Milestone 11 – Pilot Operation Finalised

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CONTROL SHEET

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Terms and abbreviations

Term / Abbreviation	**Definition**
AC	Advisory Committee
AL	Activity Leader
ASR	Action Status Report
CMT	Core Management Team
DTSJ	Data Test Set for Junction
EC	European Commission
ETA	Estimated Time of Arrival
GA	Grant Agreement
GLOSA	Green Light Optimised Speed Advice
INEA	Innovation and Networks Executive Agency
IVS	In Vehicle Signage
IPR	Intellectual Property Right
MCTO	Multimodal Cargo Transport Optimisation
ML	Milestone Leader
MS	Member State
OBU	On board Unit
PC	Project Coordinator
PVD	Probe Vehicle Data
RWW	Road Works Warning
SE	Service Editor
SPaT	Signal Phase and Timing
TCC	Traffic Control Centre
TIC	Technical & Interoperability Coordinator
TLC	Traffic Light Controller
TMS	Traffic Management System
UC	Use Case
UTC	Urban Traffic Control

1 Executive summary

Activity 3 “Pilot Operation” consists of the deployment of the actual pilot operations in the four Member States (MS). The present deliverable describes the four pilot sites in the MS at the end of the operation.

The services deployed and the location of the deployments is detailed for each MS. Technical details of the local deployments are described and the achievements during the pilot operation are listed. This includes descriptions of the vehicle fleets that were in operation.

2 Introduction

2.1 Purpose of this document

The purpose of the present document is the summary of the four pilot operations in the MS at the end of the pilot operations:

- Belgium/Flanders
- France
- The Netherlands
- United Kingdom

2.2 InterCor Contractual References

InterCor (Interoperable Corridors) links the C-ITS corridor initiatives of the Netherlands C-ITS Corridor Netherlands-Germany-Austria and the French one defined in SCOOP@F, and extending to the United Kingdom and Belgium C-ITS initiatives.

InterCor is an action co-financed by the European Union under the Grant Agreement number INEA/CEF/TRAN/M2015/1143833. The Project duration is 42 months, effective from the 1st of September 2016 until the 29th of February 2020. It is a contract with the Innovation and Networks Executive Agency (INEA), under the powers delegated by the European Commission.

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3 Pilot operation in Belgium/Flanders

3.1 Pilot operations overview

The Flanders InterCor pilot operations started with Road Works Warning (RWW), In-Vehicle-Signage (IVS) and Probe Vehicle Data (PVD) services at the end of 2018. Mobile or short-term stationary road works were added in February 2019. These services were operational until December 2019. Additionally, a limited GLOSA service was tested in March 2019.

All together 25 ITS-G5 roadside units have been installed near Antwerp on the E313 (10 km full coverage) and E34 motorway (13 km with partial coverage), and on the N12 road – covering 2 intersections (temporarily during the TESTFEST in March 2019). The IP-based "cellular" IF2-services covered all motorways in Flanders.

The IVS service ensured a digital twin of the dynamic lane signalling on the motorways in Flanders. The RWW service proved the possibility of real-time (in-vehicle) information and warnings on mobile road works activities on all motorways.

3.2 Location of pilot site(s)

The InterCor C-ITS operations in Belgium Flanders were located on all motorways in Flanders, but with a focus on the E313/E34 motorways near Antwerp.

The E313/E34 focus was chosen because of the availability of dynamic lane signalling gantries (and corresponding information, power and fibre connectivity) and the high traffic volume. At the time, it was also a probable location for the then-future Concorda and Smart Highways projects.

The long-range, cellular service coverage on the motorways is represented in yellow (RWW) and red (RWW, IVS) on Figure 1. The E313/E34 focus location is encircled in blue in Figure 1 and detailed in Figure 2. On the focus location, 23 new ITS-G5 road side units were deployed. The actual number of kilometres on which the services are deployed, depends on the service, and is represented in 3.3.1. During the Cross-border Interoperability TESTFEST in March 2019, a Green Light Optimized Speed Advice (GLOSA) pilot site was operated on 2 signalised intersections on the N12 in Schilde (North of E313/E34). Its location is shown with yellow stars in Figure 2.

Figure 1: BE/Flanders cellular service coverage (yellow and red)

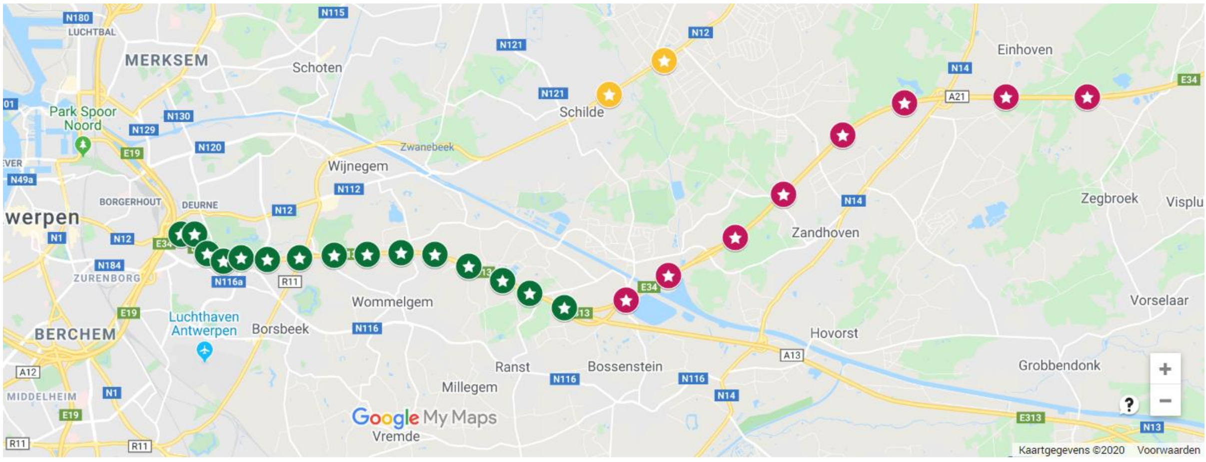


Figure 2: BE/Flanders ITS-G5 pilot site on the E313 (green) & E34 (purple) near Antwerp and the Schilde GLOSA Test Site (yellow)

3.3 Services deployed

3.3.1 Services deployment overview

Table 1: BE/FL deployment of services

Service	Use Case	Belgium-Flanders	Pilot start dates	Comments/Issues
RWW	Lane closure or other restrictions	Deployed covering 910 km of motorways	ITS-G5: 19/12/2018 Cellular: 19/12/2018	Cellular client start: 18/3/2019
	Alert planned road works – mobile	Deployed covering 910 km of motorways	ITS-G5: 7/2/2019 Cellular: 7/2/2019	Cellular client start: 18/3/2019

IVS	In-vehicle signage dynamic speed limit information	Deployed covering 155 km [1]of motorways	ITS-G5: 19/12/2018 Cellular: 19/12/2018	Cellular client start: 18/3/2019
	Dynamic Lane Management – Lane Status information	Deployed covering 155 km of motorways	ITS-G5: 19/12/2018 Cellular: 19/12/2018	Cellular client start: 18/3/2019
PVD	Traffic data collection	Deployed covering 23 km of motorways	ITS-G5: 19/12/2018 Cellular: no	
	Probe vehicle data on detected/declared events	Deployed	ITS-G5: 14/2/2019 Cellular: 25/3/2019	For cellular: tested with simulated declared events
GLOSA	Time-to-green information and speed advice	Tested on 2 intersections	ITS-G5: 25/3-28/3/2019 Cellular: 14/3-28/3/2019	No infrastructure-side speed advice
	Time-to-red information and speed advice	Tested on 2 intersections	ITS-G5: 25/3-28/3/2019 Cellular: 14/3-28/3/2019	No infrastructure-side speed advice

[1] The IVS service is provided on all 155 km equipped with gantries with dynamic lane indicator signs. Most of the 155 km is equipped in both driving directions.

3.3.2 Services details and operations

3.3.2.1 Road Works Warning service details

3.3.2.1.1 Major / Static Road Works

The static road works information was based on the existing public traffic information stream for motorways, by the Flemish Traffic Control centre. The central C-ITS server converted the information to the appropriate C-ITS message format (see 3.4.2.1). This service was first deployed in December 2018.

3.3.2.1.2 Mobile and Short-Term Stationary Road Works

For the mobile road works service, the public traffic information was lacking the necessary detail. Before InterCor, the Traffic Control centre was using planning information combined with phone calls from the road works' surveyors. A large part of the mobile road works was not included in the public data stream. In February 2019, the locations of 40 Impact Protection Vehicles (IPVs) was obtained through the Track & Trace modules and the corresponding fleet management system. The positions are sent to the central server and updated every minute. Unfortunately it was not possible yet to automatically detect which lane was closed by the IPV. Therefor the automatically generated Road Works Warning did not contain closure information. Further action is being taken and regulations are adapted to expand this pilot to all Impact Protection Vehicles in use on Flanders' motorways, and to automate the acquisition of the lane closure information.

Figure 3: Usage of Impact Protection Vehicles in BE \ Flanders

Figure 4: Road Works Warnings in the central C-ITS system on 9 Dec 2019

3.3.2.2 In-Vehicle-Signage service details

The In-Vehicle-Signage, dynamic speed limit and lane status information was based on the actual dynamic lane signalling on the motorways. In February 2017, the internal lane signalling commands and statuses were converted to an XML format and published as an open data stream in near real time. In December 2018, this data was then converted by the central C-ITS system to IVI messages (see 3.4.2.2). After an update of the conversion algorithm in September 2019, the delay was reduced to about 2 seconds end-to-end, which is about the same delay as between the command system and the physical signs themselves, improving the IVS service considerably.

Figure 5: Dynamic lane signalling gantry, information also provided by the IVS service

The IVS service was first deployed around Antwerp. The IP-based IVS service over IF2 was expanded to the Ghent and Brussels-Leuven areas on 28 May 2019. The coverage is illustrated by the red motorways in Figure 6.

Based on the IVS service, it was possible to present the user with information about upcoming speed limit and lane status information (in the awareness zone), and with the currently valid speed limit and lane status information (in the relevance zone). However, due to the HMI design only one could be shown, and the currently valid information was chosen. This is further explained in 3.4.4.

Figure 6: Locations of the IVS service in Flanders, marked in red

3.3.2.3 Probe Vehicle Data services detail

3.3.2.3.1 Traffic Data Collection

The Traffic Data Collection service through ITS-G5 was deployed on the pilot site on the E313 and the E34 motorways. The CAM messages received by the Road Side Units (RSUs) over ITS-G5 are centrally stored and logged. For testing purposes, the location of the detected vehicles was displayed on the map of the central C-ITS system (Figure **7**). This data was an essential part of the data collection used for evaluation.

3.3.2.3.2 Probe Vehicle Data on detected/declared events

The service for Probe Vehicle Data on detected/declared events was deployed and tested using the ITS-G5 OBUs. The OBUs were set up to automatically send “Stationary Vehicle” warnings when the vehicle was stationary for over 30 seconds. Additionally a test interface to the OBU enabled creating manual warnings for accidents, traffic jam ahead, broken down and stationary vehicles.

The DENM messages received by the RSUs over ITS-G5 are received, forwarded to the central C-ITS system. The event is added to the Central C-ITS system and sent out again over IF2.

DENM messages received over the read-write cellular IF2-interface were stored / logged centrally.

Figure 7: PVD in Central C-ITS system: red dot = detected vehicle position

3.3.2.4 GLOSA service details

The GLOSA service was operational for testing on two intersections during the TESTFEST 25-28/3/2019. During the TESTFEST the intersection phasing and timing were adapted during testing hours to obtain a rigid and predictable timing. Without rigid timing, the prediction was only possible and reliable for the last 4 to 5 seconds of a phase. The local intersection controller sent the SPAT information over 4G to a central MQTT server. Both the Flanders IF2 server and the local RSUs connect to the MQTT server to obtain the SPAT and MAP messages. The RSUs are (also) connected over 4G and mounted onto one of the traffic light poles. There was no speed advice added in the SPAT, and only maximum legal speeds were provided. The architecture set up during the test is represented in 3.4.2.4.

Figure 8: GLOSA site – N12 Waterstraat, with HMI

Figure 9: ITS-G5 Road Side Unit attached to traffic light.

3.4 Technical Aspects

3.4.1 BE-Flanders system architecture

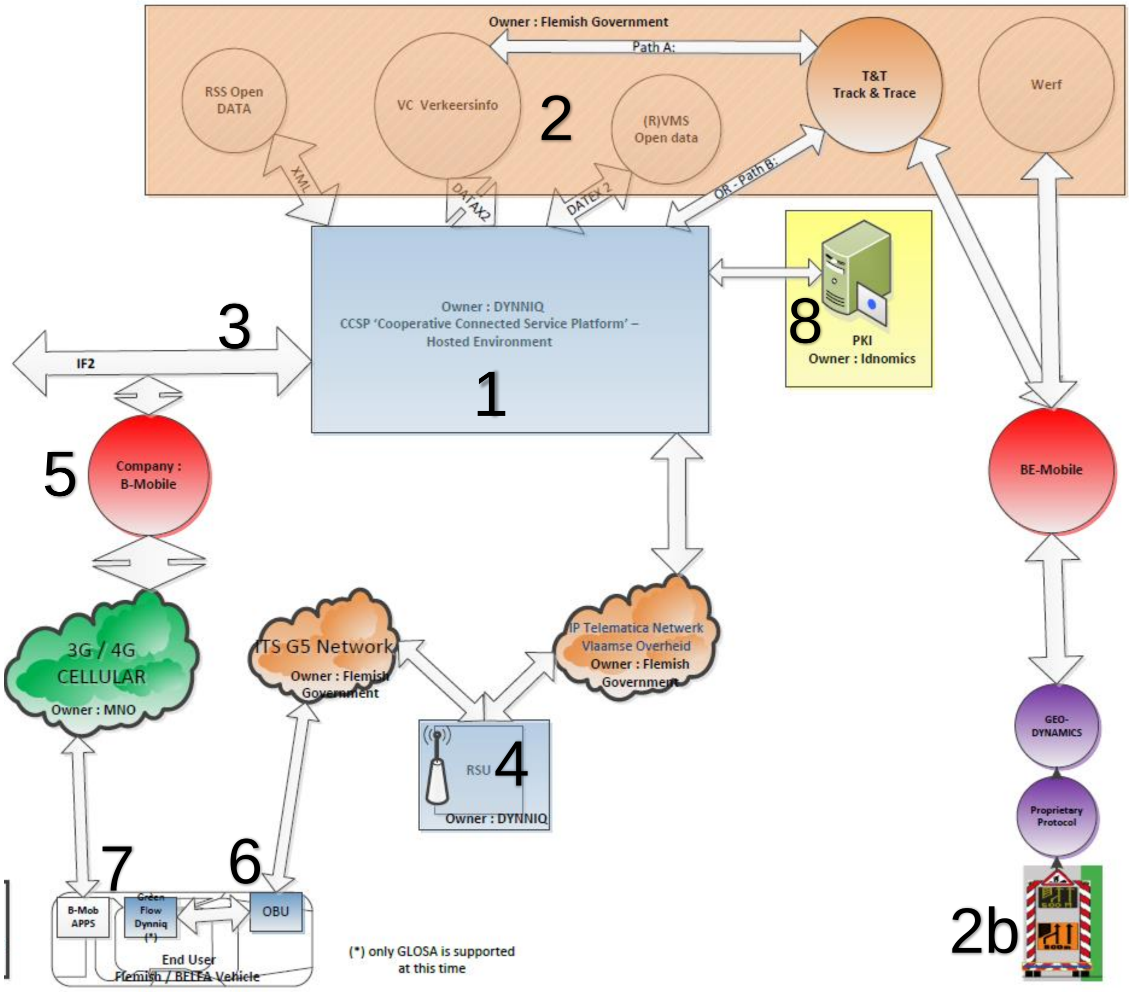


Figure 10: BE/Flanders system architecture

The major components of the InterCor Flanders architecture are

1. Central C-ITS server: the CCSP “Cooperative Connected Service Platform”, which is running in an Azure Cloud.
2. Data-sources + 2b: Impact Protection Vehicle with Track & Trace connection
3. IF2- service for communication to Service Providers and other Member States
4. Road Side Units for ITS-G5 communication
5. Service Provider, providing messages to cellular clients
6. On-Board-Unit for ITS-G5 communication
7. HMI Application, connecting to Service Provider or On-Board-Unit
8. Root Certificate, Enrolment and Authentication Authorities

3.4.2 Data sources and Message format conversions

The central C-ITS server converted the data from several data sources to the ETSI C-ITS message formats according to the “Milestone 3: Common set of upgraded specifications for ITS G5”.

3.4.2.1 Datex2 Traffic Information

The Road Works present in the Datex2 Traffic Information[2] stream from the Flemish Traffic Control Centre, were converted to DEN messages. The TMC location code has to be converted to WGS coordinates, and a path for the relevance zone has to be calculated and added. A relevance zone of 500m was chosen, matching the distance of physical warning vehicles.

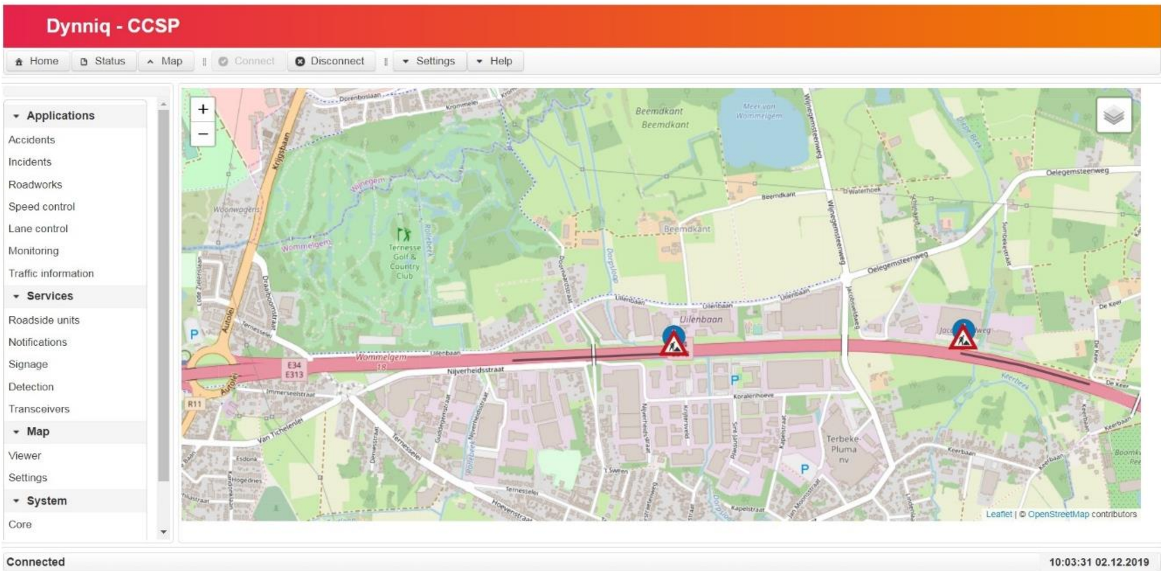


Figure 11: 2 Road Works with their calculated relevance zone in the CCSP

3.4.2.2 Dynamic Lane signalling data in XML

At the start of InterCor Flanders, in February 2017, the dynamic lane signalling data was converted to an XML format, and a near-real time open data interface[3] was created to facilitate further use. This XML dataset contains the locations of the signs, the last requests to change the signs, and the confirmed message on the signs.

By December 2018 the interface to this XML dataset was complete, and the IVI-messages were created. To convert the XML messages, certain considerations were made:

- For convenience when creating traces, all relevance zones were set to 500m, instead of calculating the actual validity (until next gantry or until next crossing). Example of the generated traces is presented in Figure 12.

[2] https://opendata.vlaanderen.be/dataset/datex2-feed-verkeerscentrum-vlaanderen
[3] https://opendata.vlaanderen.be/dataset/rijstrooksignalisatie-vlaanderen

- Individual signs had to be (re)grouped to a gantry, so one IVI message could be generated, instead of an IVI per lane.
- Only front-side signs would be integrated in the IVI-stream. Rear-side signs, for counter-flow traffic, were not integrated.
- No end-of-speed-limit message or cancellation would be used. Instead, the system would send either no message, or send a message with no information for that lane. The reasoning behind that choice was that in that case no speed limit would be displayed anyway. In retrospect, this was neither a good nor correct decision. End-of-speed-limit messages or cancellation turned out to be necessary to be able to correctly cancel speed limits upon changes, otherwise a previous speed limit message would stay valid (until expired).
- The information about the “BUS and TAXI”-lane property was not provided in the IVI-messages, since this was not harmonised in InterCor. It was intended to use ISO TS 14823 category and pictogram codes for this reserved lane. This was harmonised. However, during implementation, it was found out that there is a bus lane code, but not a combined bus/taxi lane code. Then, the most elegant way to implement the “bus and taxi” lane property would have been through the use of VehicleCharacteristics in the IVI-message. Bus and taxi vehicles would see an open lane, with a speed limit. All other vehicle types would see a closed lane. This was not implemented and seen as a lessons learned.
- An extra simulation server was inserted between the XML data source and the central C-ITS system. This simulation server was able to overwrite or fake signs on top of the real-time data stream. For example, this was used in the impact assessment experiment, to communicate speed limits when the actual physical signs were blank or black.

There are 1500 dynamic lane signalling signs (about 500 gantries). Speed limits on a gantry are recalculated every 10 seconds and updated when needed; this resulted in a lot of changes all the time, especially in rush hour periods (with peaks of 34 signs changing per second). During operations, it turned out that the conversion was suffering from huge delays (sometimes up to minutes). This turned out to be caused by the on-the-fly generation of the traces for the relevance and awareness zones for each (updated) message. In September 2019, an update to the IVI-generation resolved this issue by reusing traces previously calculated. This update improved the processing to 25 sign changes per second. This limited the end-to-end-delay to about 2 seconds (including about 1,5 seconds of delay introduced by the open data and simulation servers), with a dozen peaks up to 5 seconds.

At the end of November, changes to the source open data stream, caused major issues in the data conversion and processing at the central C-ITS server. This resulted in several days of partial and interrupted service.

Above considerations and issues are being re-evaluated before full deployment in the Mobilidata programme.

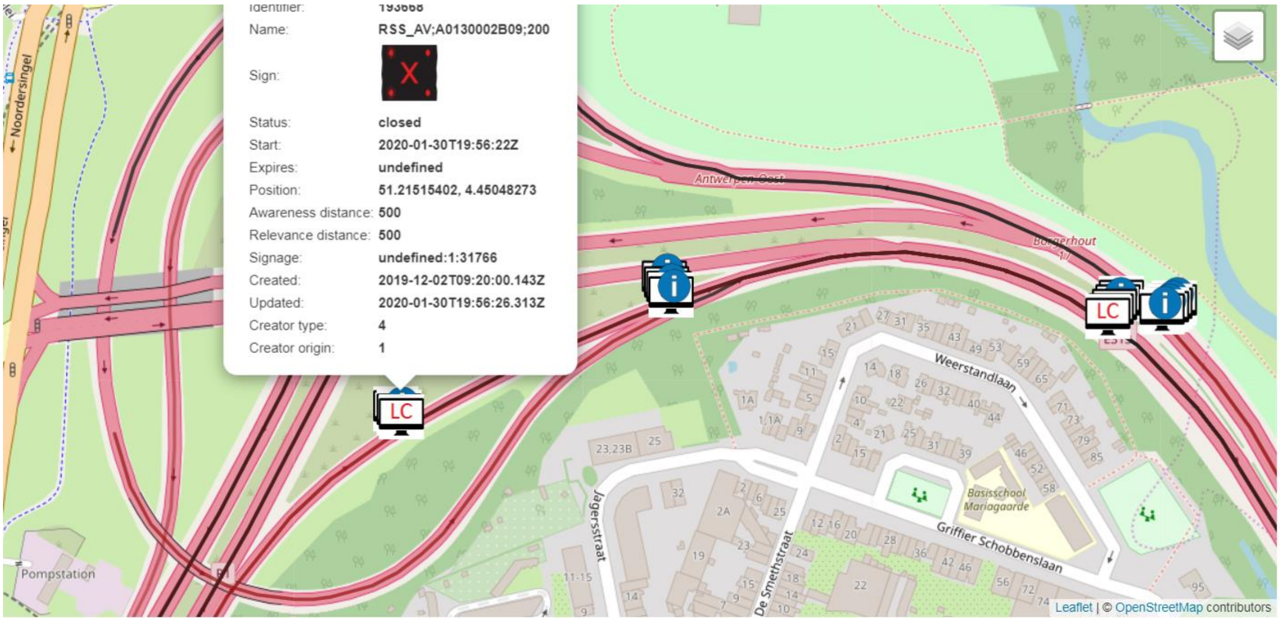


Figure 12: CCSP displaying source data for IVI, with relevance and awareness zones

3.4.2.3 Track & Trace of Impact Protection Vehicles

The fleet management system of an Impact Protection Vehicle (IPV) provider was connected to a new system for collecting and processing IPV-location data on the Flemish motorways. A json interface was set up to make this location data available to the Traffic Control Centre. This json interface was also used to acquire the data in the central C-ITS system. At first, the location data used to be updated every five minutes. However, this turned out to be insufficient, so it was later changed to once every minute.

The central C-ITS server generates the RWW DEN message, by adding a trace to the location.

The service stops generating RWW messages when the IPV position/speed either was not updated for 5 minutes (because the unit was switched off), or when the speed exceeded 30 km/h (when it is no longer stationary, nor moving slowly), assuming the RWW was finished.

As mentioned before, lane closure information is currently not available in the messages. However, for testing purposes, manually created RWW did contain lane closure information. Further action is being taken and regulations are adapted to expand this pilot to all Impact Protection Vehicles in use on Flanders' motorways, and to automate the acquisition of the lane closure information.

3.4.2.4 SPAT/MAP for GLOSA

Figure 13 presents the architecture for the GLOSA service during the Cross-border interoperability TESTFEST in March 2019. SPAT information was generated in the Traffic Light Controller, and published to an MQTT broker at a central traffic server (over 4G). The 2 Road Side Units subscribed to this information (also over 4G), signed the messages and sent them out. The IF2 server also subscribed to the MQTT, but instead of sending it out, it published the messages on its own SPAT and MAP exchanges.

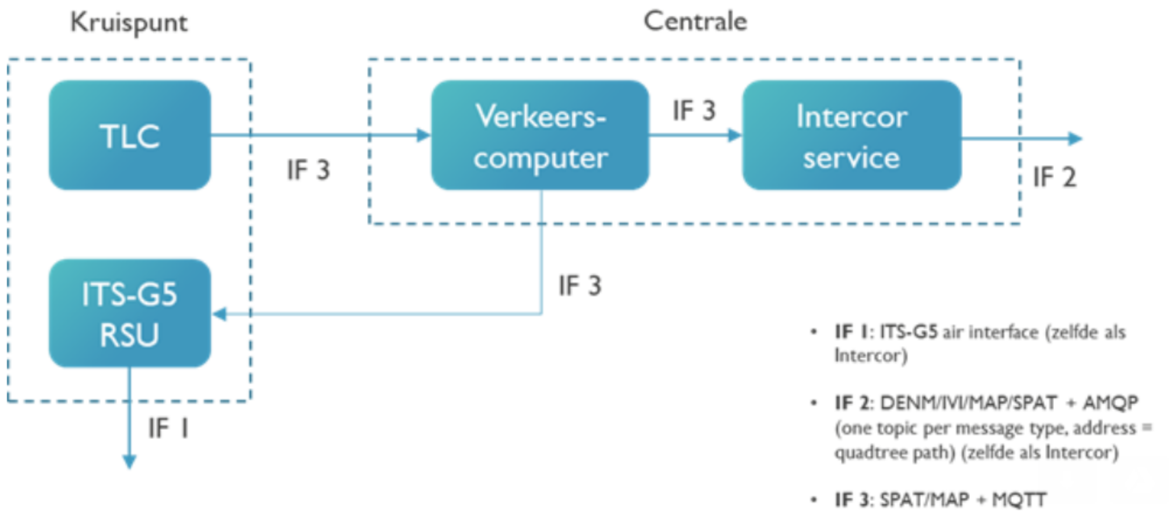


Figure 13: GLOSA Architecture for TESTFEST in Flanders

3.4.3 IF2 details

The IF2 interface was set up according to "'InterCor Milestone 4 - Common set of upgraded specification for Hybrid communication' (sub-activity 2.1b)."

The read only IF2 is operational since 19/12/2018 on ccsp-be-tools.westeurope.cloudapp.azure.com: 5671 on the virtual host production_fg. It is serving messages on the exchanges IVI, DENM, SPAT and MAP.

Since 25/3/2019, an additional read/write IF2 is operated on the virtual host production_fg_ext, receiving messages on the DENM exchange.

The cellular IVS and RWW services over IF2 is currently planned to be kept operational until at least the end of 2020.

3.4.4 RSU details and mounting

The 25 deployed Road Side Units were Dynniq / Peek Traffic 11p Mk2 RSU's. 19 of them were connected to the central C-ITS system over the internal fibre network. The 6 other RSU's were connected over 4G.

Transmission was set at a power of 0.2W, amplified with a 9dBi omnidirectional antenna. The Effective Communication Range of the units turned out to be about 350 metres.

On the E34, the RSU's were mounted either on a pole (on the side or centre of the road, height 6m, Figure 15), either at the end of the gantry (Figure 14), slightly above the first lane, at a height of about 8m.

Figure 14: RSU mounted on gantry on E34

Figure 15: RSU on a pole on the E34

On the E313, the RSU's were attached to the gantries with the dynamic lane signalling signs. The RSU's were mounted as close to the centre of the road as possible, above the innermost lane, at a height of about 8m (**Figure 16**).

Figure 16: RSU mounted on gantry on E313

3.4.5 OBU and HMI details

3.4.5.1 Communication Channel support

The On-Board-Unit (OBU) and Human-Machine-Interface (HMI) applications used in Flanders each supported a single communication channel only[4], either ITS-G5 or IP-based. Both HMI's were Android applications.

3.4.5.2 ITS-G5 On-Board-Unit details

The pilot used Dynniq ITS-G5 OBUs combined with a magnetic, external ITS-G5, 4G and GNSS antenna. The OBUs set up a local Wi-Fi network in the car, over which it provided the information to the corresponding HMI application. Installation was very easy. However, several users complained about a problem which occurred in combination with certain vehicles. In their vehicle, the OBU did not power down together with the vehicle. This resulted in several, repeatedly drained vehicle batteries.

The Effective Communication Range of the units turned out to be about 75-100 metres.

[4] Even though the Dynniq HMI was capable of using both channels, it could not do so simultaneously.

Figure 17: On-Board-Unit installed in the boot of the car.

3.4.5.3 HMI details

The Android, ITS-G5 HMI application "Greenflow" was provided by Dynniq.

The Android, cellular HMI application "Truckmeister" was provided by Be-Mobile.

The HMI applications could display the speed limits and lane status information, together with present warnings. The ITS-G5 HMI also displayed the current speed and the number of other ITS-G5 equipped vehicles or RSUs the OBU was aware of.

For warnings, both HMIs were capable of displaying Road Works, Stationary Vehicles and Accidents. The cellular HMI also displayed Traffic Jam Ahead warnings, accompanied by an aural signal. All warnings were accompanied by a distance indication. At some stage during development, the cellular application was configured to stop displaying the warning when closer than 250m to the event. This was done not to distract the driver when nearing the event. Later this change was reverted, and the warning was again displayed right up to the event since it might be confusing ("did the event itself end?"). It would be good however, to compare the difference in impact of both approaches in the future.

For the IVS information, either the upcoming or the previous gantry information could be displayed. Because neither of the applications could add a distance indication to the IVS information, it was chosen to have the currently valid speed limit and lane status displayed. Otherwise, without distance indication for upcoming signs, the meaning would be ambiguous.

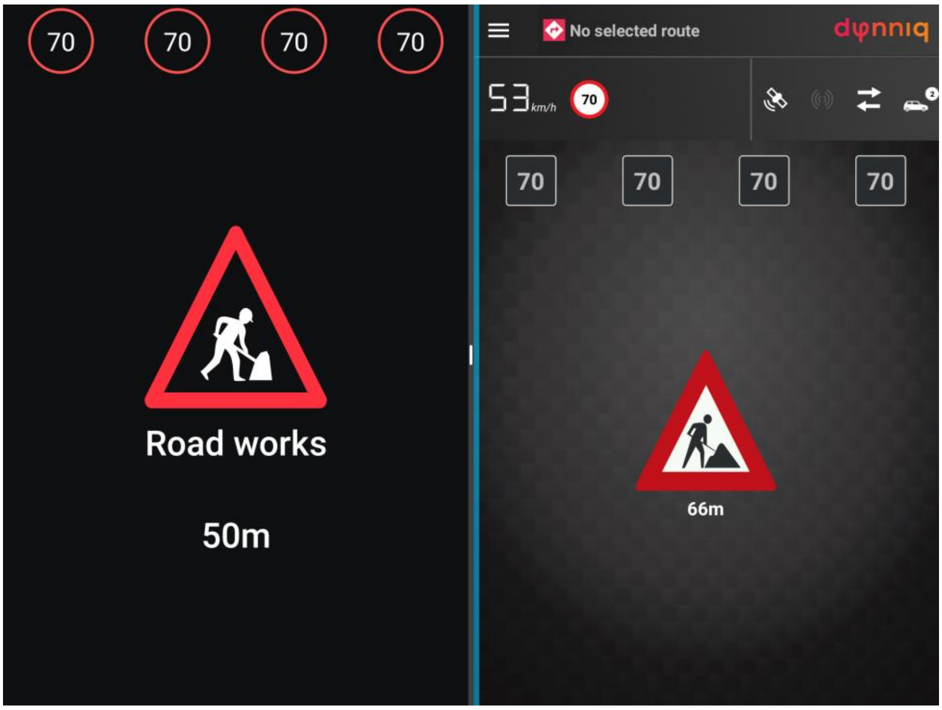


Figure 18: RWW and IVS speed limit over cellular (left) and ITS-G5 channel (right)

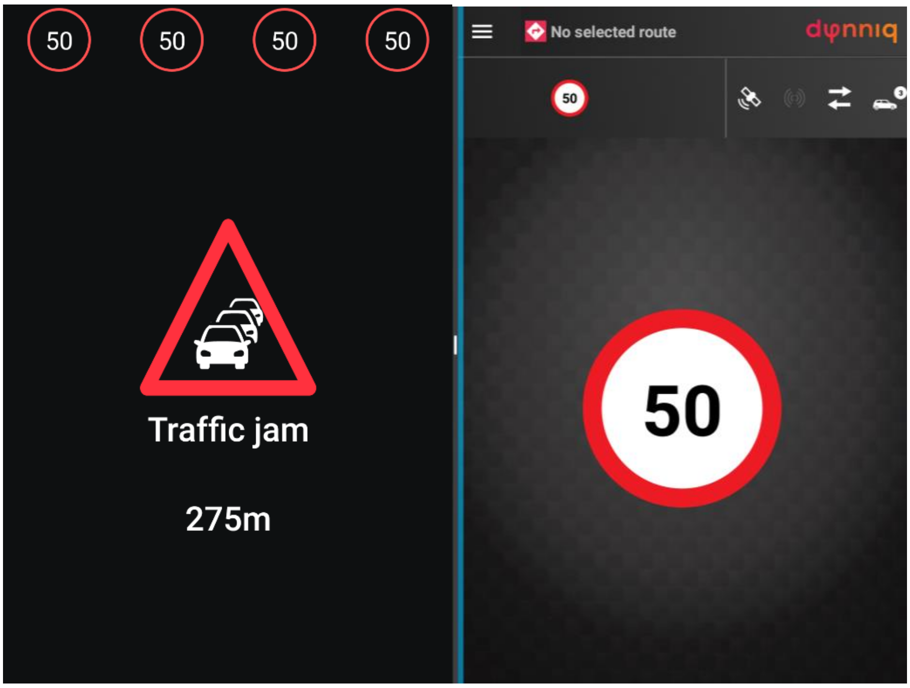


Figure 19: Cellular HMI (left) displaying Traffic Jam Ahead Warning ITS-G5 HMI (right) increases the size of the speed limit sign, when exceeding the IVS speed limit

The ITS-G5 "Greenflow" HMI was used for displaying the GLOSA service during the interoperability TESTFEST. It supported displaying the current status and indicating the time-to-red/green (Figure 20). A speed advice or speed limit was only shown when it was provided by the infrastructure in the SPATEM. For testing the GLOSA service over the cellular channel, the “Greenflow” HMI was configured to connect to a temporary service provider. This provider was then subscribed to the IF2-servers in Flanders and the Netherlands.

Figure 20: Traffic light status with time-to-red/green indication in the Greenflow HMI

Through the diagnostics web-interface HMI of the OBU (Figure 21), it was possible to manually generate warning messages. This web-interface also displayed a distance indication for upcoming signs (here "in 100m") in the awareness zone of the IVI messages. This interface was used for debugging and testing the services.

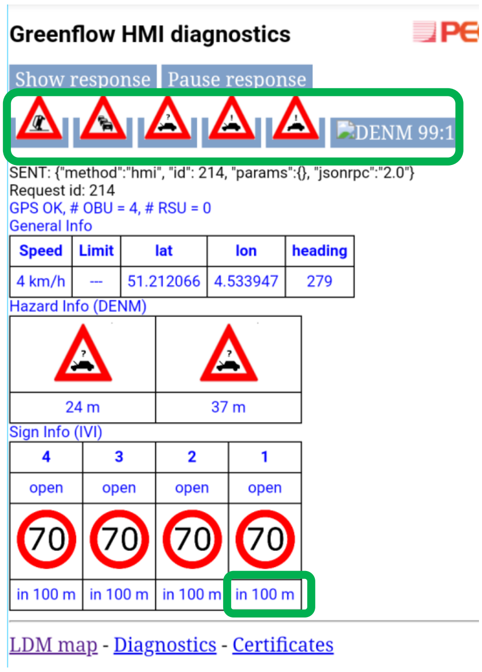


Figure 21: Diagnostics HMI, with buttons for manual event generation

3.4.6 Security and PKI deployment

In October 2018, BE/Flanders created a preproduction RCA, EA, AA *BE-FLANDERS TEST* for the duration of the InterCor project. As specified in the Milestone 5 document, the certificates were according to ETSI TS 103 097 v1.2.1.

The Flanders PKI supported the following ITS-AIDs in Enrolment Authority (EA) and Authentication Authority (AA): CAM (36), DENM (37), SPAT (137), MAP (138), IVI (139).

For the Cross-border Interoperability TESTFEST, a common Certificate Trust List was created to with all four national InterCor Root Certificate Authorities were added (See Milestone 7). After the TESTFEST, this common InterCor trust was kept operational for continued cross-border interoperability until the end of operations.

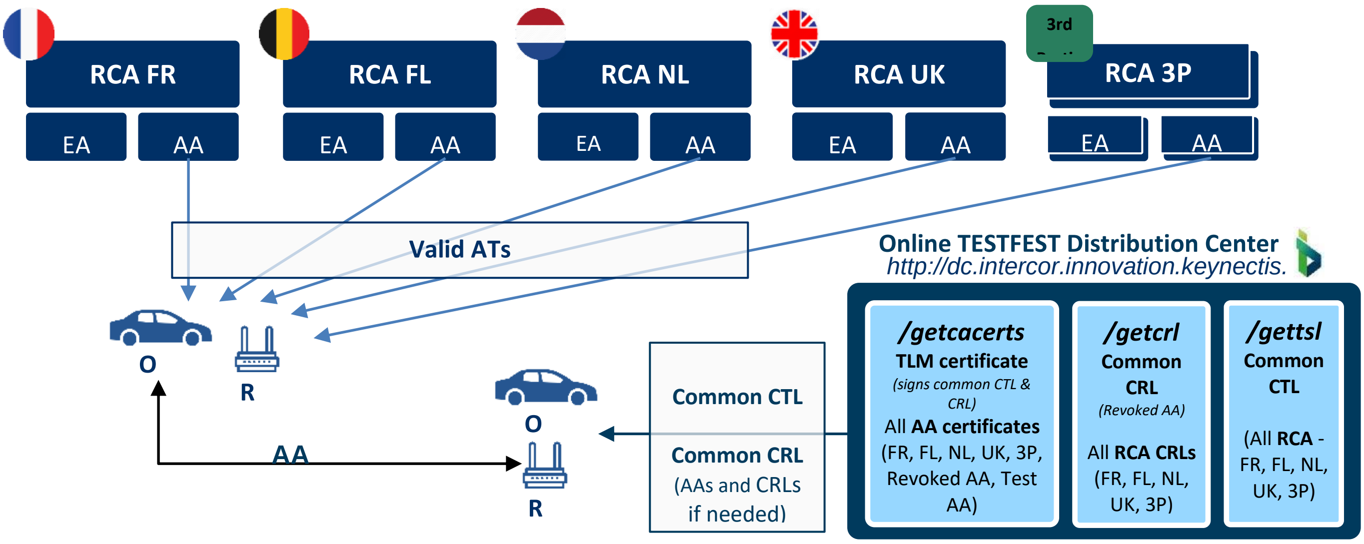


Figure 22: InterCor PKI during operations

Authentication Ticket certificates (AT's) had a validity of 1 year. The operations in Belgium-Flanders did not use an HSM in the ITS-G5 OBU, and did not use automatically rotating AT's. The AT's, trusted InterCor RootCA's of all 4 Member States and revocation lists were manually installed on the units. The units were capable of automatically retrieving the intermediate certificates of the Authentication Authorities (AA).

Messages sent by the central C-ITS server over the Flanders IF2 interface were not signed. The IF2 communication was secured by using TLS, password protection and white listing, according to the "'InterCor Milestone 4 - Common set of upgraded specification for Hybrid communication' (sub-activity 2.1b)."

3.4.7 Data Collection

Vehicle and infrastructure data for evaluation was automatically collected.

Getting correct logs was a lot harder than expected. A lot of changes, tests, analysis and validation-cycles were needed. 'Small' updates to the applications often had an unexpected impact on the logging.

The start of the detailed analysis of the log data was delayed until July 2019, because the Flanders' evaluation team had expected human readable data, and received ASN.1 structured data instead. Even though the ASN.1 format was part of the InterCor Common Log Format, this was resolved when one of the partners converted the data into human readable data.

3.4.7.1 ITS-G5 Data Collection

The ITS-G5 on-board-units and roadside units logged all communications in a pcap format, which were automatically converted to logfiles in the InterCor Common Log Format.

Additionally, HMI and security events were logged. The HMI logs were not entirely according to the InterCor Common Log Format; however they were sufficiently clear to be used for evaluation within Flanders' project.

There were several issues obtaining complete logs. For example, due to the some bugs in the logging-scripts, which were detected very late in the project, several logs were automatically overwritten. Some data was then reconstructed based on the pcap data.

3.4.7.2 IF2 Data collection

Data collection for what was made available over the IF2 interface, was very similar to the data collection of what was broadcasted by the RSU's.

3.4.7.3 Cellular Data Collection

The service provider Be-Mobile exported and delivered their log data monthly. The cellular data logging also had its share of issues. For example, in the logging for IVI-messages, timestamps had to be reconstructed for the period up to September. The logfile still contained timing information for displaying the information in the awareness zone, instead of the relevance zone (see also 3.4.5.3).

This was corrected in an update in October, after which another logging issue was introduced which caused the logging interval to be increased from every 1 second to every 3 seconds, and in case of low battery even to every 10 seconds. This was remedied when detected in the next batch of logfiles.

3.5 Operations

3.5.1 Duration of pilot operation

Flanders' InterCor Pilot operation ran from the start dates in 3.1 (December 2018-March 2019) until the end of December 2019. The cellular IVS service is planned to be kept operational until at least November 2020.

3.5.2 Active vehicle fleet

Table 2: BE/FL Vehicle fleet

Number of vehicles	Dec 2018 - March 2019	March – July 2019	Aug - Dec 2019
Dynniq ITS-G5 OBU	3	3	4
Cellular Truckmeister app (Be-Mobile)		1	4

Two of the cellular users were stationed in Ghent, using the application in the southern part of Flanders. The other users were mainly stationed in the Antwerp province.

Figure 23: Fleet consisted of vehicles of the Agency of Roads and Traffic.

A dedicated session with 11 test drivers to assess the impact of the services was organised in October. More details are available in the Milestone 13: InterCor Evaluation Report.

4 Pilot operation in France

4.1 Location and services of the French pilot

In France, the pilot area is located on approximately 400 km of roads in the North of the country. It has been designed to extend the coverage of SCOOP@F from Paris towards the North, including A1 Paris-Lille, A25-A16 Lille-Dunkirk/Calais and A22 Lille-Belgian border and the outer Paris ring road. This involves 3 road operators: 2 public road operators part of the French Ministry (DIRN and DiRIF) and 1 private road operator (SANEF), concessionaire of A1.

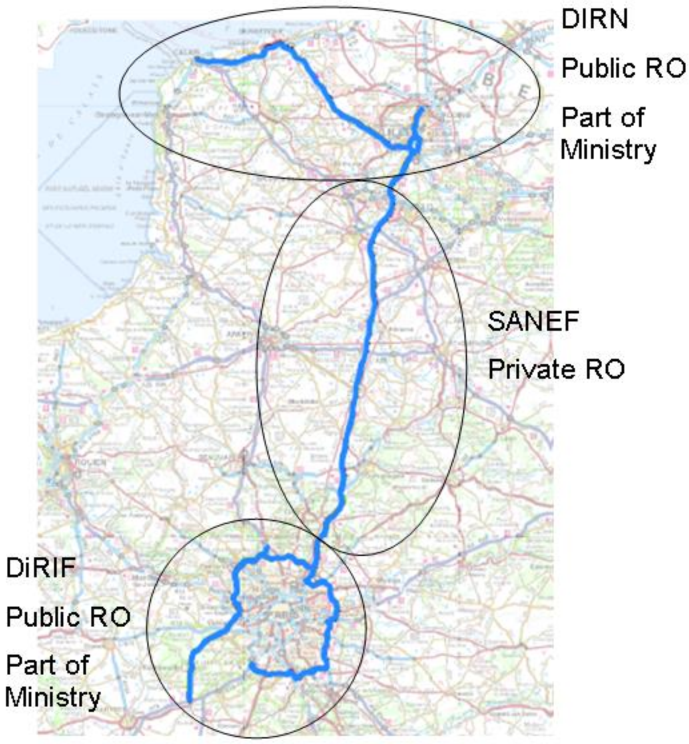
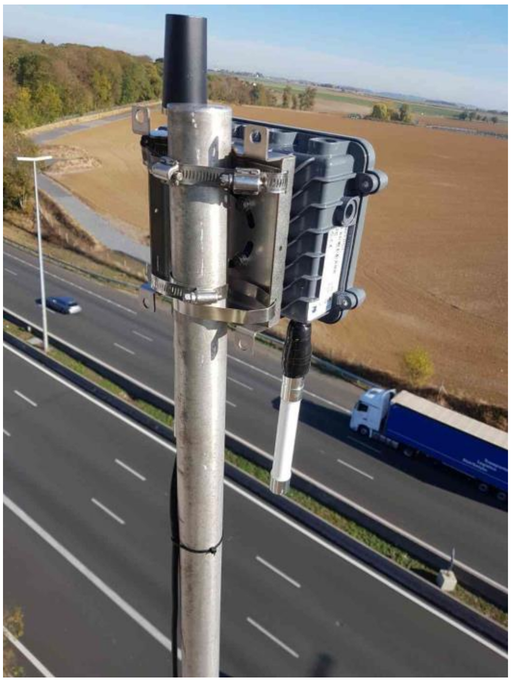


Figure 24: Total pilot area in France, with the 3 road operators involved

All three road operators have done the necessary developments to connect their Traffic Management Centre to the Road Side Units and to a national cellular node, through a dedicated platform. In total:

- SANEF has deployed 7 RSU on A1 and A2 motorway sections.
- DIRN has deployed 35 RSU on A22, A25, A16 and the connecting axes RN356, RN225, RN22) and has equipped 50 of its vehicles with OBU.
- DiRIF has deployed 4 RSU on different sections of the outer ring road: N10, A12, N184 and N186.



Road side unit on a pylon in Chennevieres-les-Louvres (A1)

Road side unit on a pylon in Esquerchin (A1)

Road side unit on a VMS in Vendeville (A1)

Concrete foundation for a road side unit on A25

Figure 25: Pictures of a few RSU installations

The French pilot covered the following services:

Table 3: Services deployed on the French pilot

Service	Use case	Pilot duration
RWW	Lane closure or other restrictions	01/04/2019 – 29/02/2020

	Alert planned closure of a road or a carriage way	01/04/2019 – 29/02/2020
	Alert planned road works – mobile	01/04/2019 – 29/02/2020
IVS	Embedded VMS	01/04/2019 – 29/02/2020
PVD	Traffic data collection	01/04/2019 – 29/02/2020
	Probe vehicle data on detected/declared events	01/04/2019 – 29/02/2020
MCTO	Multimodal ETA for cargo optimisation	01/04/2019 – 29/02/2020
	Dock reservation	01/04/2019 – 29/02/2020
Truck Parking	Information on parking slots availability	01/04/2019 – 29/02/2020
GLOSA	Time-to-green information and speed advice	*Unsuccessful attempt*

Besides, Hazardous Location Notification (HLN, also called on-board signalling of hazardous and unexpected events) was deployed in accordance with national specifications, France being the only MS deploying this service in InterCor. The pilot duration was the same: 01/04/2019 – 29/02/2020.

4.2 RWW, PVD, HLN, IVS

Road Works Warning, Probe Vehicle Data, Hazardous Location Notifications and In Vehicle Signage have been deployed in an interoperable manner with the SCOOP@F specifications, allowing the SCOOP@F vehicles from PSA and Renault to benefit from these services on an extended area.

Figure 26: Vehicles deployed by PSA and Renault within SCOOP@F

These vehicles have been sold to real customers as part of SCOOP@F to ensure naturalistic driving. The technical evaluation of SCOOP@F has indeed confirmed that these vehicles have been travelling a lot on the InterCor pilot.

Figure 27: PVD (CAM messages) emitted by PSA and Renault vehicles

For RWW and HLN, the received messages could be displayed on an embedded HMI, also allowing declaring events as part of the PVD service.

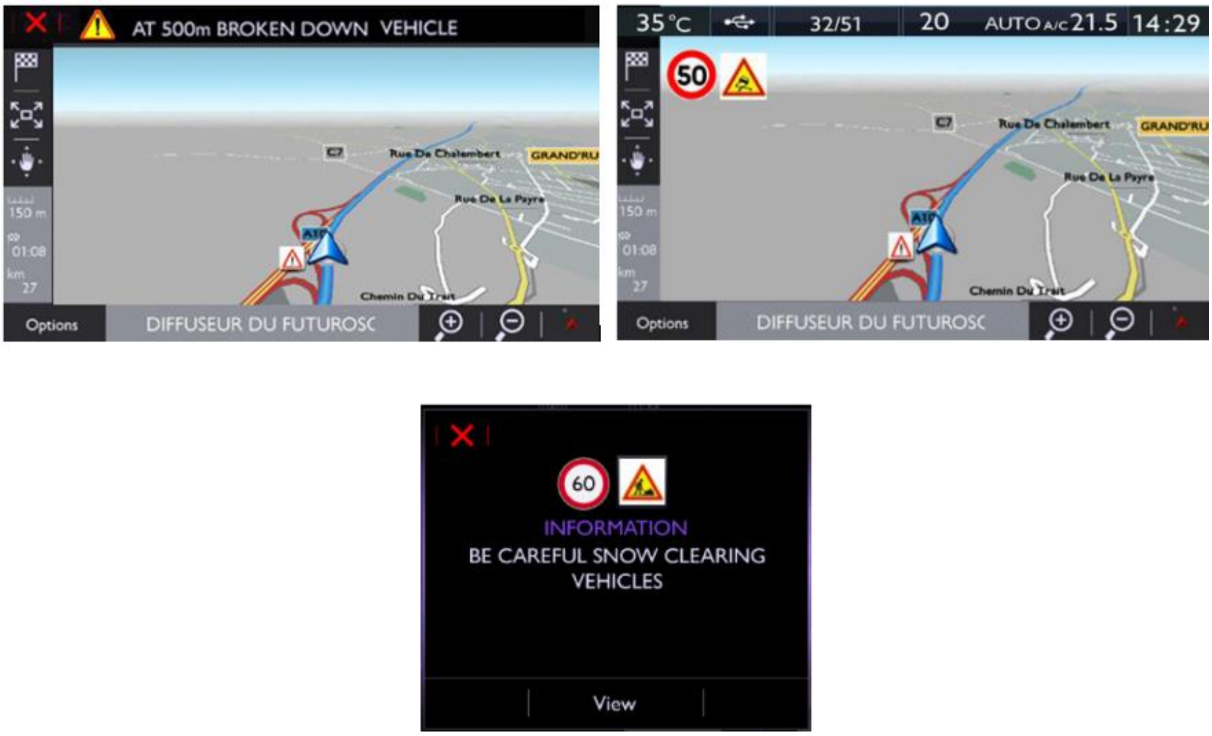


Figure 28: PSA HMI

Figure 29: Renault HMI

IVS was available on a dedicated HMI, only on vehicles equipped within the second wave of SCOOP@F.

4.3 MCTO

In preparation for the logistics services pilot in Northern France, regional InterCor partners i-Trans and DIRN organized several calls for participants, starting in 2017. These took the form of public meetings to which were invited:

- Logistics terminals and hubs (Port of Dunkirk authority, Port of Dunkirk's container terminal "Terminal des Flandres", Port of Calais & Boulogne authority, Eurotunnel, Ports of Lille, multimodal platform Delta 3 in Dourges),
- Individual road haulage companies (Bogaert, Allan, Marquis, Depeauw) and in a representative capacity their professional syndicates FNTR (Nord, Pas-de-Calais & Picardie offices) and OTRE,
- Local institutional authorities with an interest in smart freight and smart transports (Dunkirk Urban Community).

One matching pair of Terminal and Transporter could thus be engaged, the Port of Dunkirk container terminal "Terminal des Flandres" and a local road haulage SME Transport Bogaert. Their engagement was officially notified by the Ministry and they took part in the MCTO pilot between April 2019 and February 2020.

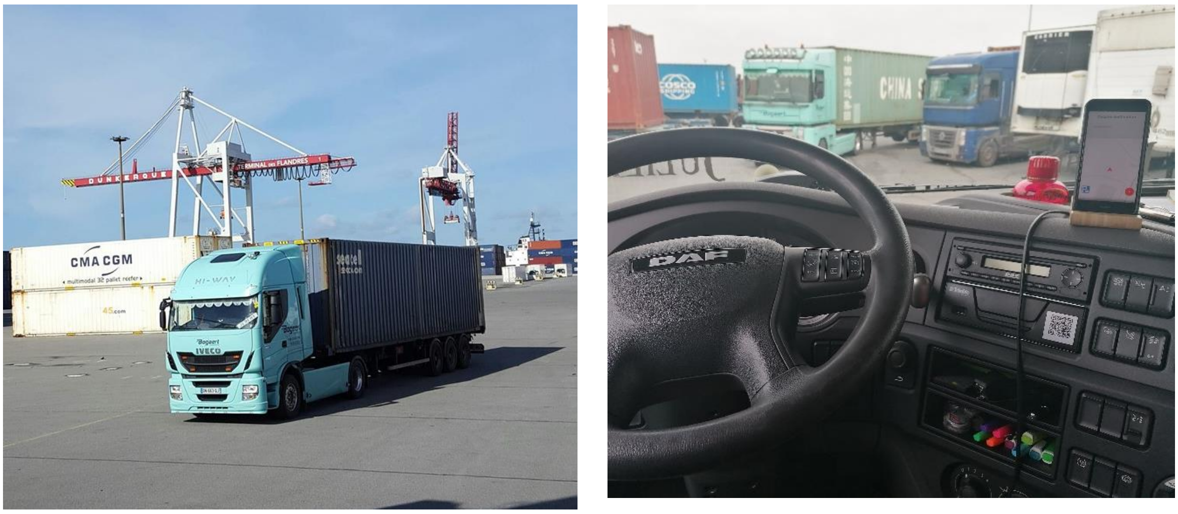


Figure 30: A truck equipped with the smartphone app

The service was delivered through cellular networks only, through a smartphone application.

The first period of the operation focused on technical integration in order to ensure that the solution delivered to operators and evaluators is of good quality in real conditions. This was achieved through several meetings of the NeoGLS and MGI partners with the Transport Bogaert (road haulage SME based in Quaëdypres). After initial identification of the correct information to be used, download and explanation of the MCTO app on the drivers' smartphones, regular phone meetings were held in order to monitor the demonstrator's advancement status.

The second phase consisted in testing the service in real operational conditions between Transport Bogaert and an identified Terminal. This operation involved then also the Terminal des Flandres (Seaport container terminal at Dunkirk port). This period started from August 2019. Bogaert Transport drivers have installed eMCTO / NOSCIFEL application in order to check their slot validity to deliver or pick-up a container at Terminal de France. The slot data is published to NOCSIFEL by MGI cargo community system AP+ and sent to national C-ITS platform. Once a slot is validated the NOSCIFEL platform calculates automatically an ETA (estimated time of arrival) displayed on the NOSCIFEL Dashboard. The ETA is updated in real time according to truck geographical position.

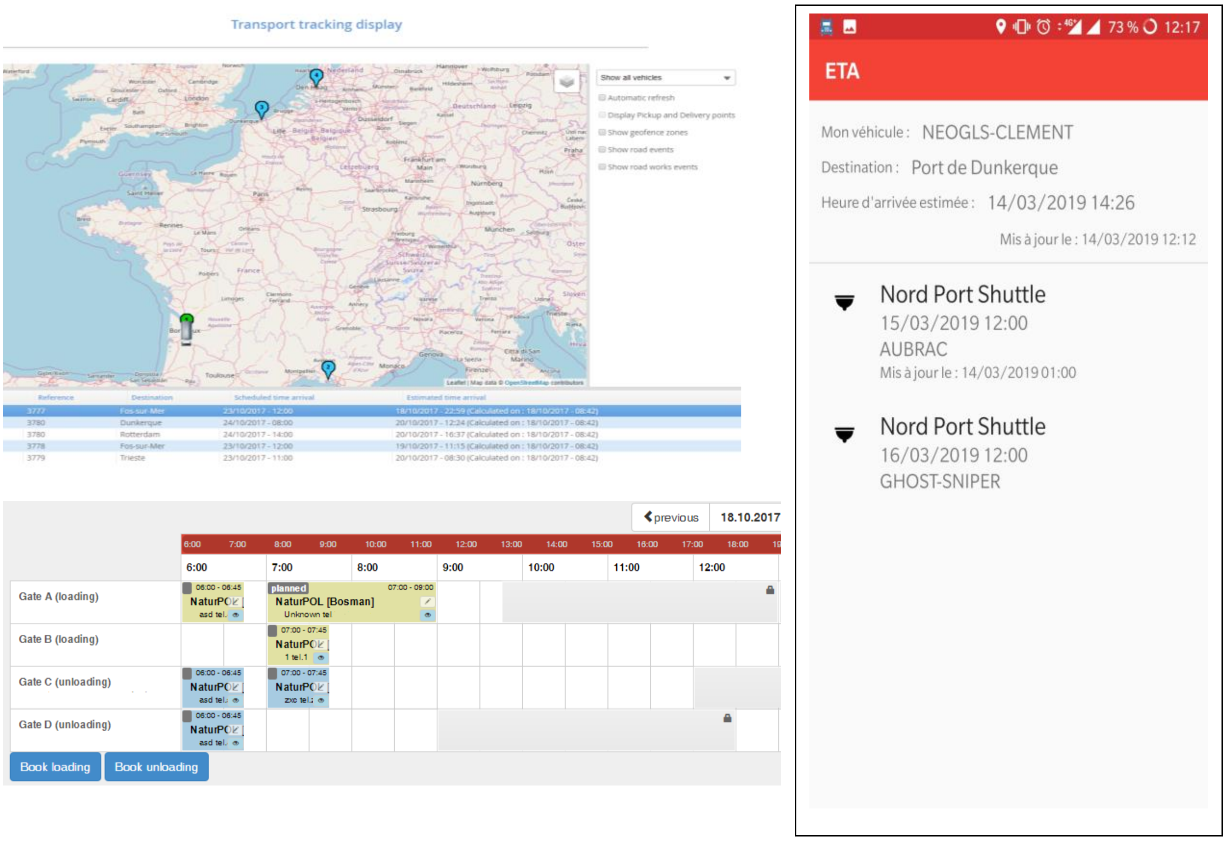


Figure 31: ETA and slot reservation at the terminal (left), on-board HMI (right)

A fleet of ten drivers of the transport company Bogaert tested the application from August to the end of the evaluation period. Driver participation was voluntary, which resulted in less drivers participating than initially planned (30), but with certainly better output given their participation resulted from interest on their part in C-ITS service on board.

4.4 Truck parking

For the purposes of the Truck Parking services, information on availability has been sent from 12 truck parking areas in the southern part of motorway A1, that are equipped with counting devices.

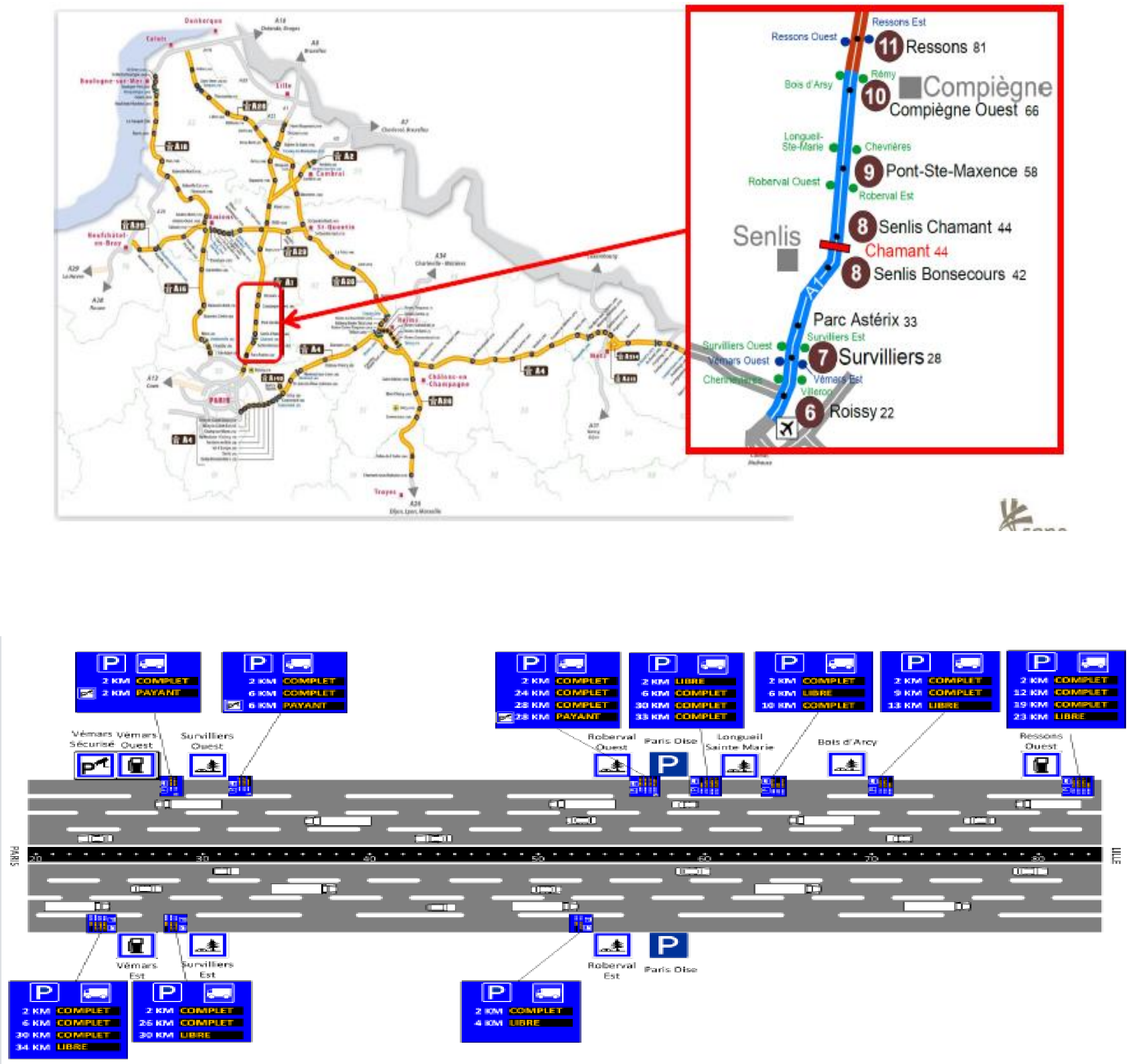


Figure 32: Truck parking areas involved in the TP service

This information was available through the same smartphone app as MCTO.

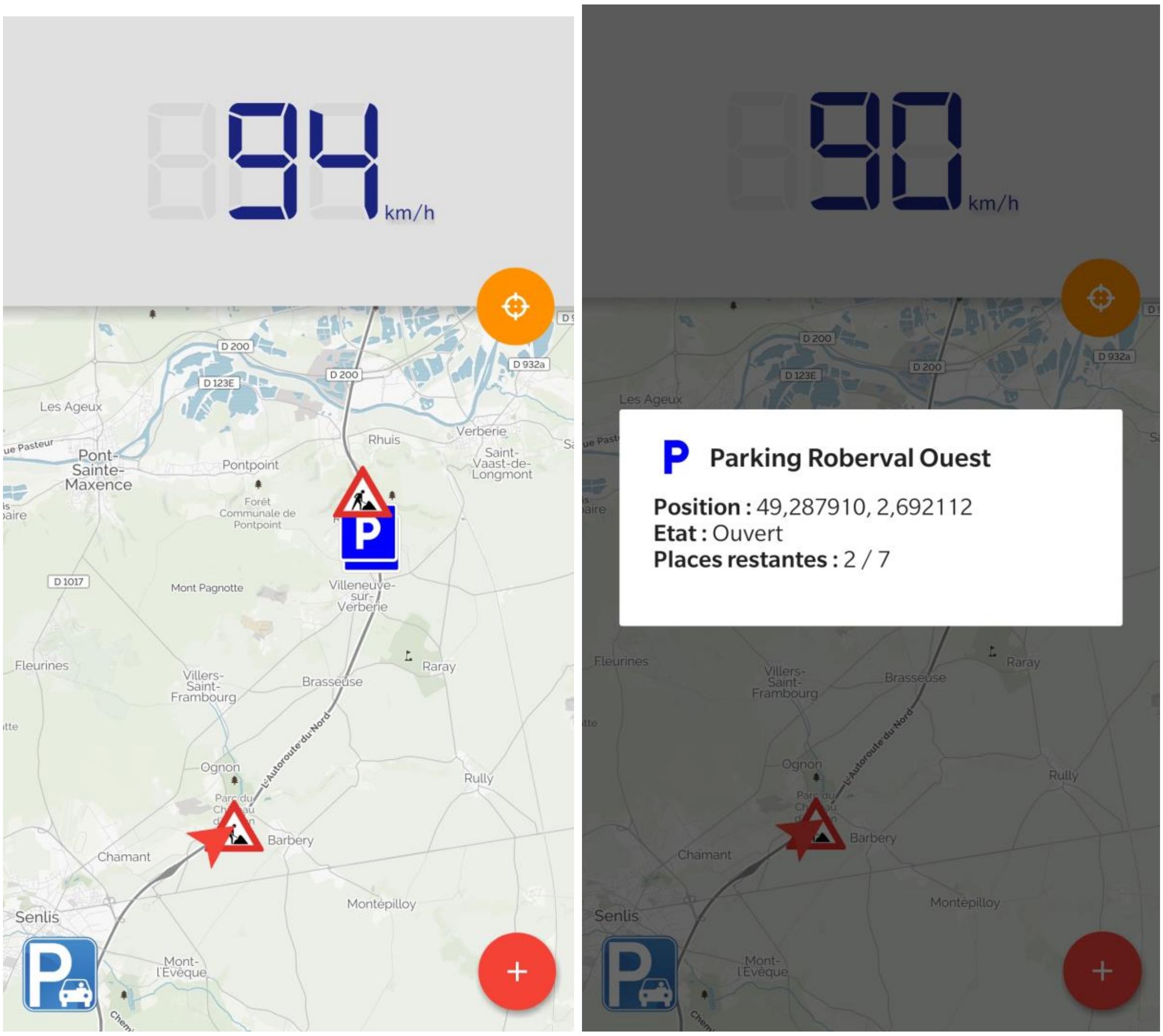


Figure 33: On-board HMI for TP

4.5 GLOSA

GLOSA is a service often deployed on traffic lights in urban environments, but has never been tested on ramp metering lights. Such a configuration has been tested in InterCor on the DiRIF network.

Ramp metering technology allows the road operator to temporarily, and automatically, contain and release the flow of vehicles wanting to enter the freeway depending on the amount of traffic. The main goal is to provide an optimal fluidity on the portion of the freeway with such equipment, with a waiting time on the slip-road inferior to two minutes. Around 75 of those are currently deployed on the DiRIF network, mostly for the A86 freeway.

Tests were carried out on the ramp metering lights localised closed to the DiRIF control centre (79c avenue du Maréchal Lattre de Tassigny, 94000 Créteil). As the monitoring station were off road, access was easier for NeoGLS experts. They were supposed to install a peculiar use-case to monitor the cycle ("contain" and "release" period) of this access control. Thanks to that information, they would have been able to duplicate the signal to synchronise the speed of incoming vehicles to the ramp metering light cycle, granting them a smooth access to the A86.

However, despite the fact that the installation took many months to ensure the system's adequateness, duplication was not technically possible. Contrary to a traditional traffic light, ramp metering lights may be shut off when not necessary or when queuing traffic goes too far on the secondary network. For each ramp metering light, configuration may also vary depending of the impending or current traffic jam.

5 Pilot operation in The Netherlands

5.1 Location and services of the Dutch pilot

In the Netherlands, the pilot area is situated in the southern part of the country and near the city of Utrecht (see figure below). The area consists of the motorways A15-A16 Europoort-Rotterdam–Breda-Belgian border, the motorways A58-A2 Breda-Eindhoven, motorway A67 Belgian border-Eindhoven-Venlo, motorway A2 and the N201 near Utrecht, as well as a number of urban roads in the city of Helmond.

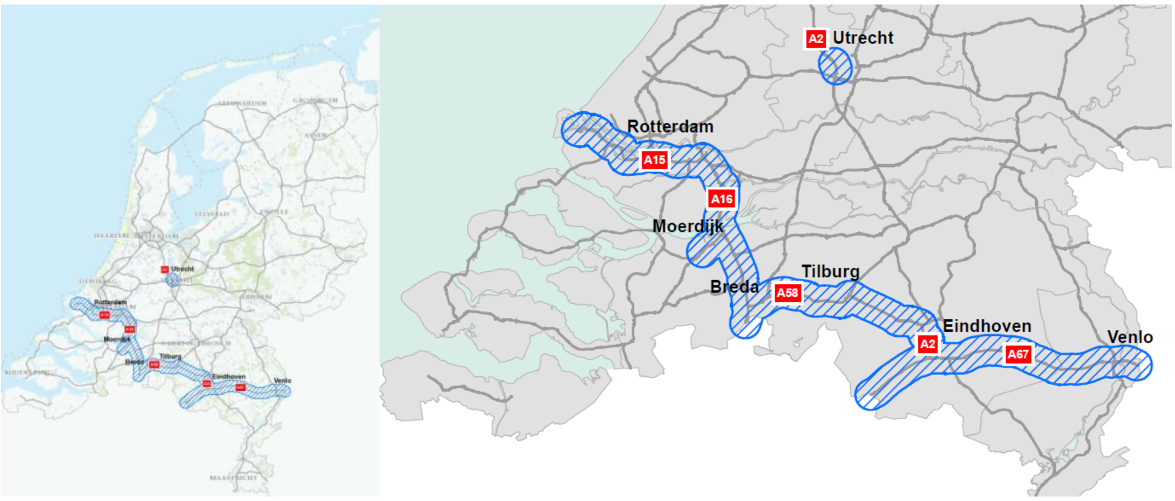


Figure 34: Total pilot area in the Netherlands

The following use cases were active during the pilot operation:

1. Road Works Warning (RWW), In-Vehicle Signage (IVS) - the total pilot area with special attention to motorway A16 & Probe Vehicle Data (PVD) - motorway A16.
2. GLOSA & Truck parking (region of Noord-Brabant);
3. MCTO (Port of Rotterdam area);
4. Tunnel Logistics (Utrecht region).

In the Netherlands an incremental approach was chosen for the InterCor pilots. The Dutch pilots can be seen as a process growing from delivering a first service with ITS-G5 communication in real traffic in November 2016 to full pilot operation with all services with cellular and ITS-G5 communication in 2018/2019. In this process not only extra services were gradually added over time, this approach also allowed to work in a ‘learning by doing’ way and to adapt to the alignment of specifications during the InterCor project in a flexible way.

A previous deliverable of the InterCor project - Start of pilot operation (M9) – describes the growing process of pilot operation in the Netherlands from November 2016 until the issue of this deliverable in March 2019. This chapter focuses on the work after this period, until the end of the Dutch pilot operation.

5.2 Use cases RWW, IVS, PVD

5.2.1 Improving and extending the services

The M9 deliverable already described a cellular RWW service using the functionality of a popular existing app with traffic information (‘Flitsmeister’), building on the work of the ‘Talking Traffic’ project. A further cellular RWW service was built based on existing backend systems and data within the Rijkswaterstaat architecture and is currently deployed for the total pilot area Rotterdam-Venlo.

Within the Rijkswaterstaat architecture Enterprise Service Bus, a service was built which creates DENMs using the data source ‘Flister’. Flister is an organisation in the Netherlands that collects and distributes ‘Early Warning Data’ from the Dutch road network. The data is collected for all objects and special vehicles that could pose a danger on the road. This includes ambulances, police, traffic officers, trailers and crash absorbers. The service providers ‘Monotch’ and ‘V-Tron’ import the messages (DENMs) from Rijkswaterstaat and deliver the communication towards the road user.

5.2.2 Collecting data for evaluation

For the pilot an approach was designed to answer the InterCor main evaluation questions; a combination of naturalistic driving and controlled driving. The naturalistic driving (study into driver behaviour during regular every day trips) made it possible to test the system over a longer period in many different situations. A disadvantage of naturalistic driving is that it is unsure how many times the equipped cars pass a location with e.g. road works warning. Especially because in the Netherlands road works on motorways mainly take place in off-peak times, so that it is less likely that test drivers will encounter road works during regular driving. To be sure to have sufficient ‘hits’ during actual road works; it was decided to organise controlled tests on the A16 test site during selected evenings with actual road works.

This combined approach of naturalistic and controlled driving makes it possible to collect data on IVS and RWW within a limited period of time. Naturalistic driving often takes place during peak hours, during which the dynamic speed signs are the most active. This provides much data on the performance, impact and behaviour related to IVS, while the controlled drives during a number of selected evenings with active roadworks provide the data on RWW.

The complete setup for the evaluation of RWW and IVS can be summarised, as follows:

- Piloting ITS G5 communication technology
  RWW: Combination of naturalistic and controlled driving
  - 10 vehicles, in use for naturalistic driving, except during the weekends/nights with controlled driving;
  - Controlled driving (3 nights or weekends) during real roadworks;
  - Goal for controlled driving: 200 passages on the track with roadworks, each person drives with and without the RWW service (Human Machine Interface visible/ not visible);
  - Questionnaires for user acceptance evaluation to be filled out, directly before and after the controlled drives and before and after the period of naturalistic driving.

  IVS: naturalistic driving during a long period
  - 3 months with in-car advice
  - 3 months without in-car advice
- Piloting Cellular communication
  RWW and IVS: naturalistic driving
  - Vehicles driving with different ways of communication
  - collection of data for complete pilot area
  - Questionnaires

To execute this evaluation plan, 14 vehicles have been equipped additional to the already equipped C-ITS-Corridor test vehicle.

- 10 vehicles from the Rijkswaterstaat fleet have been allocated for this project;
- 2 vehicles of traffic officers have been equipped;
- 2 vehicles of subcontractors have been equipped.

Figure 35: Fleet of 10 Rijkswaterstaat vehicles equipped with OBU and HMI and an equipped vehicle of a traffic officer

5.2.3 Technical aspects

The human machine interface is a crucial part of the system. During a workshop with Human Factors experts a lot of information has been collected to improve the HMI that was deployed initially.

Figure 36: First used HMI in the pilot (left) and new version HMI used starting from May 10, 2019 (right)

Improvements consisted of:

- Horizontal orientation of the human machine interface, for optimal use of the available space on the screen of the tablet;
- Perspective is used to display information on the portal further downstream;
- Black background to prevent distraction and a too bright surface when driving in the dark.

Within the framework of InterCor it was not possible to meet all the demands regarding the HMI, due to technical or organisational limitations. Moreover, the users in the pilot also expressed new demands after installing the improved interface. Subjects that would need further attention are:

- Enable notification sounds, but only limited to crucial situations;
- Locate the screen in the vehicle in a better way, many users claim it was too far out of the normal field of view (in the InterCor pilot the screen was placed in such a way that it did not cover the normal instrument panel);
- Improve visibility/readability of signs, letters and numbers, users found they were too small;
- Adapt the HMI to the time of day (daylight or dark);

- Display the number of lanes always in an accurate way (in the present technical setup, this was not possible).

Some of these remaining items were solved in the third version of the HMI, especially larger signs and greater contrast in used colours of the signs.

For Rijkswaterstaat, having an own test vehicle with an InterCor specific HMI implementation has proven to be very beneficial. Because of the HMI always being operational during test runs, a few specific service performance issues emerged. Without the use of the HMI these issues probably would not have been recognised before actual deployment. The HMI turned out to be a perfect pointer for performance issues that probably would not have surfaced by analysing log data only afterwards.

The aforementioned performance issues are typically systems integration related:

- The technical system consists of a chain of several legacy and newly developed subsystems.
- The subsystems are managed by different suppliers and different sets of service levels apply.
- Because of the technical and organisational complexity of the overall system, troubleshooting is challenging.

5.2.4 Operations

Test drivers

The test drivers were recruited in different ways. Drivers for the naturalistic driving tests were found within Rijkswaterstaat; 10 employees were willing to drive the 10 equipped test vehicles as part of their regular commuting during several months. For the controlled drives, a specialised company was asked to supply 20 test drivers per test evening. All test drivers were briefed and completed a survey, both before and after the test drive. Every driver received a participant ID to be able to fill in the questionnaire anonymously. Through the ID, the questionnaire results could be linked with the data from the vehicle used by the participant. The results of these questionnaires will be presented in the M13 deliverable on evaluation.

Figure 37: Flyer for recruiting test drivers ('test drivers wanted!')

Figure 38: Briefing the participants before the test drives in the evening / participants completing the questionnaire

8 april 1e rit 21:30

Auto:	StationID	deelnemer ID	HMI
RWS 1	30211022	100	met
RWS 2	30255176	101	met
RWS 3	30215044	102	met
RWS 4	3025228	103	met
RWS 5	3025528	104	met
RWS 6	30214752	105	zonder
RWS 7	3021534	106	zonder
RWS 8	3025522	107	zonder
RWS 9	3025159	108	zonder
RWS 10	302149219	109	zonder

8 april 2e rit 22:00

Auto:	StationID	deelnemer ID	HMI
RWS 1	30211022	100	zonder
RWS 2	30255176	101	zonder
RWS 3	30215044	102	zonder
RWS 4	3025228	103	zonder
RWS 5	3025528	104	zonder
RWS 6	30214752	105	met
RWS 7	3021534	106	met
RWS 8	3025522	107	met
RWS 9	3025159	108	met
RWS 10	302149219	109	met

Figure 39: Participant IDs

Controlled drives

The project team selected 9 evenings with actual road works on the test site:

- 5, 8 & 9 April 2019 - 50 test drivers. Each evening one of the 4 tubes of the ‘Drecht’ tunnel was closed;
- 10, 11 & 12 May 2019 - 60 test drivers. These three evenings were chosen because of the works at the ‘Van Brienenoord’ bridge.
- 16, 17, 18 July 2019 - 30 test drivers.

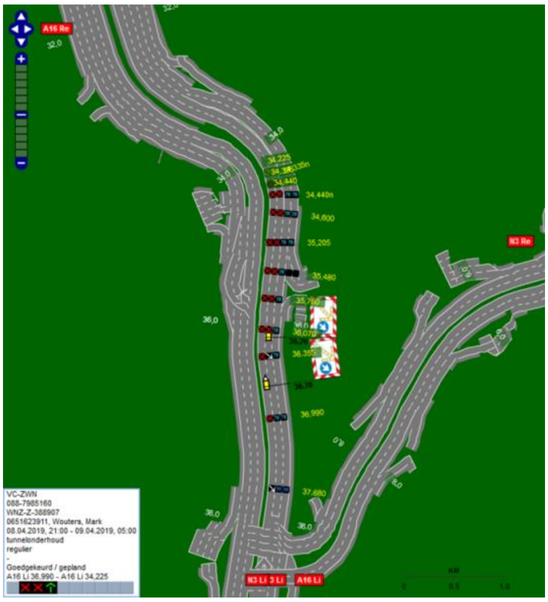


Figure 40: Example - 5, 8 and 9 April 2019 road works

This selection was done using the Rijkswaterstaat tool ‘SPIN’. Rijkswaterstaat uses the ‘System Planning and Information Netherlands’ to plan road works. This also includes the application procedure for traffic measures (e.g. road closures) by contractors at Rijkswaterstaat.

In April and May the road works started at 9:00 pm. To be sure that the road closure measures were completely implemented, the controlled drives started at 9:30. In July the road works started at 8:00 pm.

Figure 41: Impression of the controlled drives

PVD

During all naturalistic and controlled driving with the services RWW and IVS, in the background, the service PVD (Probe Vehicle Data) was operational as well. The equipped cars collected a big amount of data, sent and received by the OBU on board of the cars. Also the data from the CAN-bus was logged during the drives, in order to be analysed for evaluation.

RWW and IVS – cellular, by a service provider

Next to the activities described above, a cellular RWW and IVS service using the functionality of the existing ‘Flitsmeister’ traffic information app was set up, building on the work of the ‘Talking Traffic’ project. Information from road works and overhead VMS signs with dynamic maximum speeds was included in the app. As described in the M9 Deliverable, in August 2018 Be-Mobile introduced these services in their normal publicly available app. However, in close cooperation with Be-Mobile it was decided to use a special beta version for data collection and evaluation in InterCor. This version of the app was used by approximately 500 users during regular traffic on the total Dutch pilot area. Evaluation Data became available for the timeframe May-July 2019. A part of this group of users also completed an online questionnaire.

Figure 42: Cellular IVS service in the Flitsmeister app – 'left lane closed'

Figure 43: Cellular RWW service in the Flitsmeister app – 'trailer in 150 metres'

Workshop PVD

For the PVD service, a dedicated workshop was organised with representatives from road authorities, service providers and car manufacturers. It focused on the value of PVD, its impact on the respective organisations, the challenges and solutions. Outcome of this discussion will be shared in deliverable M13 (evaluation).

5.3 GLOSA

5.3.1 Improving and extending the service

As mentioned already in the M9 Deliverable (Start of Pilot Operations), the Dutch pilot on GLOSA consisted of two phases. The first phase till 2018 focused on GLOSA for ITS-G5. During this phase the test site was extended to 29 intersections in the city of Helmond. The second phase in 2019 focussed on GLOSA, as a hybrid service (ITS-G5 and cellular). For this phase the Province of Noord Brabant and Helmond migrated their intelligent intersection controllers to the hybrid InterCor GLOSA profile of the standards.

The preparations for the InterCor pilot GLOSA started in 2017. Following the hybrid approach that also was being taken in international context (ITS Directive and Delegated Act); Helmond step-wise invested in the capabilities of its intersection controllers. The Province of Noord Brabant and Helmond participated in a Dutch national standardisation effort that specified the architecture and interfaces of these controllers. This architecture not only defines how Traffic Light Controller (TLC) data such as SPaT and MAP is being provided to third parties, it also allows for the implementation of controller-logic, independently from any supplier-specific characteristics.

In 2018 Helmond started the process of specifying the requirements for the infrastructure underlying the InterCor GLOSA use case. The Province of Noord Brabant participated in the Dutch association ‘Standards and Practices’, ensuring that the Dutch profiles for these messages are in line with the InterCor specification of SPaT and MAP. In the same year the Province of Noord Brabant initiated a public-private R&D project, through which it could upgrade the Helmond intersection controllers at two small trajectories to the InterCor standards. Part of this project was the delivery of the InterCor TESTFEST infrastructure of the GLOSA TESTFEST in the Netherlands. In June 2018 the Helmond specifications as such have been verified and approved for further upscaling.

Figure 44: GLOSA service Province of Noord Brabant, version 1

Early 2019 the Province of Noord Brabant and the city of Helmond deployed intersection controllers in this city, according to the hybrid InterCor profile of the standards, enabling the start of the second phase of pilot operation. The Province of Noord-Brabant and Helmond provide the messages on the status of the traffic controllers. A number of service providers, who are already operational in the Netherlands, are able to process the cellular messages and provide the information on GLOSA to be displayed on a smartphone in-car. The GLOSA service in Helmond will stay active (and probably also further updated, if necessary), also after the end of the InterCor project.

5.3.2 Collecting data for evaluation

In InterCor a certain logging format has been determined, in order to carry out the evaluation of the services. The service provider, with whom the Province of Noord Brabant cooperates, has implemented these InterCor logging-specifications. The province has made TNO responsible for retrieving the data from the service provider allowing for technical verifications and evaluation.

5.3.3 Technical aspects

GLOSA pilot specifications:

- ETSI G5 Road side units (fixed solutions) – multi-vendor;

- > 50 Vehicles equipped with OBUs (trucks, emergency vehicles);
- Based on standards ETSI for Wi-Fi-P and open Talking Traffic iVRI (intelligent Traffic Light Controller) specifications;
- iVRI capable Roadside ITS Station sending SPaT, MAP;
- Central Unit for generating and/or processing required DENM, CAM, IVI messages according to iVRI Talking Traffic architecture;
- Central cloud-data unit according to InterCor IF2 specifications operational since 2nd half 2018;
- Interfaces with several existing subsystems (data collections);
- Early 2019 20 OBU and test drivers according to full hybrid InterCor Specifications.

5.3.4 Operations

To carry out the GLOSA pilot, the Province of Noord Brabant has acquired users of this service through its existing relation with a number of transport companies in ongoing projects. The operations started in 2018 (phase 1) with about 50 vehicles using priority and GLOSA services. In 2019 (phase 2), the work has been continued with 20 test drivers. There were 10 users driving for a period of two months. In May 2019, 10 instructed users tested the GLOSA service during a special test-day. In addition to the user questionnaires that were completed, several of the 10 test-drivers drafted a log, further facilitating the evaluation-analysis.

As stated before, after finishing the InterCor project, the GLOSA service in Helmond will stay active. Also after the InterCor-project service providers will be able to use data from the traffic controllers to continue their services to the end-user.

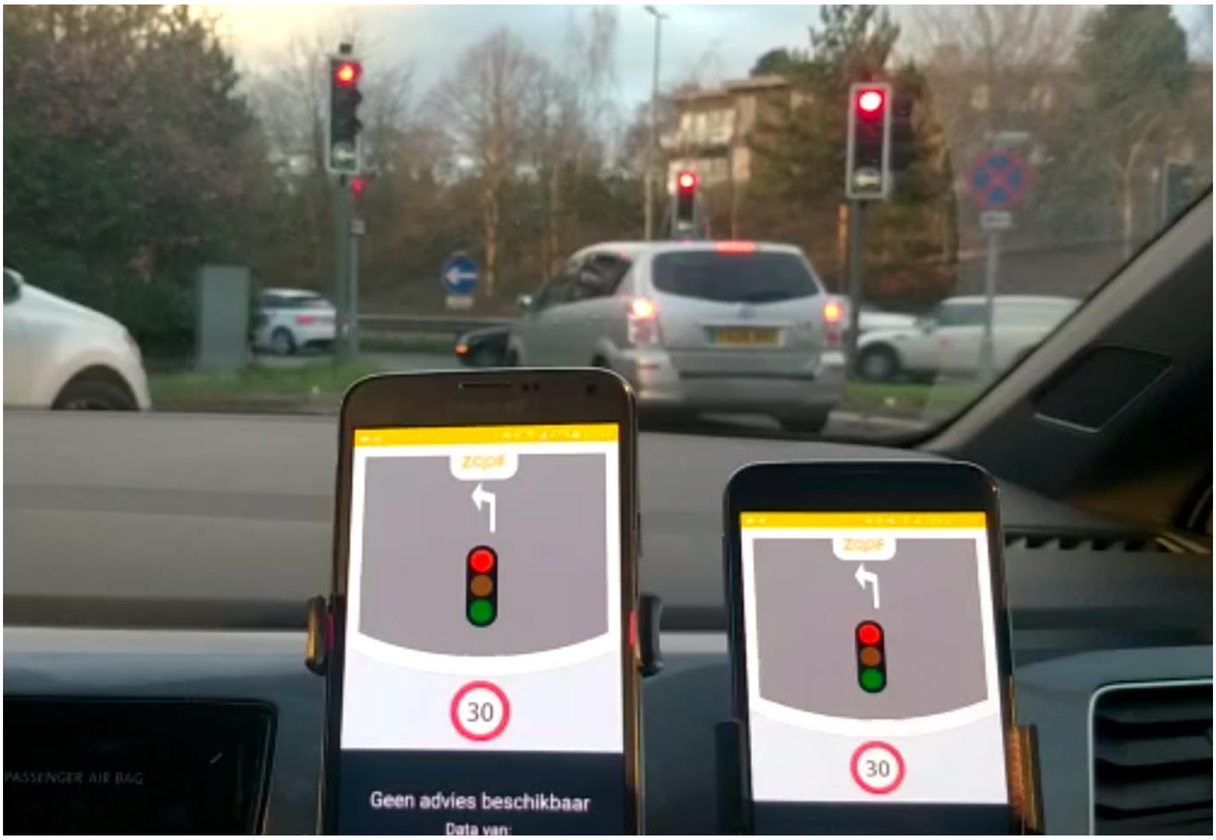


Figure 45: GLOSA service Province of Noord Brabant, version 2

5.4 Truck parking

5.4.1 Improving and extending the service

The truck parking pilot preparations started in 2018. The Province of Noord Brabant carries out a diverse set of measures including improvement and extension of parking facilities, coordination of the cooperation between various stakeholders involved and information services. The InterCor activities on Truck parking are to improve the information services by providing a technical basis for interoperability for the exchange of truck parking data between different service providers, and across borders. The truck parking service differs from most InterCor projects in the way that it does not provide information which is tightly tied to place and time of the vehicle. The purpose is to provide information for the trip planning, and it has to be displayed long before the truck arrives at the actual parking area.

The Dutch approach is to facilitate the existing truck parking ecosystem rather than to set up a new one. The existing truck parking ecosystem is built up of international service providers that provide an international service to the truck drivers. Interoperability across borders at the end-user is realised by these service providers that have international coverage. However, the exchange of dynamic truck parking data is not (yet) internationally organised. In 2018 the Province of Noord Brabant had the truck parking data-interface implemented through which third parties can access dynamic truck parking data in DATEXII format.

In 2018 this interface has been tested against operational requirements and compliance with the DATEXII EU truck parking specifications. Early 2019 this was followed by a test of the interface against the InterCor truck parking data specifications. An expert in this field compared the different values in the source data with the results in the DATEX-II for the values that were expected based on the InterCor specifications. Examining this for all the defined DATEX-II elements and for all relevant combinations of values resulted in a complete set of test cases for the Truck Parking data. In this way it could be proven that all mandatory fields are present and used in the right way.

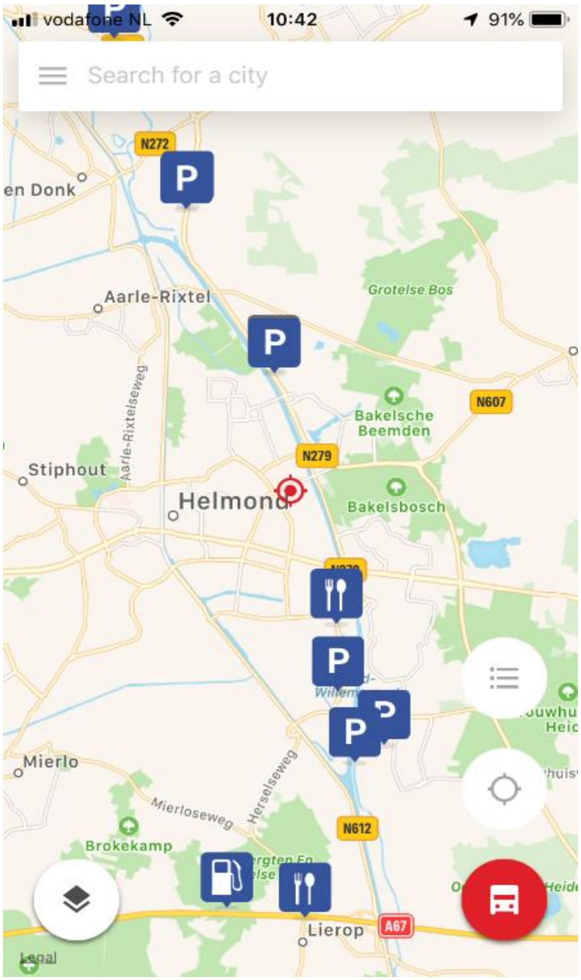


Figure 46: InterCor Netherlands Truck Parking Service

The service provider who was involved by the Province of Noord Brabant, Truck Parking Europe, implemented the static data about the parking area correctly as described in the DATEX-II specification. The dynamic data was available in a proprietary format of the service provider, but it was not implemented in the right way in the DATEX-II format. When this problem was identified, the service provider released a new version with both static and dynamic data available in DATEX-II. This new release still needed a minor correction for the DATEX-II field “occupancy”, but this could be implemented the same day (21 March 2019).

5.4.2 Collecting data for evaluation

In June 2019 the service provider distributed the InterCor questionnaire, in this way providing the basis for user acceptance evaluation of the truck parking pilot. This user-acceptance survey was conducted among 337 truck drivers using the application from the service provider. This evaluation is based on the experience of internationally operating truck drivers that have ample experience with the truck parking service.

5.4.3 Operations

The Truck Parking service has been operational since 2017. In 2018 the Province of Noord Brabant had the truck parking data-interface implemented through which third parties could access dynamic truck parking data in DATEXII format; technically this did not modify the truck parking service itself. It increased the data-availability because of the exchangeability of parking data between different service providers. Since March 2019 this InterCor truck parking data interface enables international truck parking data-exchange between service providers. The Truck Parking service will continue to be operational, also after the end of the InterCor project.

5.5 MCTO

5.5.1 Improving and extending the service

The pilot operation of the Multimodal Cargo Transport Optimisation (MCTO) service in the Netherlands was connected to the Rotterdam Mainport Traffic Monitor project, which started in autumn of 2018. Since the start the organisations TLN and Simacan, working on this part of the InterCor project, did many efforts to attract transport companies to join the Rotterdam Mainport Traffic Monitor. This resulted in a substantial increase of the number of vehicles that joined the project (see the figure below).

The trucks share a minimal set of data which includes their Location, Vehicle ID, Trip, Route and Shipment. This set of data is derived from the on-board units of the trucks or the Transport Management System and goes via a cellular network to Simacan. This data is harmonised with the OpenTripModel. This is a simple, free, lightweight and easy-to-use data model, used to exchange real-time logistic trip data on the web. It makes it easier for shippers, carriers, software vendors, OEMs, and truck manufacturers to create new multi-brand applications and services[5].

The data is used to show the vehicles in the Traffic Monitor and to calculate waiting times.

[5] For more information see https://www.opentripmodel.org/

Based on the results until now, further extensions of the services are foreseen. This may become a part of a next phase of the Rotterdam Mainport Traffic Monitor project. Another approach could be to deliver the data to other platforms that will develop and market these additional new services.

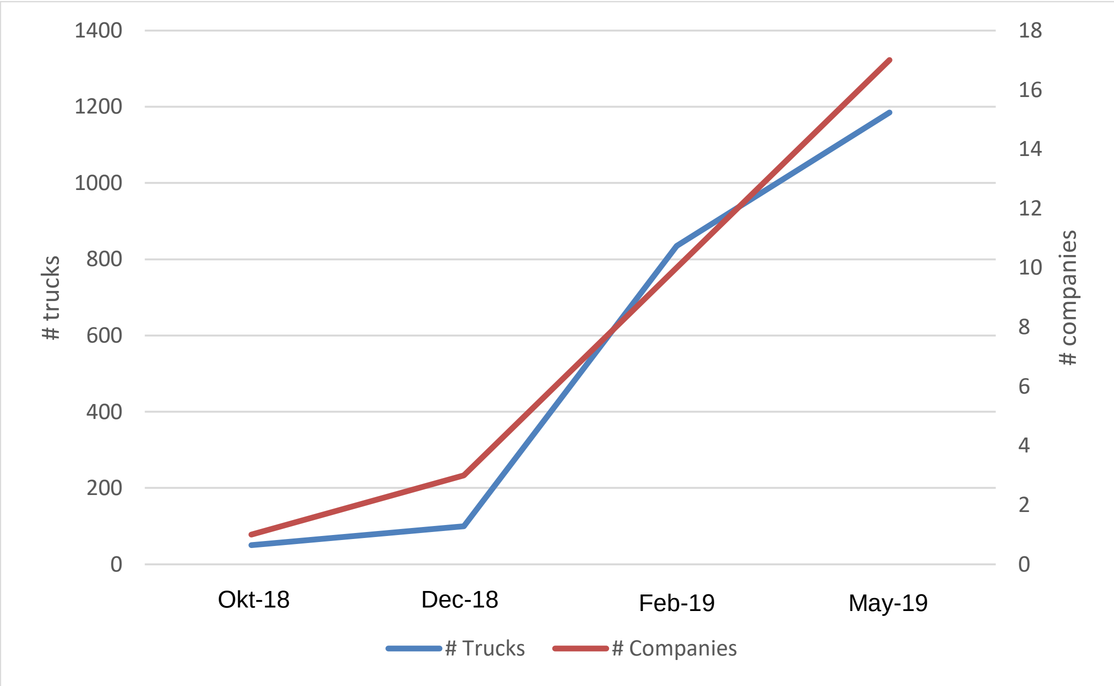


Figure 47: Graph of participating trucks and transport companies

5.5.2 Collecting data for evaluation

The evaluation of the MCTO service in the Netherlands focussed on the planners of the trips in the transport companies, who make use of the service. The planners filled out a questionnaire, which was aligned with French partners in InterCor. In this way, a comparison of experiences between the Dutch and French MCTO service in InterCor was enabled. Through interviews information is gathered on working with the services and the experiences of transport companies and terminals. Furthermore, the trip data of participating trucking companies have been analysed.

5.5.3 Operations

The MCTO service applies to the participating trucks in the pilot area, consisting of the main roads through the Port of Rotterdam, which are motorway A15 (between Junction Ridderkerk and Oostvoorne) and the N15 (Oostvoorne and “Tweede Maasvlakte”). These roads are highlighted on the map below (blue line).

TLN, Port of Rotterdam and Simacan aim to implement the service, and not just to run the pilot. Therefore, participating truck companies are expected to be connected to the project and the Monitor, also after the InterCor project has finished. All truck companies are frequent users of the same corridor in the Port of Rotterdam, as shown below

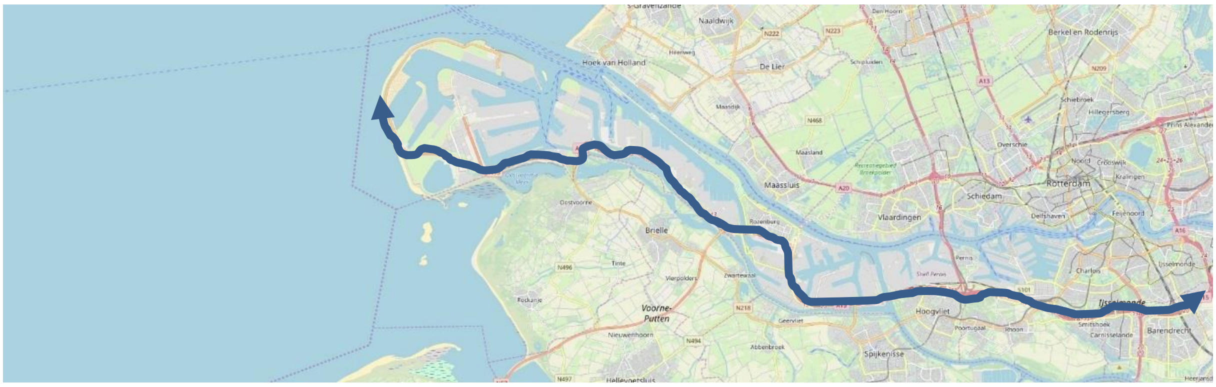
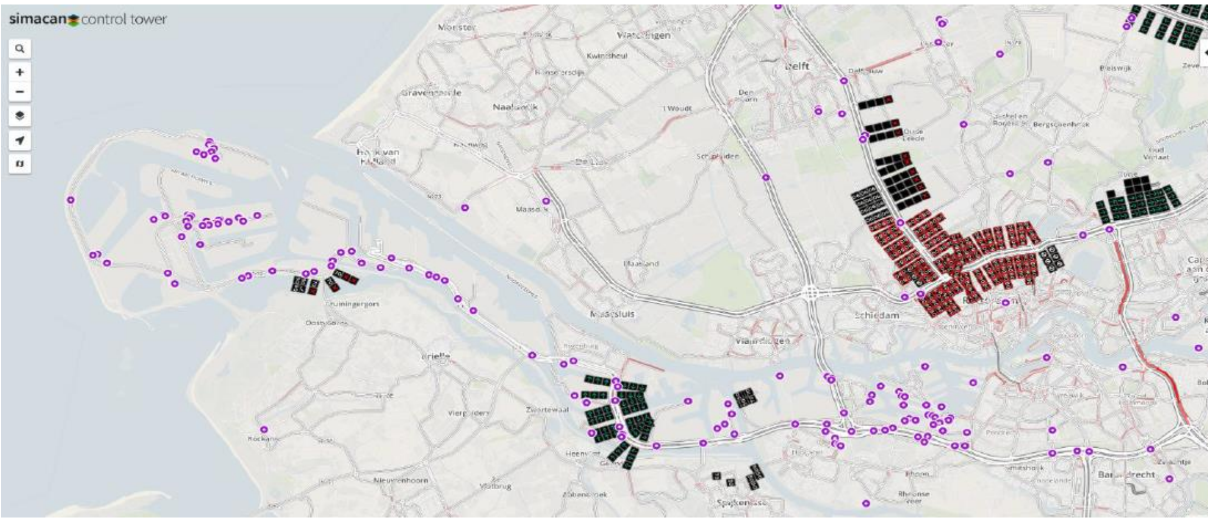
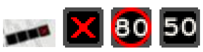


Figure 48: Main roads in the pilot area of the MCTO service in the Netherlands

The figure below is a screen shot of the Mainport Traffic Monitor with information on the actual position of all participating trucks in the port area and variable message sign information on the motorway network showing traffic problems or free flow of traffic.



Live position of 1 truck



Variable message sign information

Figure 49: Screenshot of Traffic Monitor showing live positions of trucks in the Rotterdam area

The two screenshots of the Traffic Monitor below are an illustration of the available information for the transport companies. These screenshots show:

- The historic waiting time at the gate of the selected terminal for a full day (1st graph), based on data collected with the Traffic Monitor;

- The historic turnaround time on the selected terminal for a full day (2nd graph).

Transport companies use this data to improve the planning of their activities (for example to avoid peak hours at the terminal) and to present objective data to their customers on the trips and delay at the terminals as part of the commercial process.

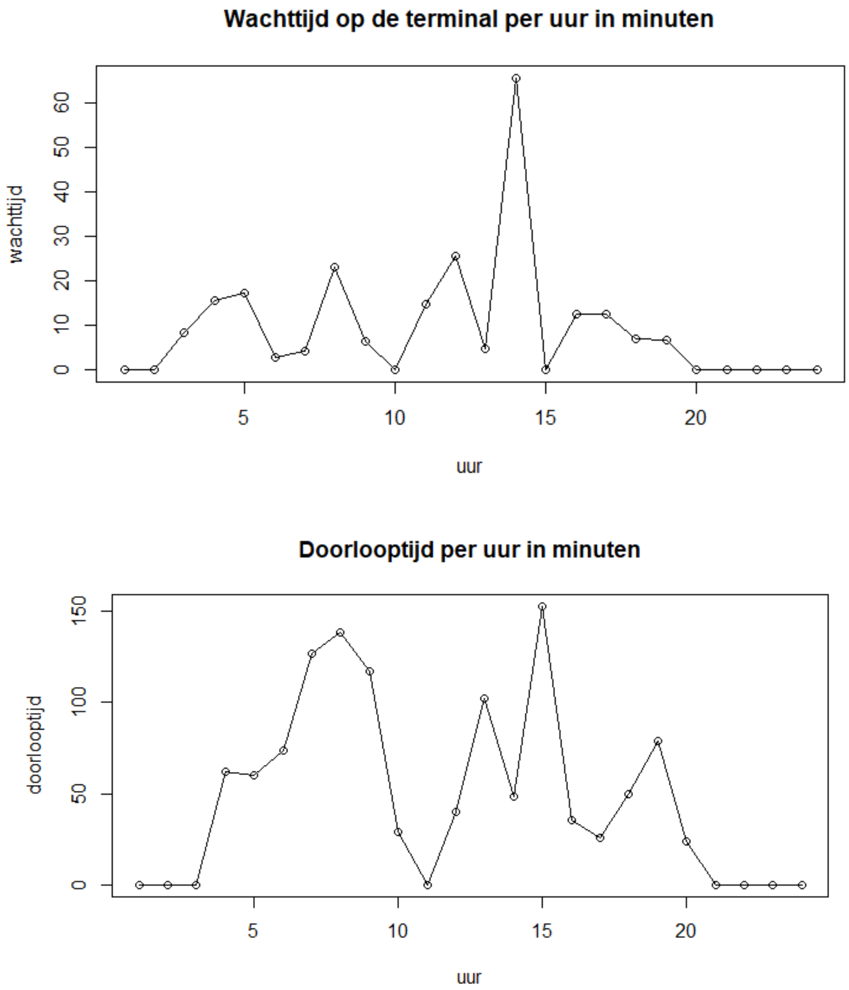


Figure 50: Screenshot of Traffic Monitor showing waiting times and turnaround times on 1 terminal in the port

5.6 Tunnel Logistics

5.6.1 Improving the service

As already described in the M9 Deliverable, the pilot on the Tunnel Logistics service in the Province of Utrecht concerns two use cases, related to the Leidsche Rijn tunnel: optimal route advice for heavy vehicles and balanced priority for dedicated vehicles. These use cases were integrated in one app, which was used by drivers of heavy vehicles, often driving in the pilot area.

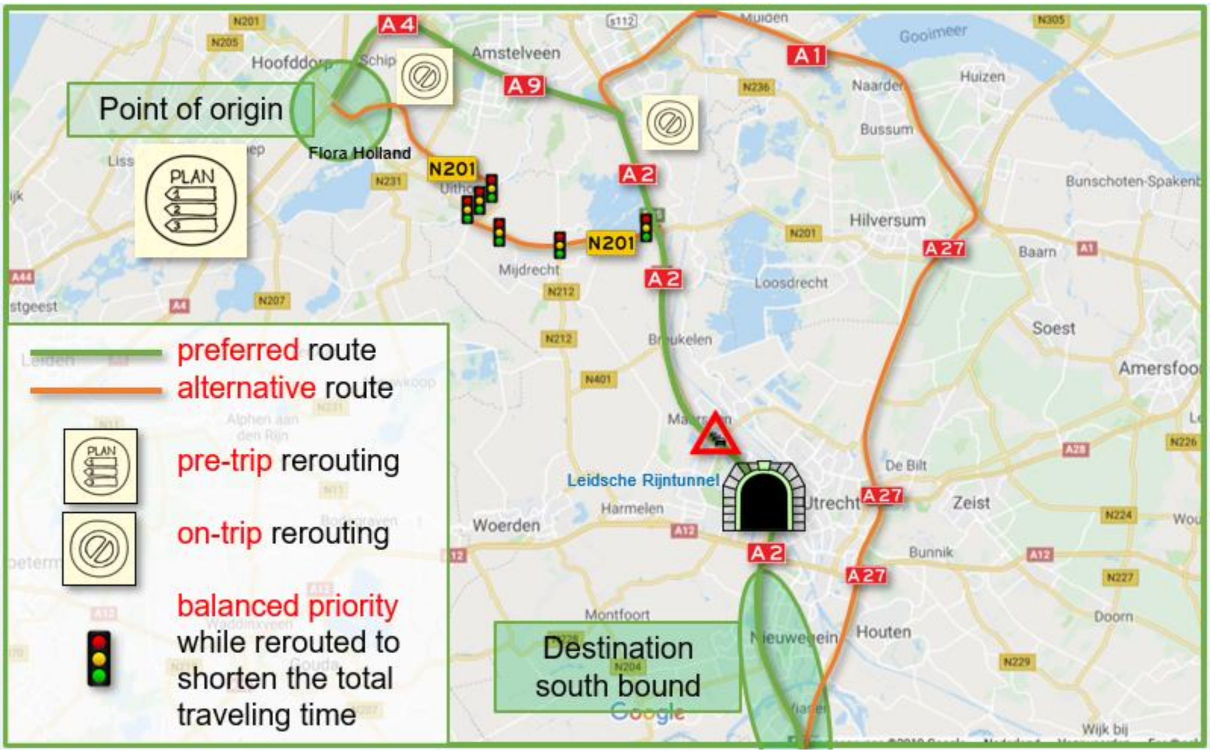


Figure 51: Pilot area for Tunnel Logistics

For the second use case six intelligent traffic lights (iTLCs) on the N201 (Flora Holland – A2) were used. These iTLCs enable communication between the traffic light controllers and the heavy vehicles in the pilot. This means that in principle the actual time to green and time to red can be made available to the road user. However, experience from the tests on the N201 showed that displaying the actual time to green/red – as such – was not very useful. The iTLCs in the Netherlands adapt their signalling on the traffic volumes continuously, resulting in often varying values. Therefore, showing seconds (as a countdown) on the HMI was not an option. Instead of counting down, the values could also go up, which would make no sense for the end user. This is why it was decided to show the colour of the traffic light and a 'count down radar' (clockwise). In this way, it was possible to speed up or slow down the count down without the driver noticing this. Due to the highly dynamic traffic lights, displaying a reliable speed advice on the HMI appeared not possible either within the scope of InterCor, even when only showing to speed up or slow down. Therefore, it was decided not to display such a speed advice.

Figure 52: HMI with a 'Count down radar'

5.6.2 Collecting data for evaluation

In order to be able to do a meaningful evaluation, in the tender for carrying out the pilot, the Province of Utrecht required that there would be at least 1200 relevant trips during the pilot operations. For the evaluation data has been collected on data resources, number of messages, end-to-end latency, reliability of information and performance of the I2V and V2I communication. In addition, a questionnaire has been distributed among and filled out by the drivers of the heavy vehicles about e.g. usefulness and distraction level of the OBU.

5.6.3 Technical aspects

Deployment of the service consisted of the following (technical) steps:

- As a basis for the app, an existing map and route planner (including current traffic state) has been used, in which it was possible to integrate heavy vehicle specific information (height, weight, etc.), intelligent traffic light controllers (iTLC) and tunnel metering predictions.
- A connection had to be made between the app and the iTLCs, concerning the following functions:
  - Priority
  - Time to green / time to red

  In the Netherlands, the TLEX[6] platform has been developed and was operational during the pilot operation. The backend of the app communicated via the TLEX with the traffic lights on the N201 to ask priority (SRM-message) and to receive an answer if priority was granted (SSM). Time to green and time to red has been derived from SPAT messages.

[6] https://www.monotch.com/en/platforms/tlex

- The tunnel metering prediction for the Leidsche Rijn tunnel had to be developed and integrated in the app. The backend of the app asks the status of the tunnel metering prediction every minute via an API. The tunnel metering system replies with a json message, in which a category (metering now – between now and 20 minutes – between 20 and 40 minutes – between 40 and 60 minutes – not within an hour) is included to indicate the availability of that specific tunnel road section. The app uses this prediction to reroute heavy vehicles if their original planned route is through the Leidsche Rijn tunnel.

5.6.4 Operations

For this service, two transport companies were willing to join the pilot with a total of 35 heavy vehicles. Those companies had to show that they often carry out trips in the pilot area to ensure a sufficient amount of data for evaluation. In consultation with the transport companies, the vehicles were equipped with dedicated smartphones, installed in the vehicle on the place preferred by the end user.

The CEOs of the transport companies were involved in the project, already in the development phase. This allowed to provide them background information on decisions in the project, but also to take into account their views during the whole process. After preparing the instructions for the drivers, the CEOs decided that they wanted to do the instructing themselves. To their opinions it would be more likely that the drivers would be willing to cooperate than when external people would brief them. Based on the outcome of the evaluation, the Province and its partners will consider the options for a possible continuation of the services.

6 Pilot operation in the United Kingdom

6.1 Location of pilot site(s)

The UK's InterCor C-ITS testbed is located in the South-East of England on a corridor that extends 110km from Greenwich in London to Dover. It was implemented by four partner organisations: The Department for Transport (UK project lead), Transport for London (TfL), Highways England (HE) and Kent County Council (KCC), with technical support from consultants WSP and Capita. The route incorporates urban, inter-urban and rural roads that provide a variety of operational environments in which to develop, test and evaluate the UK's pilot C-ITS services. The urban section of the corridor is within Greater London on highway that is owned and managed by Transport for London (TfL). It comprises the A102 Blackwall Tunnel Southern Approach, A2 Shooters Hill Road and A2 East Rochester Way up to the Greater London boundary. The inter-urban high speed (70mph) section of the corridor is owned and managed by Highways England. It comprises the A2 Watling Street from the Greater London boundary eastwards and the M2 motorway in Kent. The rural section of the corridor is owned and managed by Kent County Council. It comprises the A229 from the M2 to Maidstone, Kent. The figure below indicates the areas of the corridor where the C-ITS services have been deployed (Phases 1 and 1A) as well as potential areas for future service deployment.

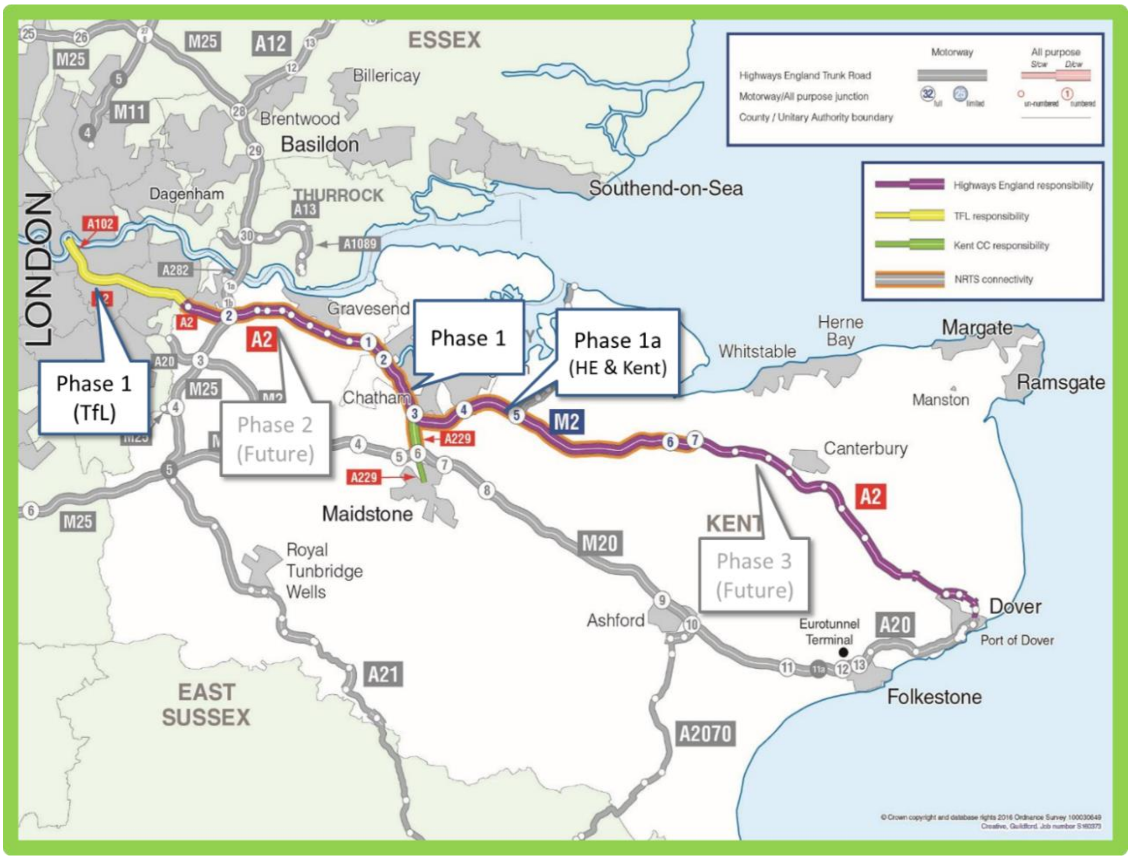


Figure 53: Overview of UK pilot site

The C-ITS services were deployed by the UK partners in phases between October 2018 and November 2019. They comprise long-range cellular only services on TfL's network, long-range cellular and short range (ITS-G5) on HE's network (hybrid) and a short-range ITS-G5 GLOSA service on KCC's network.

New roadside G-5 infrastructure was deployed for HE's and KCC's pilot services, this included 32 new roadside units that were installed by HE on the M2 (see figures 54 and 55 below) and a G-5 beacon that was installed at KCC's GLOSA site (Figure 56 below)

6.1.1 ITS G5 sites

Figure 54: Short range deployment on M2 (Road Side Units (RSUs))

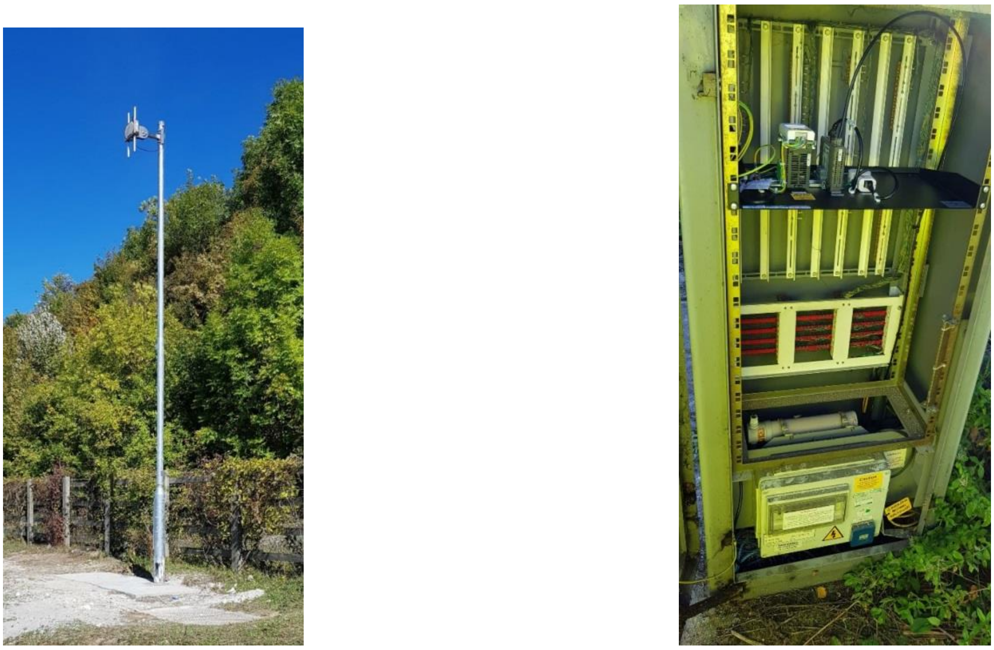


Figure 55: Short Range Deployment on M2 of 32 ITS G5 Roadside Units

6.1.2 ITS G5 rural GLOSA site

The rural test site is located at Junction 6 of the M20 which connects the M20 to the A229; it is graphically marked in figure 56 below (using blue squares).

The rural test site operates a GLOSA service only using local ITS G5 communication. This is a fixed time traffic signal (unlike the TfL GLOSA service).

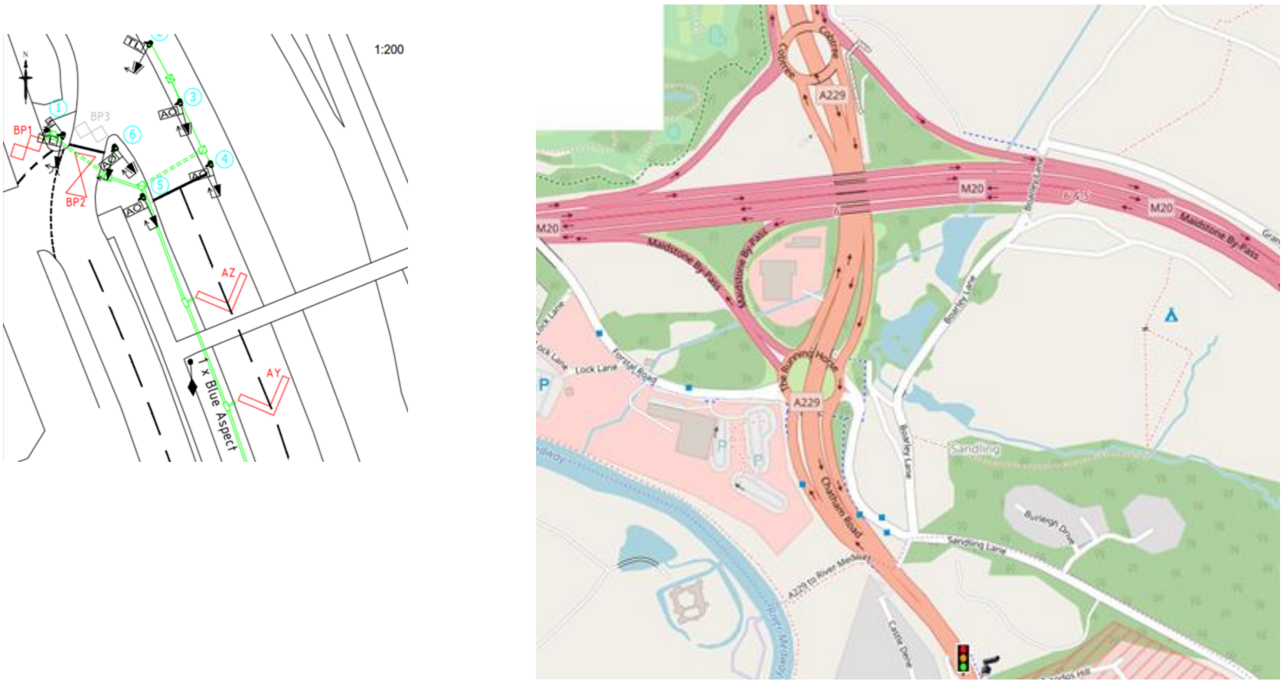


Figure 56: Short range deployment A229 – Kent GLOSA site

6.1.3 Hybrid Deployment

Figure 57: Hybrid Deployment (ITS G5 and Cellular) - A2 M2 Corridor

Hybrid coverage is as above (figure 57) so that comparison and evaluation between cellular and ITS G5 could take place. The ITS G5 roadside units are directly connected to the Highways England NRTS (Network Roadside Transmission System) fibre network. The hybrid area services include In–Vehicle Signage, Road Works Warning and Probe Vehicle Data.

6.1.4 Urban Cellular Deployment (A2 and A102)

Transport for London (TfL) has deployed cellular only services for GLOSA, IVS and RWW. No additional road-side infrastructure has been installed for the pilot. Figure 58 below indicates the general area of coverage of each service.

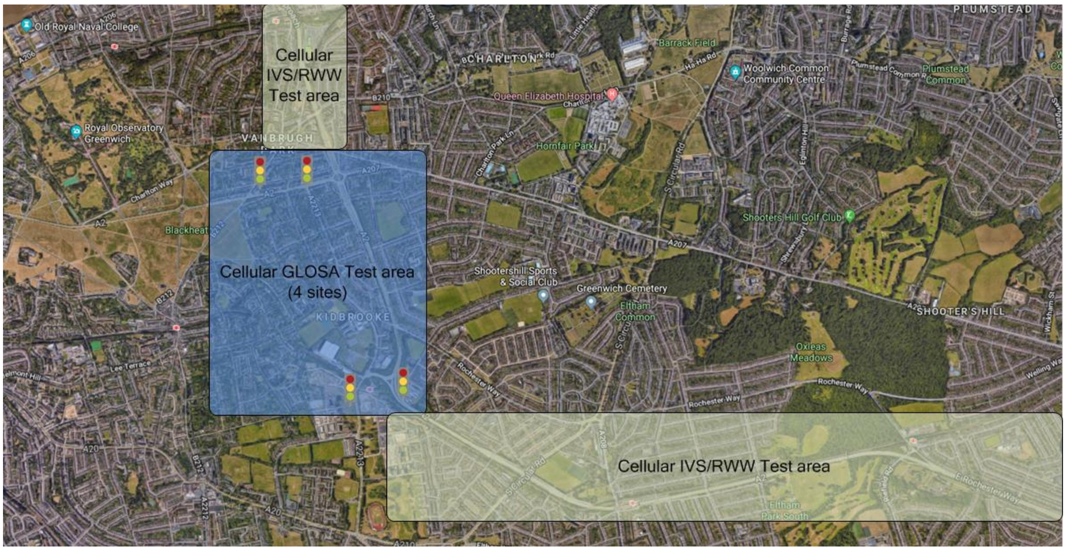


Figure 58: Urban Cellular Deployment overview - A2 and A102 Transport for London area

TfL's pilot IVS service operates at locations where there are variable message signs on the A2 and A102 and at lane control gantry signs on the A102. The lane control gantry signs are used for general lane control, including lane closures and temporary speed restrictions on the A102. They also support the management of traffic during incidents within the Blackwall Tunnel, or in the vicinity of it, and during planned closures of the tunnel.

TfL's pilot RWW service is configured to operate on East and Westbound carriageways of the A102 Blackwall Tunnel Approach and on the A2 East Rochester Way Relief Road, as far as the Greater London boundary.

TfL's IVS and RWW service information is provided by its back-office VMS and tunnel control systems. SPAT messages for TfL's cellular GLOSA service are provided by its Urban Traffic Control System (UTC), which controls and coordinates approximately 4,500 of London's 6,400 sets of traffic signals.

Figure 59 below provides the location of each on-street asset that is associated with the GLOSA, IVS and RWW services, and it indicates the current extent of TfL's urban C-ITS testbed.

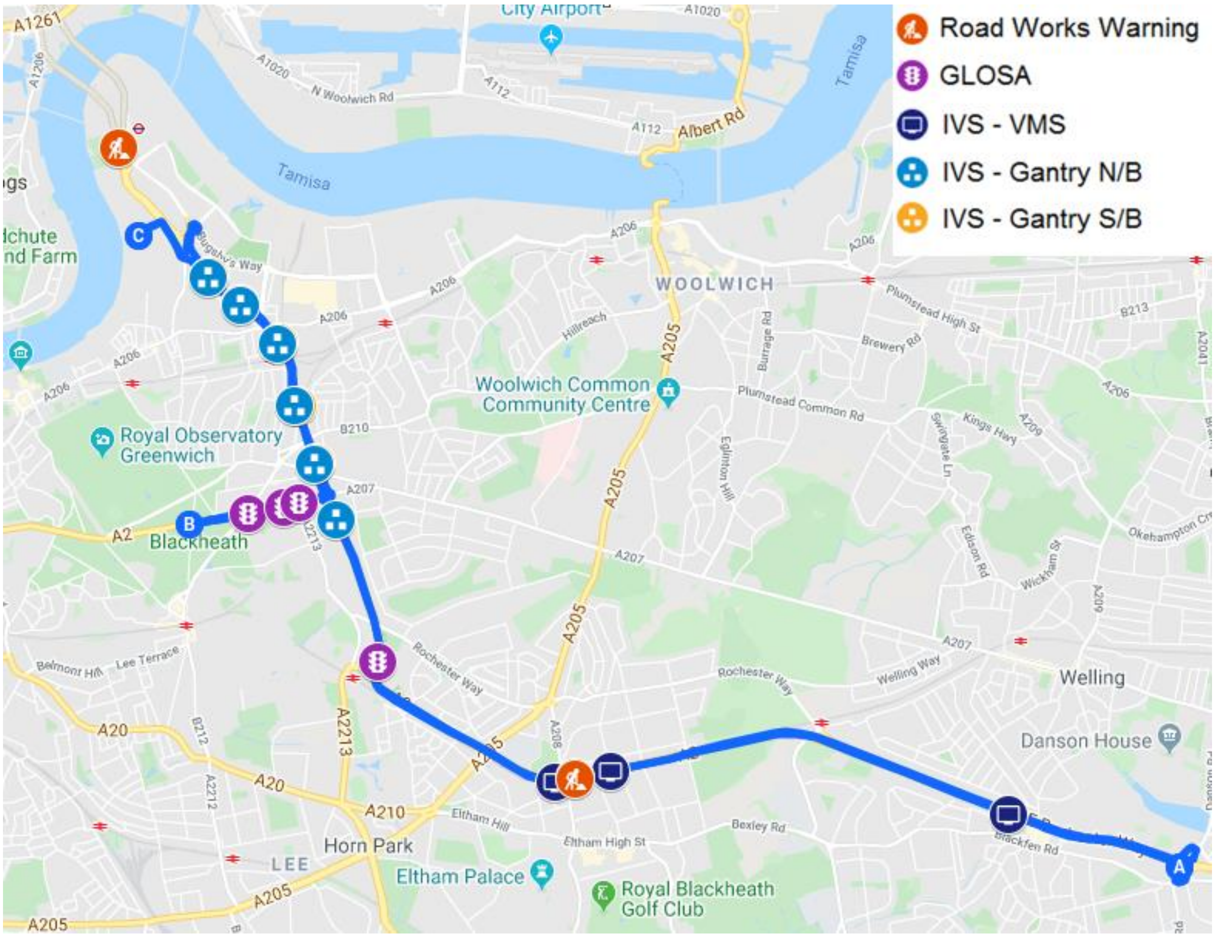


Figure 59: TfL on street assets and associated services

GLOSA operates at four signal controlled junctions: one on the A2 Rochester Relief Road /Kidbrooke Park Road junction and three adjacent junctions on the A2 Shooters Hill (see figure 60 below).

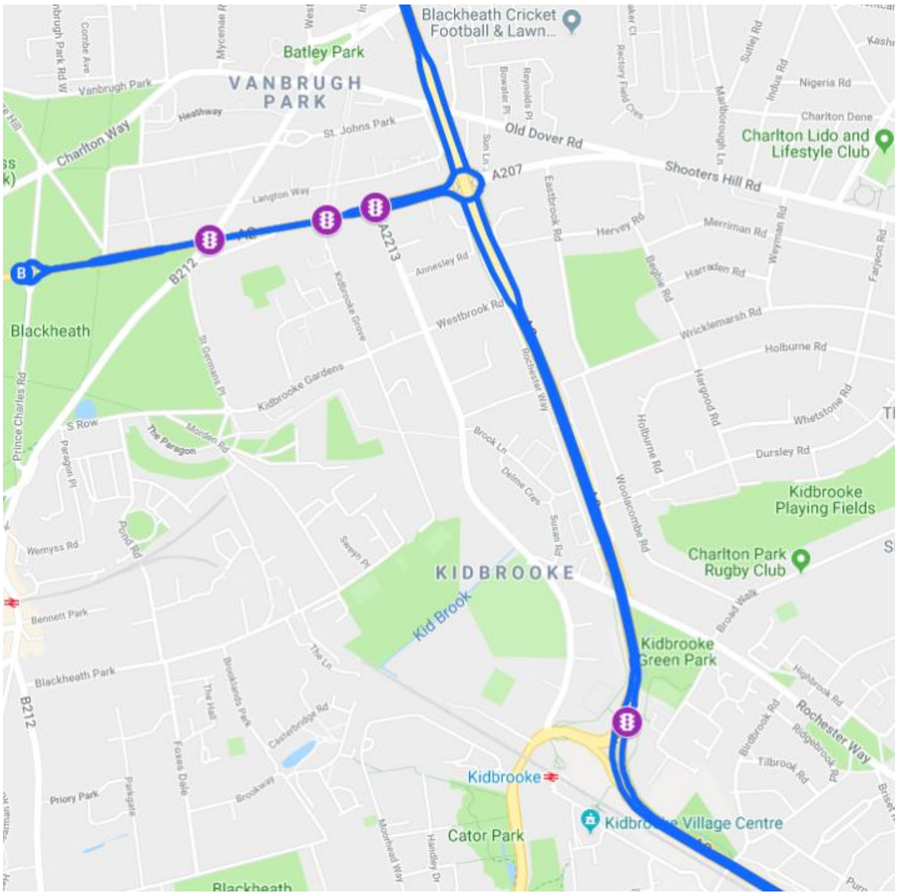


Figure 60: Urban Cellular Deployment – A2 specific GLOSA test sites

The purple icons on the map above indicate the location of the GLOSA sites.

.**<u>TfL GLOSA Service</u>:**

TfL's Urban Traffic Control (UTC) system, which controls and coordinates approximately 4,500 of London's 6400 sets of traffic signals, employs a SCOOT (Split, Cycle Offset, Optimisation Technique) algorithm that dynamically adjusts the signal timings at groups of traffic signals in real-time, according to traffic demand, in order to minimise vehicular stops and delay. In addition to operating under SCOOT control, three of the A2 testbed signal controlled junctions are also equipped with Bus Priority (BP) technology and a 'stage ghosting' facility. On detecting approaching buses on either the A2 or side road, BP can permit local extensions to traffic signal phases or the early re-calling of traffic phases under certain network conditions. This functionality minimises delay to buses. However, because TfL's GLOSA service is based on information from the central UTC system, it cannot detect local changes to the traffic signal timings that are implemented by the BP facility. This could therefore lead to inaccurate time to red and time to green times. Stage ghosting is a feature of UTC that ignores demand dependant stages that have not been called within a certain time period. If they are then called locally, this is not reflected in the central UTC DTSJ (Data Test Set for Junction) messages; they simply pause until the demand dependant stage is complete. In the context of GLOSA this will show the end user a pause in the countdown to green or red

The highly dynamic and complex mode of signal operation that is employed at the four GLOSA testbed sites on the A2 and the significant variations in local network operating conditions that occur throughout the day provided an interesting and challenging environment in which to thoroughly test and evaluate the performance of TfL's GLOSA service. The UK project's test team therefore tested and evaluated the GLOSA service at different times or day, under a variety of network operating conditions, and with dynamic control either fully enabled (i.e. with SCOOT, BP and stage ghosting enabled), or with it partially inhibited (SCOOT enabled, but BP and stage ghosting disabled) . The test results are documented in the InterCor M13 document.

The following paragraphs and GLOSA site layout diagrams (figures 61 to 64) describe TfL's cellular only GLOSA service deployment in more detail. The diagrams indicate the ingress and egress reference points that build each MAP file that was created for the GLOSA service

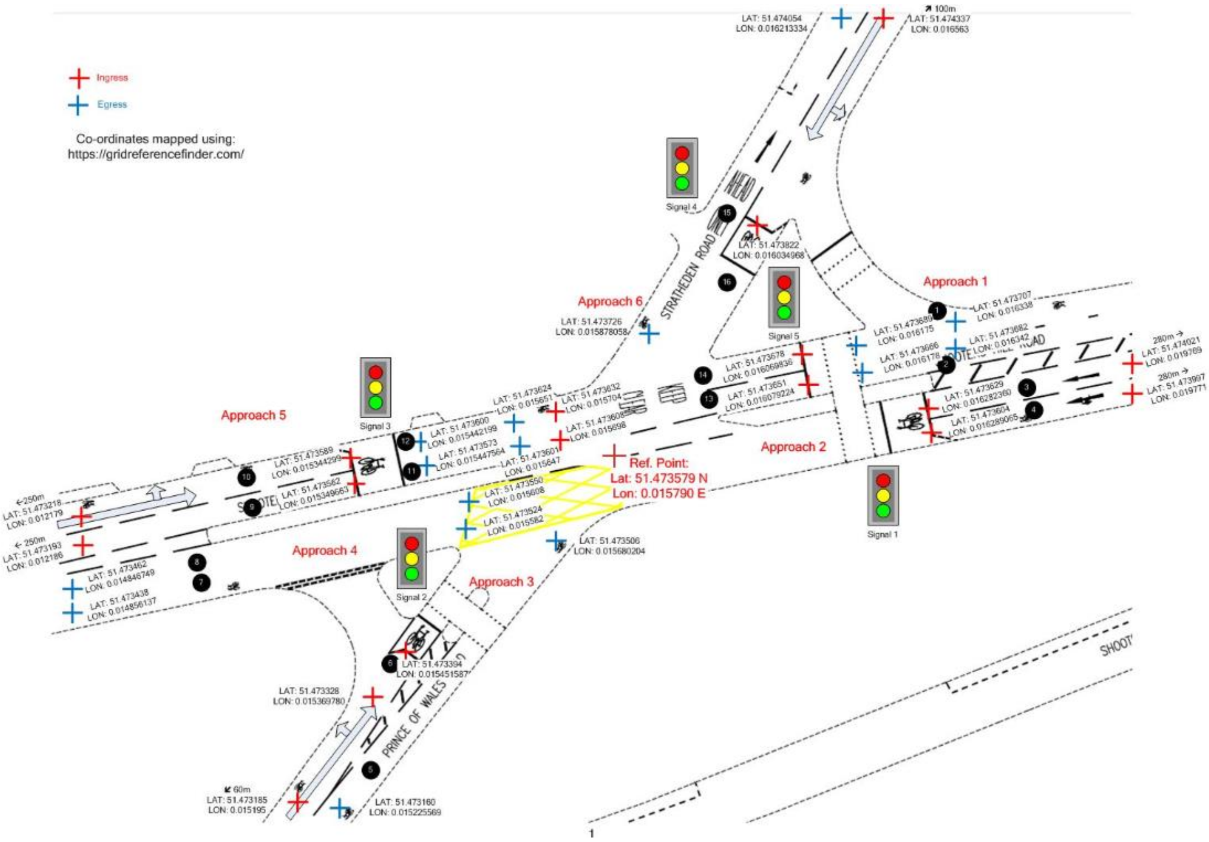


Figure 61: A2 Shooters Hill / Strathenden Road (junction reference 06/001)

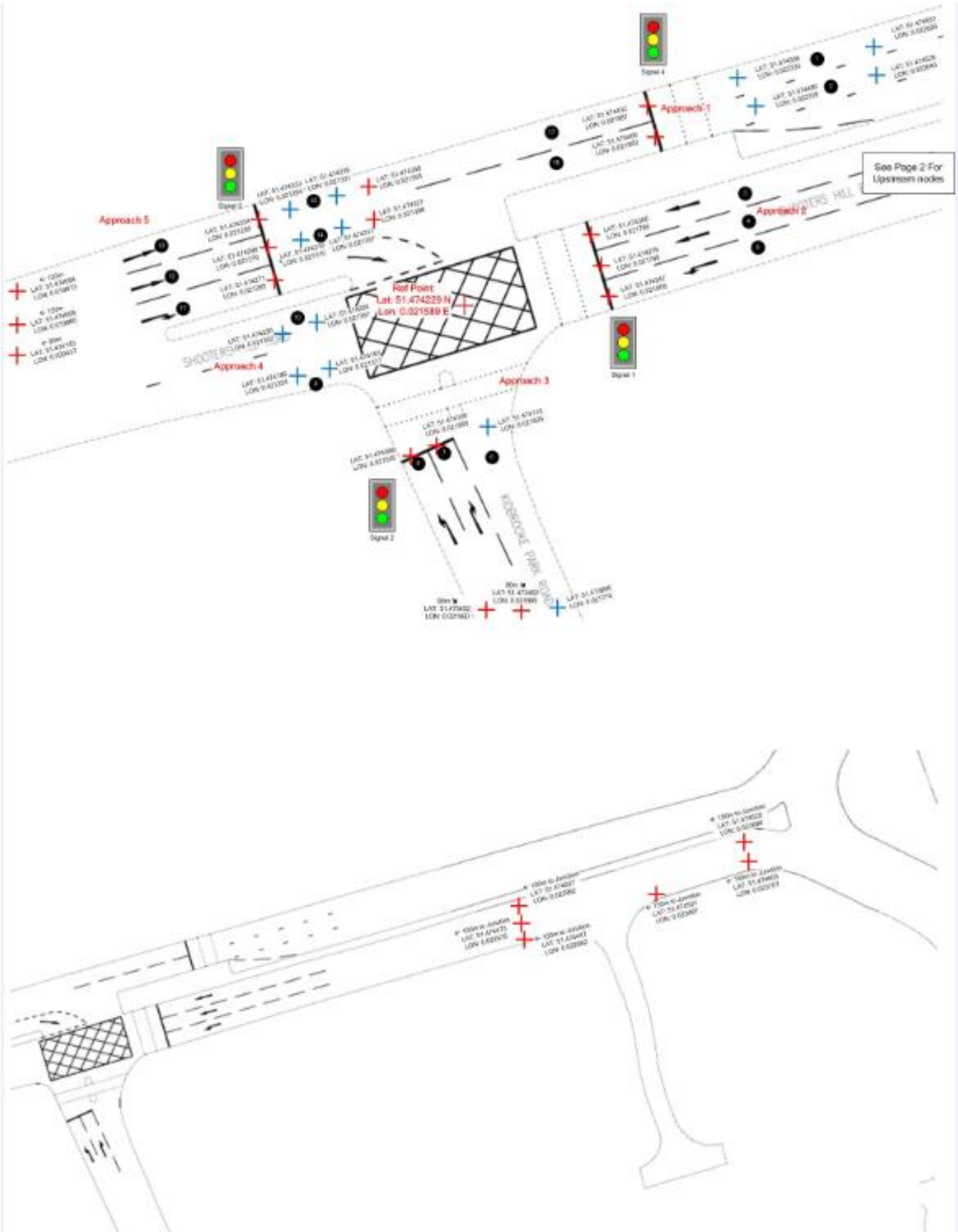


Figure 62: A2 Shooters Hill / Kidbrooke Park Road (site reference 06/021)

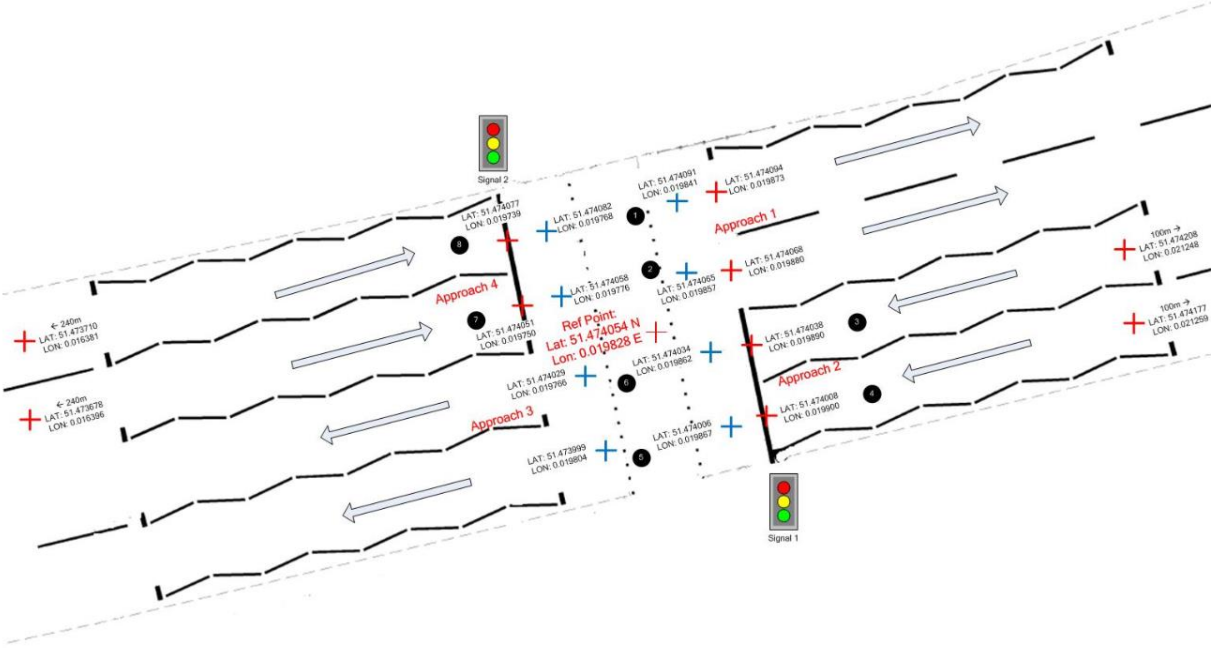


Figure 63: A2 Shooters Hill – Pedestrian Crossing (site reference 06/163)

Junctions 06/001, 06/021 and 06/263 are located in close proximity to one another on the A2 Shooters Hill Road, on a corridor that is prone to exit blocking during peak periods and where there are more complex traffic movements than 06/091. These junctions therefore offer a more challenging operational environment, where dynamic SCOOT UTC control is also combined with bus priority (BP) is also employed. Under appropriate network conditions, to aid efficient bus movements BP is able to rapidly curtail green signal phases on some approaches and to 'hurry call' other green phases where there are buses.

<u>A2 Rochester Way Relief Road/ Kidbrooke Park Road (site reference 06/091):</u>

Site 06/091 is a simple two stage signal controlled junction on the A2 Rochester Way Relief Road, which is 50mph dual carriageway. This junction experiences minimal interaction with adjacent traffic signals and has very little exit blocking. It was therefore used for the initial technical evaluation of TfL's GLOSA service under SCOOT UTC control.

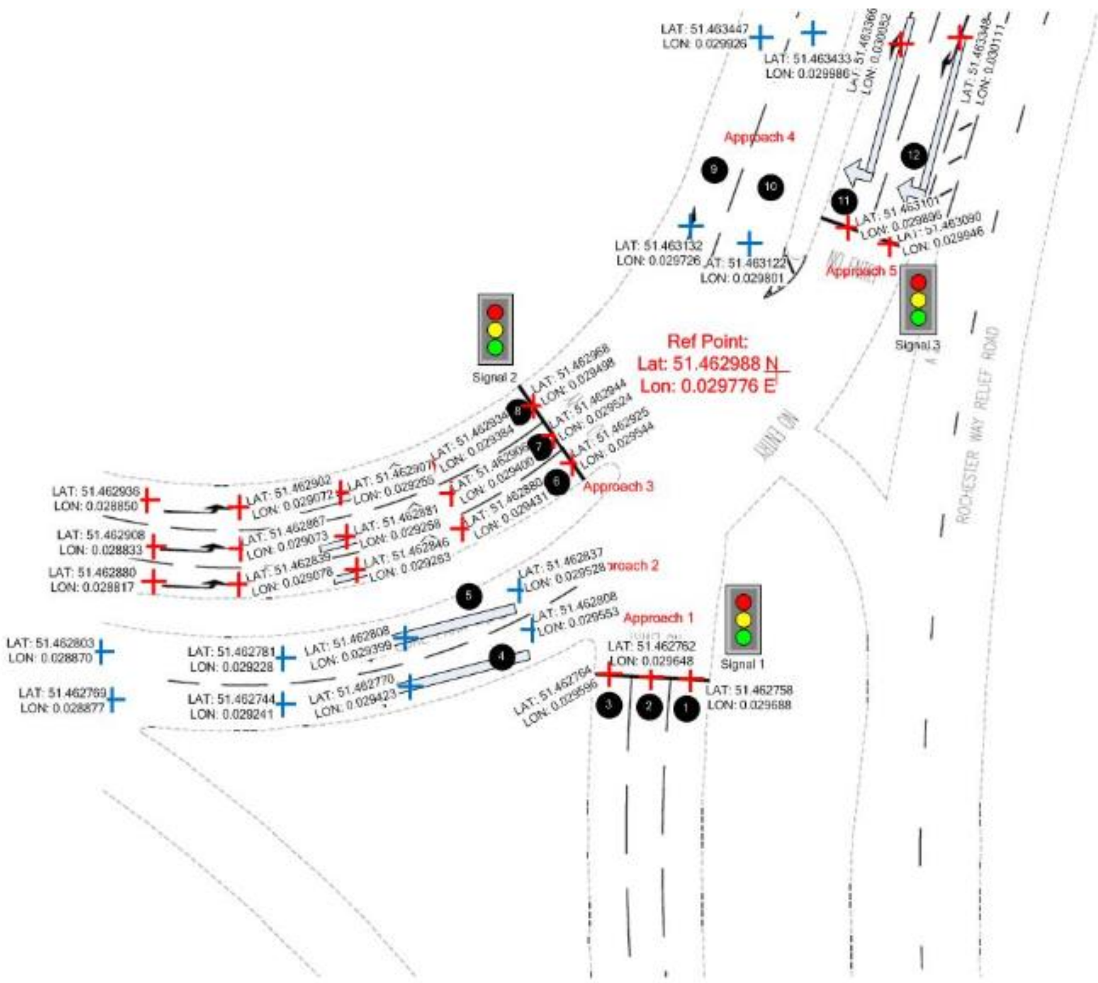


Figure 64: A2 Rochester Way Relief Road/ Kidbrooke Park Road (site reference 06/091)

This combination of sites and modes of signal control enabled us to better understand the performance and operational limitations of the pilot cellular GLOSA service under a variety of network conditions that are often experienced in congested urban areas of London.

6.2 Services deployed

The table below sets out the services deployed, supported use cases, date of deployments, and the communication type (ITS-G5 and/or cellular) used for service delivery.

Table 4: UK deployment of services

Service	Use Case	United Kingdom	Pilot start dates	Comments / Issues
RWW	Lane closure or other restrictions	Deployed	ITS-G5: Oct 2018 Cellular: March 2019	
	Alert planned closure of a road or a carriageway	Deployed	ITS-G5: March 2019 Cellular: March 2019	
	Winter maintenance – Salting in Progress	Deployed. Note: this information will be provided from the Road Operator's back office, not from a vehicle equipped with a beacon	ITS-G5: June 2019 Cellular: March 2019	
IVS	In-vehicle signage dynamic speed limit information	Deployed	ITS-G5: Oct 2018 Cellular: Oct 2018	
	In-vehicle signage embedded VMS	Deployed	ITS-G5: Oct 2018 Cellular: Oct 2018	
	Dynamic Lane Management – Lane Status information	Deployed	ITS-G5: June 2019 Cellular: March 2019	
PVD	Traffic data collection	Deployed	ITS-G5: Oct 2018	
GLOSA	Time-to-green information and speed advice	Deployed	ITS-G5: Oct 2018 (Kent site) Cellular: March 2019 (TfL sites)	
	Time-to-red information and speed advice	Deployed	ITS-G5: Oct 2018 (Kent site) Cellular: March 2019 (TfL sites)	
MCTO	Multimodal ETA for cargo optimisation	Not originally planned, but investigation has been carried out		
	Dock reservation			
	Assigning a slot for multimodal terminal access management			
	Information on the site's access conditions			
	Guide truck in the port (terminal or truck parking)			
Truck Parking	Information on parking lots location, availability and services via internet	Not originally planned, but investigation, high-level design and planning have been carried out		
Tunnel Logistics	Optimal route advice for trucks	Not originally planned, but investigation has been carried out		
	Balanced Priority for dedicated vehicles on road sections around tunnels			

The UK has focussed on the development, operation and evaluation of an interoperable C-ITS platform and the Road Work Warning, In Vehicle Signage, Probe Vehicle Data and Green Light Optimised Speed Advice services.

The MCTO, Truck Parking and Tunnel Logistics services were never within the scope of the UK's InterCor pilot and they were not budgeted for in the UK's original project cost plan or the UK's Grant Agreement (GA) submission. Unfortunately, due to a clerical oversight, they were included in the Grant Agreement and this error was not identified until after the GA had been signed by the DfT.

With the UK C-ITS platform now in place and the four services that the UK committed to deliver having been successfully deployed, the UK has begun the steps towards developing MCTO, Truck Parking and Tunnel Logistics services. The following sections outline the progress that has been made and the aspirations for the future development of these services, should funding become available.

6.2.1 MCTO Service

After initial consultation with the UK partner organisation stakeholders, the UK project has developed a staged plan which focuses on the establishment of a Truck Parking C-ITS service (as outlined in section 6.2.2) in the first stage, and subsequently extending the solution to deliver the MCTO sub-use case to 'Guide truck in the port (terminal or truck parking)'.

Remaining MCTO sub-use cases delivery planning will follow further stakeholder engagement to establish priorities.

As can be seen in section 6.1 the UK's C-ITS pilot corridor leads to/from the Port of Dover (which is also a key route to other European member states) and so the UK wish to establish trial services that integrate into the port's existing data streams which include a number of driver services. Engagement with the Port of Dover has not been possible to date, but it is hoped a C-ITS MCTO solution would complement their existing offering and the potential for it to lead to European wide technical standards is a key benefit the trial can offer.

6.2.2 Truck Parking Service

The InterCor Truck Parking related activities are intended to improve the information services by providing a technical basis for interoperability for the exchange of truck parking data between different service providers, and across borders. The UK approach has been to:

- understand the areas of interest / opportunities to deliver benefits to the road operations undertaken by UK partnership organisations;

- understand the existing truck parking ecosystem and consider options for facilitating this and understanding how integration could be established in order to reach a wider uptake of any services delivered; and
- investigate options for building on C-ITS platform established to deliver other services (as already described) – especially as this offers the interoperability required.

Improvements in truck parking related activities are of interest to the UK partner organisations to support the wider UK economy, but specifically to manage freight traffic across their networks – truck parking at ports, management of congestion on the approach to ports, and efficient management of traffic to and from construction sites (particularly in/through urban areas).

As recognised by our Dutch colleagues, the existing truck parking ecosystem is built up of international service providers that provide an international service to the truck drivers. Interoperability across borders at the end-user is realised by these service providers that have international coverage. However, the exchange of dynamic truck parking data is not (yet) internationally organised. The UK have sought to build on the work undertaken by our Dutch colleagues in their data-integration with the Truck Parking Europe system for the Province of Noord Brabant.

The UK have undertaken a high-level design for a solution to integrate and share truck parking information in line with figure 65 below:

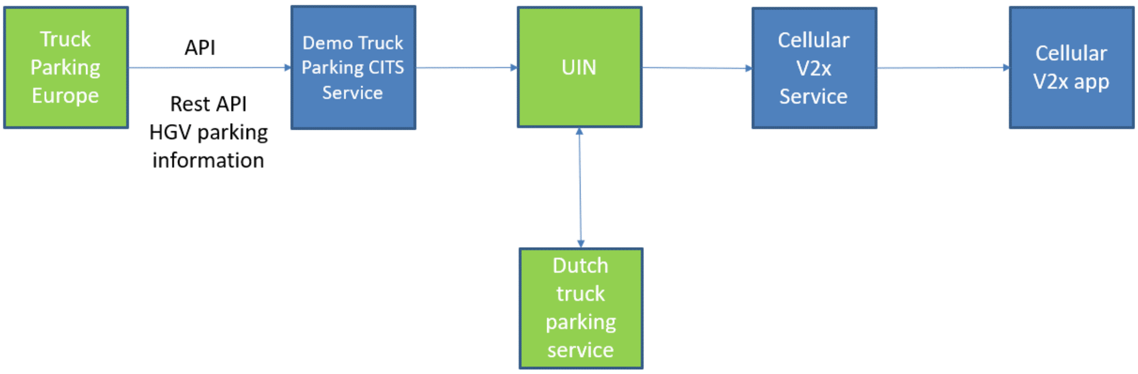


Figure 65: UK high-level design for Truck Parking service integration

As part of a staged implementation, the potential for simulating the data from Truck Parking Europe API has also been investigated. This involves the development of a simulated service which creates messages based on the DATEX II schema for truck parking, connecting to the UIN and passing the messages where they can be accessed by other subscribers (most likely testing with the Netherlands in the first instance). This would involve a modification of the UIN to accept the IF2 payload from the Truck Parking C-ITS service.

To further test the interoperability it is planned to work with the Dutch colleagues (initially) to agree a schema for C-ITS message for truck parking, with the expectation that this would be based on the DATEX II schema and adapted to cater for elements such a geo-networking information. This will lead into the C-ITS and UIN standard development supported by operational rules and technical requirements that would need to be developed (and may be country specific).

6.2.3 Tunnel Logistics Service

The UK's cellular GLOSA sites are part of TfL's Urban Traffic Control (UTC) system, and utilise Split Cycle Offset Optimisation Technique (SCOOT) to provide real time adaptive traffic control at the intersections. The GLOSA sites selected on the A2 also utilises Bus Priority and Stage Ghosting system (which are described in section 6.1.4 TfL GLOSA Service).

The Bus Priority system delivers dynamic road network optimisation through signalised junctions in the same way as the Tunnel Logistics sub-use case 'Balanced Priority for dedicated vehicles on road sections around tunnels'. As a result, the UK plan has been to first understand the complexities of implementing GLOSA together with dedicated vehicle priority systems (i.e. the existing Bus Priority system on the A2). To this end, during Focussed Testing Event 6 (FTE-6), the GLOSA testing at the A2 sites was arranged as follows:

- Day 1: GLOSA enabled, SCOOT enabled, Bus Priority and Stage Ghosting disabled
- Day 2: GLOSA enabled, SCOOT enabled, Bus Priority and Stage Ghosting enabled

This will allow a comparison and enable evaluation of any impact on GLOSA performance, feeding into future system (and/or process) improvements.

The UK's GLOSA sites (TfL) are in close proximity to the southern portal of the Blackwall Tunnel (as outlined in section 6.1) – a pair of road tunnels on the A102 that run underneath the River Thames. The route regularly suffers congestion and improvements to traffic management, especially for heavy goods vehicles, that a C-ITS service could offer would be beneficial.

Delivery planning for a more complete C-ITS service to meet the Truck Parking sub-use case 'Balanced Priority for dedicated vehicles on road sections around tunnels', would be subject to further stakeholder engagement to establish priorities and high-level requirements. However, the UK project has considered the following staged approach:

Delivery planning for the remaining Truck Parking sub-use case (‘Optimal route advice for trucks’) will follow further stakeholder engagement to establish priorities and high-level requirements.

In general, traffic management information from road authorities in the UK is shared with all road users and not targeted to specific types, such as heavy goods vehicles. However, there are circumstances where specific messages are sent via VMS, such as closure of bridges to high sided vehicles, or a more specific example in proximity to the UK pilot sites when the northbound Dartford Crossing is completely closed and HGVs divert onto other routes such as the A2 – then TfL displays a 4.00m height limit warning for the Blackwall tunnel. These messages would already be picked up by the C-ITS in Vehicle Signing service and displayed in any trucks equipped with an OBU and HMI.

There are several apps on the market that allow truck drivers to enter personalised information (such as size, type, emission standards, Hazmat) and provide drivers with routing and navigation information to suit. The UK plan would be to investigate the potential to interface with one of these apps in a similar manner to that already described for the Truck Parking service (section 6.2.2). This would also be supported by an investigation into the potential operational benefits and requirements for implementing systems that are specifically targeted at vehicle types.

6.3 Technical Aspects

6.3.1 UK Systems Architecture

The UK does not currently have a national data centre for real-time traffic systems data. Therefore, C-ITS service data from the UK highway authorities that are participating in InterCor (TfL, HE and KCC) is integrated at a Unified Interchange Node (UIN) which was developed specifically for the InterCor project (see UK System Architecture diagram below).

Each highway authority was responsible for developing its back-office traffic control systems and the development of systems interfaces (APIs) as indicated on the colour coded systems architecture diagram, to enable their systems data to be output and then received by the UIN. The UK’s high-level systems architecture was developed by the UK project team in discussion with other European project partners, to ensure that there was compatibility between the UK’s and the other member state’s systems.

To enable the C-ITS services to be internationally inter-operable and to enable provision of the UK’s cellular C-ITS services, the interface between each highway authority’s C-ITS

Services API and the UIN, and between the UIN and third party service providers complies with Interface 2 (IF2) as defined in document 'Intercor_2.1b_IF2_specs-v1.0 final' and in alignment with the requirements of 'InterCor Milestone 4 - Common set of upgraded specification for Hybrid communication' (sub-activity 2.1b).

IF2 has been secured such that only authorised users and systems can connect. The security controls and features that have been implemented for IF2 are as follows:

- Data in transit is secured using the TLS protocol.
- IP whitelisting is enabled for all connections to the UIN from the internet. Internal/trusted connections between the UIN and other back office systems are not subject to IP whitelisting.
- AMQP PLAIN authentication (username/password) is required for users and systems to establish a connection with the UIN.
- The UIN InterCor IF2 AMQP broker is payload agnostic
- It is the responsibility of the C-ITS service to publish the payloads in conformance to ETSI message specifications

The ITS-G5 interface between vehicles and road side systems complies with Interface 1 (IF1) as defined by sub-activity 2.1a, in alignment with the requirements of 'InterCor Milestone 4 - Common set of upgraded specification for Hybrid communication'.

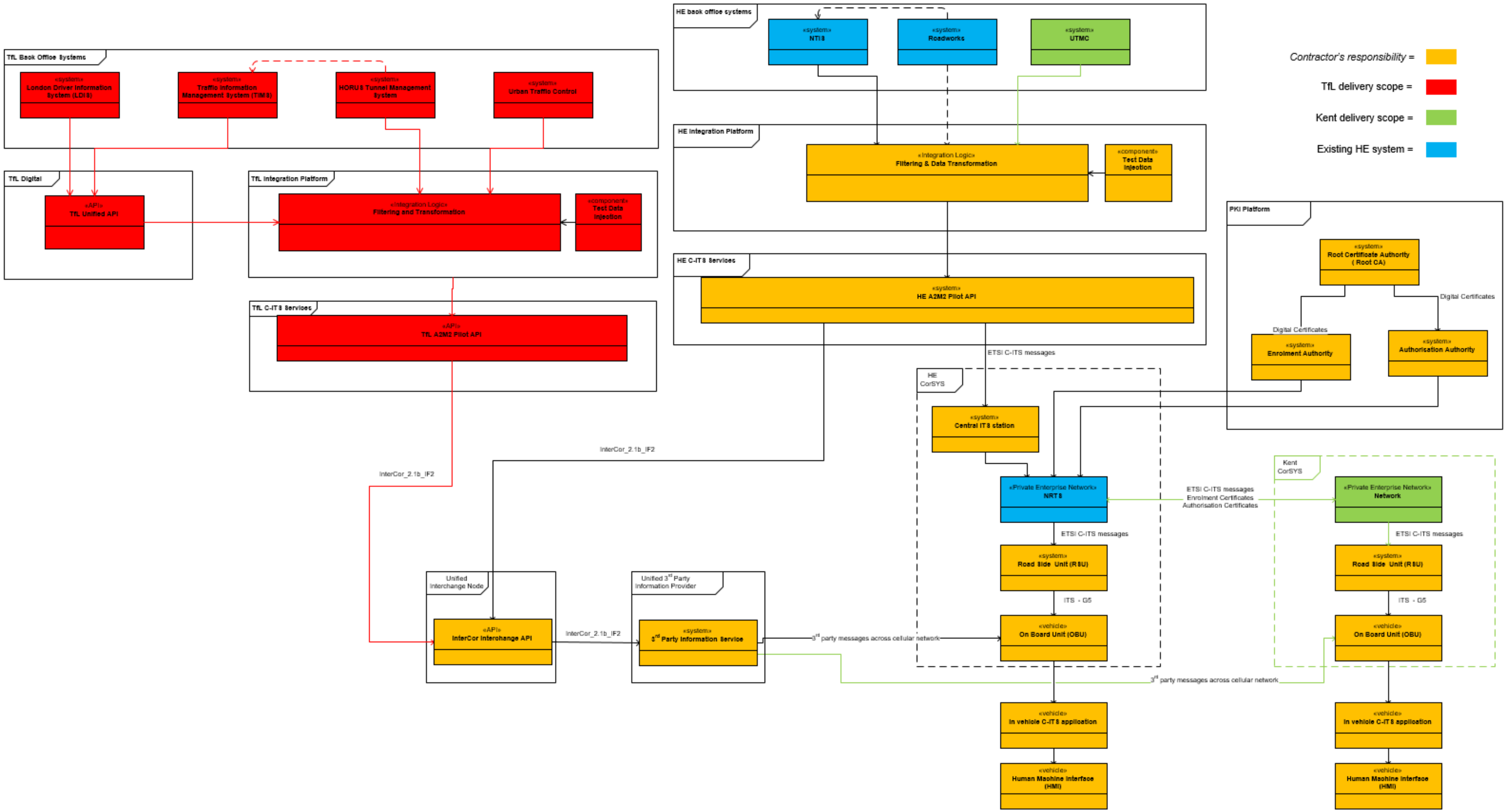


Figure 66 UK System Architecture Diagram

6.3.2 PKI *(ITS-G5)*

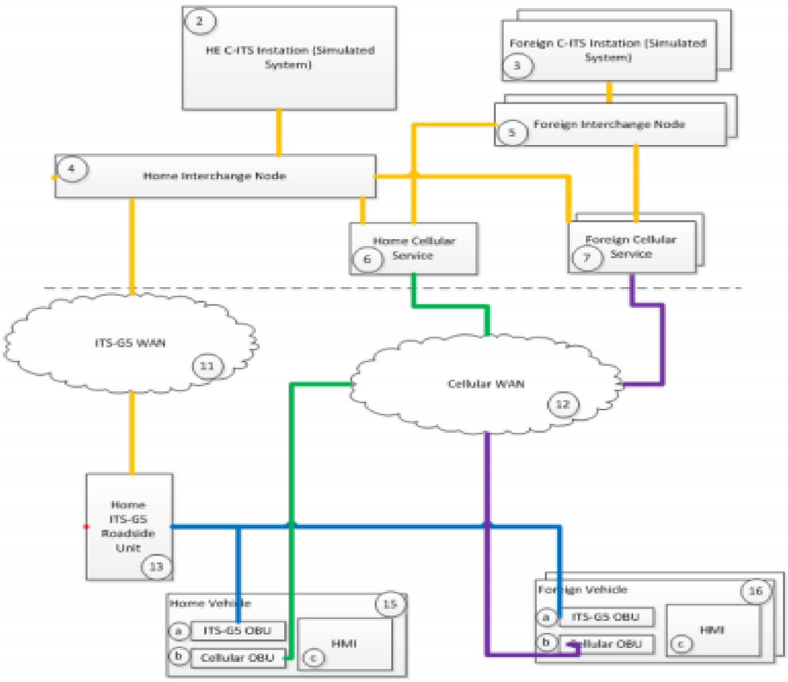


Figure 67: PKI

- In the long-term UK has a preference to implement its own ITS-G5 PKI service, contracted out to a PKI service provider.
- Currently certificates are valid only for the duration of the chosen Testing Event
- The UK has:
  - Established a RootCA – enabling the UK to share the RootCA certificate with the Central Trust List (CTL), so that UK messages can be verified by other European member states
  - Produced Authorisation Tickets – Certificates (signed by the UK RootCA) have been provided to each UK C-ITS station
- Certificates are compliant with ETSI TS 103 097 v1.2.1
- All certificates are manually installed
- The same (static) certificate is installed

6.3.3 In-vehicle equipment (OBU/ HMI)

A consortium led by Costain was contracted to provide the C-ITS service to a fleet of test drivers and test vehicles who were predominantly from Kent County Council (day-time testing) as well as from the other UK project partners and Capita (night-time testing). Test arrangements are described in more detail in the Operations section below.

The in-vehicle test equipment comprised a Cohda on-board unit (OBU) that was connected to GPS, cellular and G-5 antennas and was capable of receiving and decoding hybrid (cellular and ITS G-5) C-ITS messages (see Figure 68 below). During testing each OBU was installed in a briefcase that was located in the boot or cargo area of the vehicle. Each OBU was connected via Bluetooth to a Human Machine Interface (HMI) screen (Figure 69) that mounted on each vehicle's dashboard or windscreen (Figure 70). The HMIs were manufactured by TomTom but used bespoke software that had been developed for the InterCor pilot.

The UK partnership organisations planning for Pilot Operations included consideration for the potential for the on board equipment to distract test drivers. With testing undertaken on live roads the safety risk to test drivers and other road users were carefully considered and mitigations put in place. This included ensuring that all test vehicles included a dedicated passenger to monitor the HMI during TESTFEST events, allowing drivers to concentrate on driving only. However, during the pilot operation it was recognised that a key element of the evaluation required the gathering of evidence of the impact of the system on the drivers themselves. In order to minimise the safety risk a set of Driver Distraction Principles were developed to guide all planning and implementation activities. These covered the following areas:

- **Golden Rule** – an overriding principle to be considered during all planning and implementation – in our case this was that the driver should treat the system information as advisory only.
- **Installation Principles** – relating to positioning of equipment in the test vehicle.
- **Presentation of Information Principles** – relating to the simplicity and intuitiveness of the HMI interface.
- **Principles of Interactions with Displays/Controls** – relating to simple and minimal interactions with the HMI interface by the driver.
- **Principles of System Information/Training** – relating to driver briefings and training.

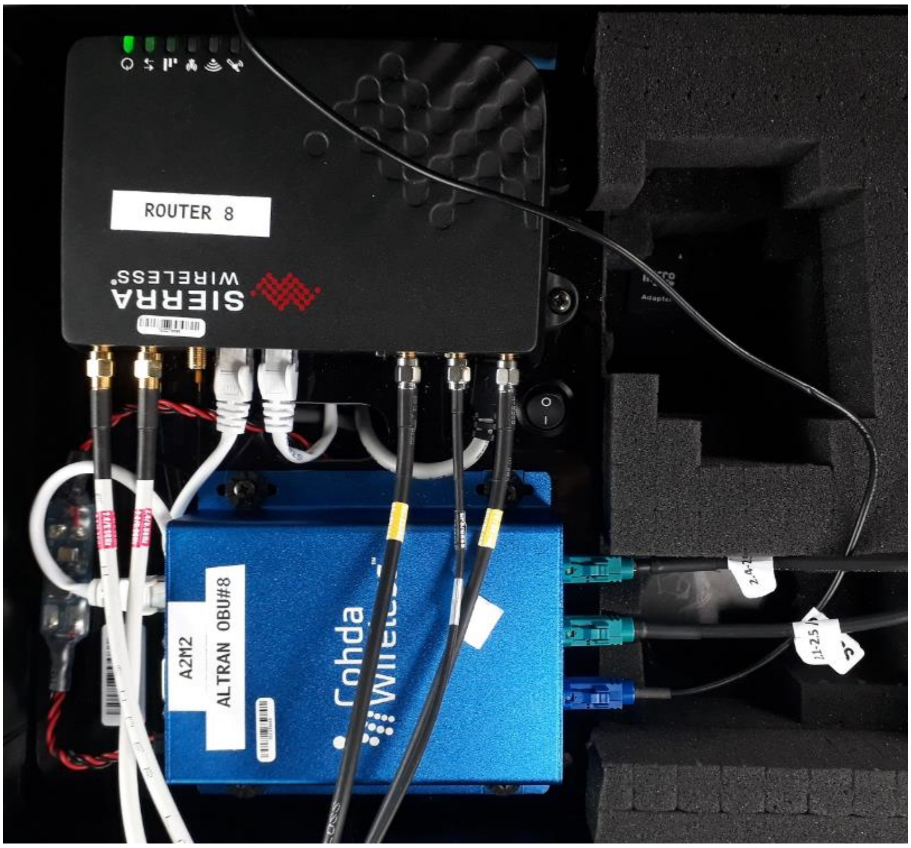


Figure 68: Cohda OBU and wireless router.

Figure 69: UK supplied HMI displaying IVI messages on the A102 in London

Figure 70: UK HMI installed in vehicle displaying IVI on the M2 in Kent during a UK TESTFEST

6.4 Pilot Operations and maintenance

6.4.1 Pilot planning and preparation

The UK's pilot services were deployed in phases from October '18 (see section 6.2). Pilot Operations commenced in March '19 and it completed at the end of February '20. A structured approach was taken to preparatory planning for the pilot phase of the project, to the implementation of the pilot and to the management of the UK pilot during its pilot operations phase.

The testing, which was held on TfL's, HE's and KCC C-ITS testbeds was planned and coordinated on behalf of the UK partner organisations by WSP who were contracted by HE to undertake this work. Key operational documents were produced by WSP in discussion with the UK project partners, to support the management of pilot operations. These included:

- **Concept of Operations (ConOps) –** this document sets out who the stakeholders are, what their operational needs are and how these needs are addressed by the pilot during its operation. This document addresses "what" needs to be considered in order to meet the operational requirements and who needs to be informed in various operational scenarios. This is captured in the ConOps as a series of process diagrams that cover areas such as safety, maintenance, incidents and business-as-usual operations.
- **Implementation and Management Plan (IMP) –** the IMP extends the Concept of Operations (ConOps) document by converting the operational requirements ("what")

defined in the ConOps into an operational plan ("how") that provides a framework for the implementation, operations, safety governance and evaluation aspects of the trial. Through a set of processes and procedures, the IMP helps to define the level of coordination and collaboration between stakeholders and operational roles to enable seamless operation and evaluation of equipment and C-ITS services.

- **Plan for Monitoring Operations (PfMO) –** sets out how safety performance of the on-road testing will be monitored. The PfMO provides a description of the process to be followed to enable the safety assessment for on-road testing to take place. It describes how monitoring will be used to identify significant occurrences ("Trigger Events") and the appropriate response.
- **Combined Hazard and Safety Log –** the purpose of the Combined Safety and Hazard Log is to demonstrate that an appropriate level of safety governance has been applied to assess the expected safety performance of the connected corridor.
- **Risk Management Plan –** this document defines the process for identifying, recording and managing risks throughout the pilot. The document also contains information about assigning risks to groups/individuals as 'risk owner' and the method for escalating risks to the appropriate level within the governance structure.
- **Stakeholder engagement –** due to the complexity of the pilot and number and diversity of stakeholders involved, a Communications Plan was developed that contained information about the stakeholders, their interest in the pilot, a meeting schedule along with the frequency and type of information to be shared with stakeholder groups.
- **Safety Governance arrangements –** the safety governance methodology is captured in the Safety Plan document. This plan seeks to address the question *"What is the impact of the connected corridor trial on safety risk and is the proposed operation of the trial acceptably safe?".* During the pilot a Safety Log is used to record any safety issues/risks/events that occur or are raised by stakeholders during the pilot stage.

To meet InterCor's test requirements the UK undertook six focused test events (FTE). Each event tested different aspects of the C-ITS services under a variety of simulated and real operational conditions. This included some night time testing when there were maintenance road works on TfL's and HE's road networks. An Operations Plan was developed for each of the six FTEs.

During the FTEs, communication was maintained between test event coordinators as well as TfL's and HE's Traffic Control Centres. The control centre was able to intervene whenever significant congestion occurred, to reduce its impact on the testing.

6.4.2 *Vehicle test fleet*

The main body of the vehicle fleet used for evaluation was made up of Kent County Council works vehicles that use the routes regularly and were called upon for randomised controlled testing as per the evaluation detailed methodology (Focussed Test Events). In addition, the UK partners and associates as well as European partners taking part in the TESTFESTs all contributed towards the testing and evaluation. The number of vehicles varied at each Focussed Test Event – six events in total of 12 full days and one testing during night. In total there were 271 usable evaluation test runs over the entire pilot operation period. Full details relating to the testing and evaluation are available in Milestone 13 report.

To ensure that drivers were fully prepared for the FTEs, they were asked to attend a training session which included material about the purpose of the trial, their role as a participant in the trial, key information about the equipment and the evaluation process in general. The driver training was not part of the FTE and could take place some days/weeks prior.

Prior to commencing on-road testing drivers were given a short safety briefing which covered important safety topics and what to do if an incident occurs. The briefings were also an opportunity to describe the route and for drivers to ask any questions/raise concerns before going out in their test vehicle.

On returning to the meeting place having completed a test session, drivers were asked to complete as short online questionnaire and to undergo a face-to-face interview, so that driver feedback could be noted in detail for later analysis.

6.5 Data collection

The backend system contains a number of log creation points for measuring messages as they travel through the system. Created logs are stored in the system's data lake to allow granular analysis to be undertaken.

RSU logs are periodically uploaded to the data lake via the fibre backhaul. After testing, each OBU was power cycled. This action uploaded the test data logs (that had been stored on the OBU's SD card during the testing) to the data lake. This was done via the OBU's cellular connection. The data was collated in conformance with InterCor's logging format. OBU log data was uploaded immediately after testing rather than during testing, so to ensure that the data upload process did not negatively affect the performance of the cellular C-ITS services.

In addition to technical data, data relating to user attitudes and experience was collected prior and after on-road testing of the technology. Drivers from Kent County Council were recruited as participants and drove the test routes to get a first-hand experience with each of the tested services. Online questionnaires were used to measure participants' attitudes towards the services prior to experiencing them (measure of acceptability) and after exposure (measure of acceptance). Additionally, semi-structured face-to-face interviews were conducted with participants just after each test drive to collect more detailed feedback about user experience with each of the tested services.

4k HD video recording devices were also used to record in vehicle HMI displays, driver behaviour, external signal/sign setting and vehicle engine telemetry via a Bluetooth enabled dongle that had been connected to each vehicle's On-Board Diagnostics (OBD) port. Video and telemetry data were timestamped to enable it to be cross-referenced with OBU log data during the data analysis phase.

7 Bibliography

InterCor Milestone 9 report: “Milestone 9 – Start of Pilot Operation in the four MS”, V1.1, 31/05/2019

