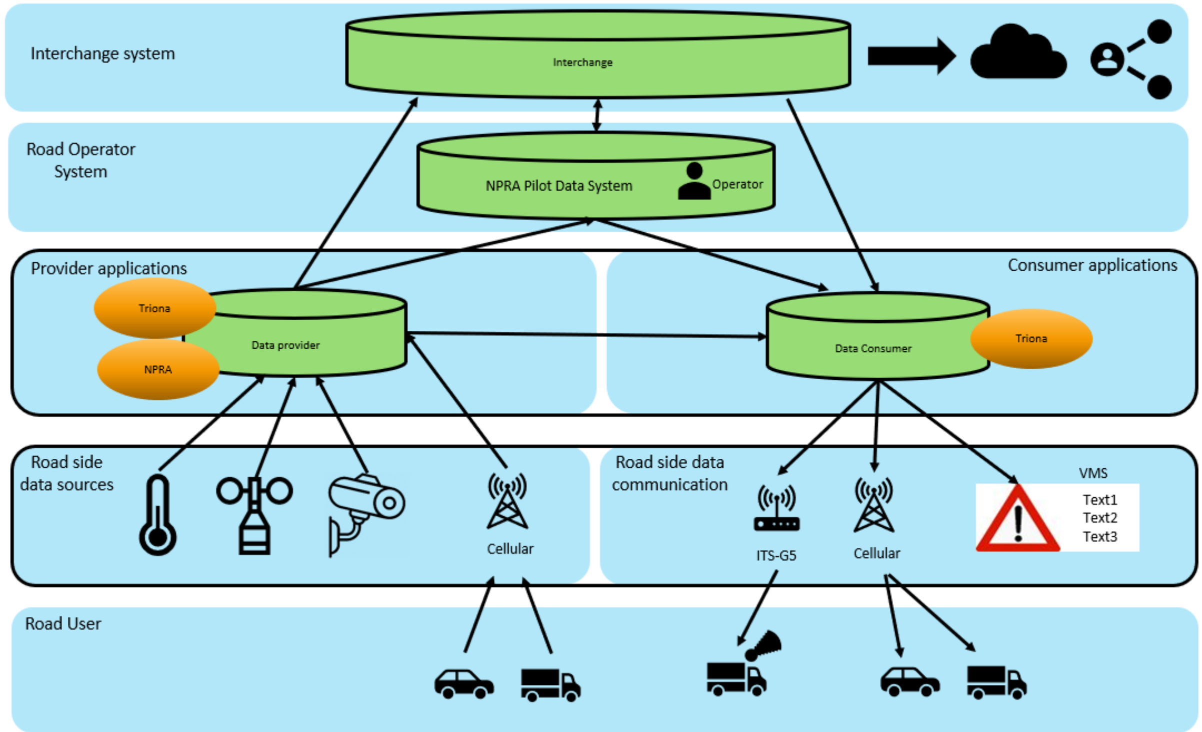


Figure 61 NPRA Pilot Data System for Weather and Road conditions, ecosystem.

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 be-tween	s	**Median** Aventi 0.6 s	N = 5 from OBU to Datex node Clocks were not synchronized
KPI_Q12	Cross-border continuity of services	Cross-border continuity of services	Yes / No	**Yes**	Reported in Nordic Tour re-sults
KPI_Q13	Cross-organiza-tional/ cross-brands data sharing	Data sharing between or-ganization within a coun-try or cross-border	Yes / No	**Yes**	

Table 30 Summary of the results of the Service performance KPI's.

5.1.3 *Other tests results*

<u>Nordic Tour tests</u>

- Main results from the Nordic Tour:
- The Norwegian Public Road Administration (NPRA) needs to look at processes and automation that requires coherence between the digital and physical world. This could be an extra use case for C-ITS with cellular connection.
- GNSS shows that GPS locational services are subject to global forces and this should be considered.
- There are GNSS issues with entering and exiting tunnels. On average this is not bad for a consumer grade GPS, but this is only the internal error estimate. The real absolute error will be a challenge without correction data.
- GPS jammers exists and C-ITS services are susceptible to GNSS interference – there is a need for cooperation with experts in the field.
- Cellular coverage: There are differences related to the equipment used – the cellular network seems to be quite complex and different user equipment seems to be supported differently.
- There also seems to be some priority schemes related to roaming and different types of subscriptions / sim cards. NRA's should be aware of sim card/subscription priorities.
- Border crossing has concerns since there is typically a loss of reception at a border before re-establishing a connection after crossing the border.

<u>Bouvet Interchange node: 2000 messages, sent continuously (as soon as possible)</u>

When messages are sent continuously, the growth of latency as the number of messages increase indicates that there is a bottle neck where messages are piling up (Figure 62).

One possible bottle neck is the interchange app (includes validation). It is possible that the interchange app cannot read messages fast enough. To test this, we tried a different number of interchange apps, from 1 to 20, to see if this would lower the latency. In theory having several interchange apps to read from the queue would mean that one could process a number of messages simultaneously. The results gave no significant results to support the best configuration. Shown in the graph, with a higher number of interchange apps in use there is greater variation in the order the messages arrive in, causing more noise in the graph.

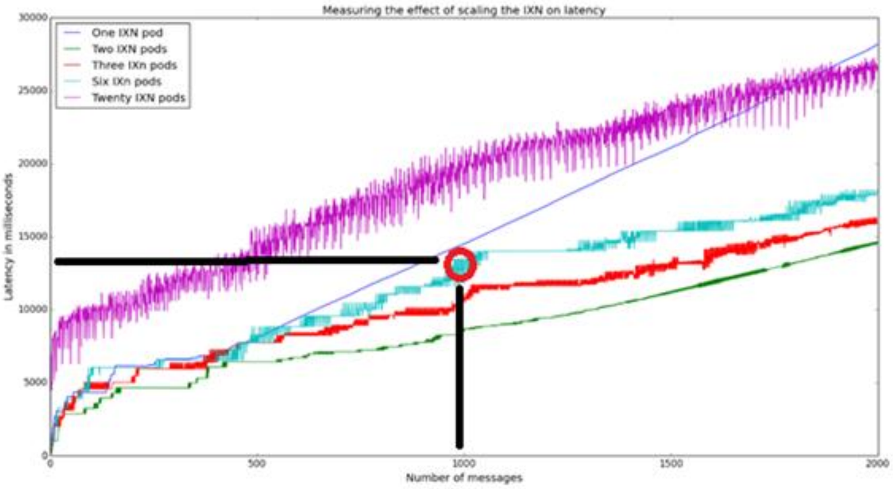


Figure 62 Data logging latency service application-Interchange node, 2000 messages as soon as possible.

The test show processing time when continuously pushing messages into the interchange node. At the red circle in Figure 62, the system processed 1000 messages within 13500 ms. from the starting point. We also see that the processing time (latency) per message is highest in the beginning and this is coherent with the tests with sending one message (60 ms latency).

Bouvet Interchange node: Send 1 message, receive 1 message, 2000 times

In this test, one Datex message was sent after the previous message was received. Running this scenario with one client did not reveal any performance issues, hence the tuning does not give a notable effect. The median latency lies between 59 and 60 milliseconds when running with different tuning options, see Table 31.

Variables	Average of 5 runs
1 app	min: 50 ms max: 806 ms avg: 61.0794 ms median: 59.0 ms message loss: 0
3 app	min: 50 ms max: 814 ms avg: 65.2151 ms median: 60.0 ms message loss: 0

Table 31 Data logging latency service application-Interchange node, 1 message 2000 times.

5.2 Service ecosystem

This chapter focuses on providing insight into the ecosystem perspective including the business modelling experiences from pre-deployment and deployment activities in the field of Cooperative ITS.

The chapter discusses ecosystems and the related company motivation aspects (pains, gains and commitments), organizational and operational aspect and scalability.

The evaluation results are presented in detail in report Eco-system evaluation Input-Norway [7].

5.2.1 Method

Practical implementation of the ecosystem evaluation included workshops that invited C-ITS service providers to define, based on their own ecosystem, the ideal ecosystem that they saw as the most sensible and feasible to provide such services. This included the definition of roles (including the roles of public authorities) and the necessary agreements between the ecosystem partners (who pays to whom - without going into actual monetary prices). C-ITS service providers were also invited to assess and express their views on the business potential of the various services as well as on the key deployment issues that have risen or are foreseen in the service build-up and in the short- and medium-term future.

As a summary, the ecosystem evaluation work aimed at investigating the following:

In Service Ecosystem

- Partners
- Roles (data collection, data enrichment, quality control, service delivery, etc.) including the public sector
- Value network (including data sharing)

Feasibility and viability of the ecosystem

- Business potential (short to medium term potential)
- Business case validation (how partners accept it and see its utilization)
- Challenges within the value network
- Deployment Issues

The following actors were included in the Norwegian evaluation:

- NPRA
- Aventi
- Q-Free
- ITS perception
- OneTraffic
- Triona
- Bouvet

5.2.2 Results

5.2.2.1 Pain, Gains and commitment

This part is about Role and individual company input, pain, gain and commitment.

Pain = the “sacrifice”, i.e. input, changes in ways of thinking, changes in processes, investment, etc.

Gain = expected business outcome of being involved in this pilot.

*Commitmen*t = main reasons for joining

Here are some key comments from the partners.

<u>Pains</u>

Regulations

- Many actors and take time.
- Continuous developments/adaptions, waiting for standardizations.
- Further development and supported by new requirements.
- The ITS field is undergoing rapid development and we see challenges related to the standards to be used and that different solutions choose different variants / implementations of these standards.

Infrastructure

- Need of infrastructure not clear and Road operators’ obligations not clear.
- Basic infrastructure needed.

Competence/ R&D

- Need of new competence.
- It is not possible to hire people with C-ITS knowledge in Norway.
- The area of expertise requires employees to keep up to date with developments.
- Constantly renewing itself and adapting to new market situations through participation in R&D activities - testing and introducing cutting edge technology.
- C-ITS is still a fairly new concept, and the learning curve is steep.
- Challenge us for innovation, which often involves the use of new technology.

- In order to maintain services offered we are dependent on being able to involve ourselves in R&D processes.

Funding

- Dependent on demand through pilot projects and / or other funding to develop and test relevant solutions
- Small R&D budget
- Lack of investments, no obvious/mature commercial market potential
- Require investments
- Participation in these types of projects requires a large proportion of investment. It is therefore important that you have a concrete plan for how to use the results of the projects, and that these are continued.

<u>Gains</u>

Strategic

- Fulfil the strategic goals: better environment, less accidents and more efficient traffic flow.
- Aiming to be one of the first movers in this market.
- Builds good reputation
- New business opportunity
- A strategic goal is to develop fixed service within those of our market segments that require professional and specially composed services.

Prospects

- Believe there will be a huge demand for integrators that can employ these systems for cities and highway operators
- A pan European rollout of C-ITS could grow the company.
- New customers could be cities and highway operators, vehicle fleet owners, vehicle OEMs., providers of information platforms etc.

Economy/market

- The lack of competition would also mean higher margins for turn-key projects
- Good position to provide competitively priced C-ITS solutions.
- Creates market recognition
- Increased interest and traction
- We believe that participation in the pilots provides a greater opportunity for us to sell services directly or indirectly to consumers (car users) and transport companies

Competitiveness:

- Participation in this type of project enables the company to profile itself for the outside world. The company has developed several new products and services.
- We are already seeing more results: -The solution has got a bigger profile -We have implemented integrations with variants of sensors that have brought new products / solutions. -We have tested several variants of hardware that have been proven very useful in putting other solutions into production.
- We have gained several new customers related to the management of signs and integrations with the road traffic centers.
- The ITS initiative has led to competitive products
- The company's ITS efforts have contributed to being first in the market with products and services. This gives the company increased competitiveness.

Commitment

- Active member of several technology clusters and trade organizations related to C-ITS and CCAM.
- Sponsored several Master Theses related to C-ITS at the NTNU and has cooperated with the NMBU to develop a small C-ITS test bed at their campus.
- In the forefront in Europe to implement hybrid C-ITS communication and C-ITS Service Announcement Messages (SAM)
- Development of own products and services
- Developing solutions for assignments
- Part of cooperation and alliances
- Participation in research projects with own contribution
- Participation in seminars

5.2.2.2 Current state and roles

Figure 63 present an ecosystem for one of the services as it is now. It shows which actors are involved and how data, services, goods and money flows between them.

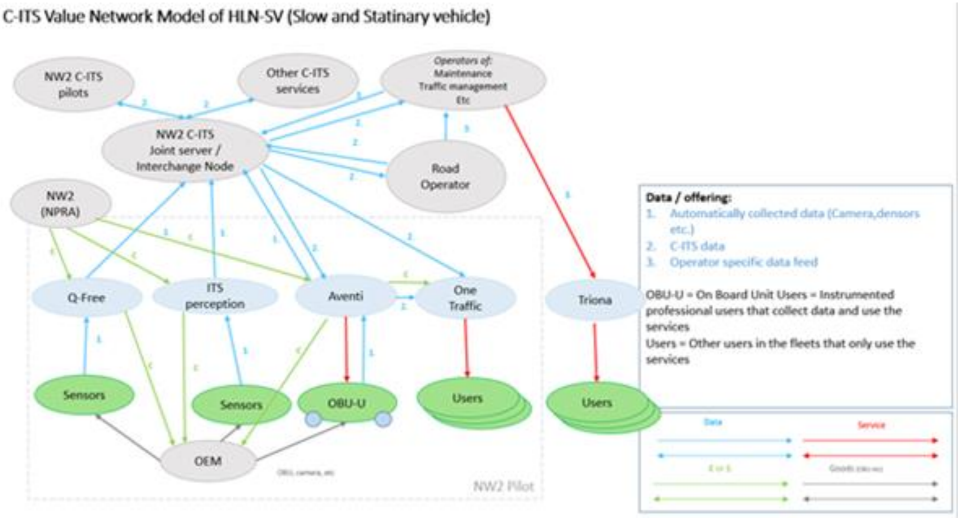


Figure 63 Current status ecosystem for Slow and stationary vehicles.

5.2.2.3 Scaling up the ecosystem

How should this service (see Figure 63 look/work in 5 years from now?

The geographical coverage should be most of the difficult uphill's roadway section in Norway, especially those with demanding winter weather conditions.

Deployment of such a service is a cost value decision. The tested solution is deployed by many sensors and other hardware.

NPRA think that a future solution will include geofencing and self-reporting. The uphill's sections could be a geofence area and vehicles self-reports when speed is below a set rate (0-10 km/h) inside that geofence.

What is required to reach this vision?

To increase the number of sites a positive cost value needs to be confirmed. To deploy the geofence solution a organization needs to take responsibility to define those geofences. Such a solution is much less dependent on physical infrastructure, and more dependent on digital infrastructure. The draw back will be deployment period of digital infrastructure installed in vehicles. This could take many years.

The HLN-SV 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 this service. Value is 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. For drivers the main value is predictability.

In the ecosystem NPRA is one public actor but there will be more actors owning and managing roads in the transport system and therefore more Road operators were added.

OEM's will have a more important role because the deployment with the geofence solution is dependent on distribution of geofence areas to the vehicle's internal ITS equipment and the vehicle need to self-report situation of slow or stationary vehicle.

Moving from pilot stage to a deployment “in real life” - what is needed.

Here are some key comments from the partners.

- Long term planning for deployment, reduce the risks for investments.
- We see that pilot projects are often completed without any thought of continuation. We want the customer to use the opportunities found in the policy instrument to carry the result into new projects.
- Agree about both technical and functional specifications, so then we can move from pilots to a tender for deployment.
- We need participation on a daily basis from government entities like police, cities, NPRA and other stakeholders to get the messages and data flowing in the network.
- A clear long-term public commitment and plans for regular increments in development with funding (private/public) of R&D projects and procurements
- To move from the pilot stage to real-life large-scale deployments, we need road operators, regional governments, and cities with a willingness to invest in smart technologies like C-ITS for the public good.
- Alternatively, we can build a privatized C-ITS platform for basic services and charge for add on services required by public actors and private businesses alike.
- Reduce market risk, uncertain costs and price prospects.

5.3 User acceptance

5.3.1 Method

Part of the evaluation consists of mapping users' knowledge of, use and acceptance of C-ITS services. In this context, users are all those who drive and use the transport system, i.e.. driving on a public road. The user survey is expected to provide answers from approximately 1000 respondents. The customer submits questions to be answered to the consultant in a digital form (an excel spreadsheet)

Primary data was collected through electronic data collection, where email invitations with a unique link to an online questionnaire are distributed to a representative selection of a Response Panel. The sample was drawn randomly and proportionally to the population of each region by gender and age, adjusted for expected response rates within the different population groups. At the client's wish, no weighting is carried out, but quotas are subsequently managed in the region.

The expected interview length eas 7-8 minutes, based on 31 question units (the first statement in matrix is calculated as one question and subsequent statements in matrix are calculated as half a question, questions with more than 15 answer options are calculated as 1 extra question per 15 additional answer options , and open questions with up to 5 answer boxes count as 2 questions with the addition of eventual categorization), as well as 9 background questions (based on draft + zip code) Of these, none are open.

Respondents

In terms of geographical representation in Norway, the survey sample is satisfactory, with only minor deviations between survey target and survey results.

	Result		Goal		Deviation		
	Percent	Number	Percent	Number	Percent	Number	%
Oslo og Viken	37,3 %	373	35,7 %	357	+ 1,6 %	+ 16	+ 4 %
Innlandet	6,7 %	67	7,3 %	73	- 0,6 %	- 6	- 8 %
Agder og Sør-Østlandet	15,3 %	153	13,6 %	136	+ 1,7 %	+ 17	+ 13 %
Vestlandet	23,1 %	231	25,4 %	254	- 2,3 %	- 23	- 9 %
Trøndelag	8,7 %	87	8,8 %	88	- 0,1 %	- 1	- 1 %
Nord-Norge	8,9 %	89	9,3 %	93	- 0,4 %	- 4	- 4 %
Total	*100,0 %*	*1 000*	*100,0 %*	*1 000*	*0,0 %*	*0*	*0 %*

Table 32 Geographical representation in Norway.

5.3.2 Results

Result from this survey is summed up in the report User-acceptance-survey Input-Norway [8].

5.4 Socio-economic

This evaluation was not conducted on national level and the results are summed up in [5].

6 Dissemination

The aim of the communication and dissemination activities has been to ensure an efficient communication of results, lesson learned, and key milestones achieved in the project, thus also drawing attention to the importance of C-ITS and the benefits of European cooperation and CEF.

Further, a proper exchange of information to relevant European platforms such as C-Roads and the CCAM Platform (Cooperative, Connected and Automated Mobility Platform) and disseminating the NordicWay findings through these platforms and other relevant platforms is also important.

6.1 Communication and dissemination activities

NordicWay has conducted a wide range of activities on dissemination to external parties via numerous communication channels – All activities related to Norwegian Pilot 1 is presented in Table 33.

Type of Information	Description
NordicWay Web	NordicWay 2 web site www.Nordicway.net The web site contains all the videos and presentations from the project.
NordicWay YouTube channel	NordicWay 2 YouTube channel with some of the videos produced by the project https://www.youtube.com/channel/UCiwtpH2DNQSxaEQi_4OtenQ
PR materials and video	NordicWay 2 Brochure. NordicWay 2 film: Tour de NordicWay 2 – A video cavalcade of short visits to many of the NordicWay 2 demonstration sites with real life pilots
Presentations and pilot videos	Various presentations at congresses, seminars and relevant platforms etc. (www.Nordicway.net) ITS World Congress Copenhagen, September 2018, 6 presentations in technical sessions/ special sessions and in addition: Finnish Winter Road Congress. The arctic intelligence test ecosystem, February 2018 ITS conference Norway- Is C-ITS suitable for traffic regulations. March 2019 ITS Arena conference Oslo-ITS pilots in urban areas. April 2019 Workshop on common challenges and GDPR, May 2019, Gothenburg ITS Europe, Eindhoven, June 2019 ITS World Congress, Singapore, October 2019, Nordic Pavilion in exhibition, Video presentation in continuous loop on screen Video launched September 2020, NordicWay 2 Norwegian pilot: Traffic Ahead warning Video launched September 2020, NordicWay 2 Norwegian pilot: Mobile Road works warning Video launched September 2020, NordicWay 2 Norwegian pilot: On street parking information in Trondheim Norwegian Pilot showcase, 29 Oct 2020 a. Services piloted b. Test sites c. Interchange d. Automatic speed adaption e. ITS Perception – Lidar technology

	f. Sensor network for vehicle speed profiling g. Smart road signs and weather stations h. Services Skibotndalen i. Mobile Road works and Traffic ahead warning j. Nordic Tour route and technology k. In-vehicle speed limits l. The C-ITS test beds E8 Borealis and E6 Petterød m. Showcase Q&A
Articles, notices etc.	Teknisk Ukeblad (Norwegian technical magazine): "This road has been closed 39 times…New technology to predict the problems" PSI-Group-article in magazine Production-Manager- AI prediction of travel time
PR Events and demonstrations and showcases	Launching events to announce the start of the pilots in the different countries NordicWay 2 demonstration at ITS World Congress Demonstration area in Copenhagen, 2018 (E.g. The Nordic Transport ministers attended) NordicWay Tour, a data logging expedition through all NordicWay 2 countries, 5000 km with 5 border crossings (The story about NordicWay was shown in e.g. national Norwegian Television, Sept. 2019) Norwegian Pilot Showcase, large on-line event with many participants (29 Oct. 2020)
Final Workshop on Evaluation results	Large on-line workshop to publish the results and lessons learned to partners, EC, C-Roads Platform, C-ITS stakeholders etc.

Table 33 External communication.

7 Highlights.

The reports [5] and [9] presents results and findings for the Norwegian part of Nordicway2 project. To sum up the main findings we will highlight the following:

<u>Technical</u>

- Before deploying the services, one has to be sure of the quality of the service. This includes both the quality of the event data and the distribution of messages. The pilots and their use of new sensor technology indicated that the data to trigger different events is not good enough for automatic distribution. Some of the detection data is critical for the service to be thrusted and during the pilots we have seen some false/incorrect data which mean we have to include manual verifications. But this does not mean that the services are not ready for deployment, but just that one has to include some verification in the ecosystem. For many of the pilots the latency from detection to distribution to users is not time critical.
- The distribution of the services through the Interchange node have worked within specifications and is not seen as a showstopper.
- The service level for the services are mainly dependent on the connectivity and the system uptime. The Nordic Tour verified a good level of connectivity along the main roads, also when border crossing. System up time was not good enough in Skibotn Valley, mostly because of network issues. To secure network functionality one has to increase the service level agreements with the suppliers.

Organizational

- The “top level” of the ecosystem needs to be included. In Norway this is the NPRA organization. Involvement of the road operator is crucial for deploying of the services. The service tested in the pilots should be an integrated part of the TMC services. The services are also dependent on data from the road operator, data from National Access Point and Datex node. This data must have known quality and the service providers need to cooperate with the road operators.
- Data quality is essential for C-ITS to be useful. The Nordic Tour has shown that there are examples of sub optimal quality. It is believed that road operators may have to change their processes to increase the data quality. Stricter adherence to standards and monitoring are important areas that need to be further studied.
- Nearly all of the suppliers pointed out the road operators as the most important actor in the ecosystem. The road operator should make specifications and be a driving force for developing a sustainable marked situation. The suppliers need to be sure that there will be a marked, so they could get payback for their investments in R&D.

References

[1] NordicWay 2, NordicWay Federation Use-Cases.

[2] NordicWay 2, NordicWay Federation Protocol.

[3] NordicWay 2, NordicWay Interchange CLIENT specification.

[4] Core Technical Equipment Deployed.

[5] NordicWay 2 Evaluation report.

[6] Technical evaluation Input-Norway.

[7] Eco-system evaluation Input-Norway.

[8] User-acceptance-survey Input-Norway.

[9] NordicWay2 – Norwegian pilot 2 – Final report.