Rijkswaterstaat
Ministry of Infrastructure and Water Management

Smart Forward!

Cooperative ITS Corridor

Cooperative
ITS Corridor
Joint deployment

The proof of the pudding

‘The proof of the pudding is in the eating’. These are words so often used that they have almost become a cliché. But in fact, this is a very old proverb where 'proof' is a verb meaning 'test'. And this saying is very appropriate for the recent activities on the Cooperative ITS Corridor. We already knew that the technology works. Previous tests showed that it is perfectly possible to show safety information about road works and speed limits in the car. But then there is putting it into practice. Does it work day in day out, over a longer period of time, with random users? Is the information clear to the road user? Is the signal being displayed at the right moment? How does the driver experience the additional information? Does it help or does it distract? And what about a foreign vehicle driving on our roads? Does the driver also receive the information? These are all questions we can only answer by performing long-term, focused tests.

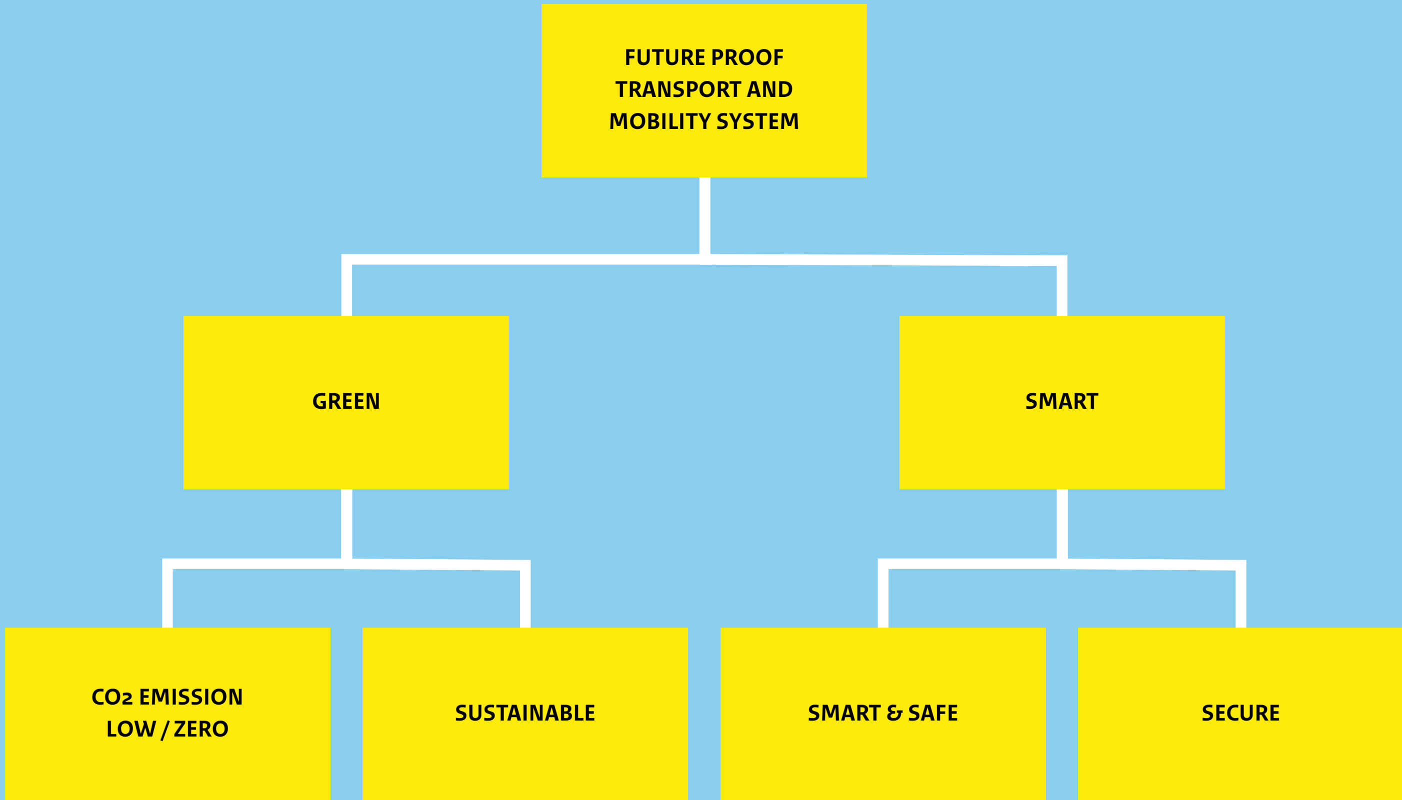
In cooperation with market parties, the Dutch project team has undertaken significant efforts in order to realize those tests. And with that, a step from a controlled test environment to everyday operations for the purpose of collecting data and gaining insight into the answers to all those questions.

In our first two booklets, which can be downloaded from the C-ITS Corridor website, we already described how we tested the cooperative services step-by-step in a number of field tests. Major milestones: the four C-ITS Corridor ‘Pre-deployments’ and the first three ‘TestFests’ of the EU-funded InterCor project. In this booklet we continue the story with the fourth and final InterCor TestFest and the many naturalistic user tests and controlled tests during live road works we performed as part of the Dutch contribution to the so-called InterCor Pilot Operation.

What was the result? Was the pudding indeed edible? I think I can answer that with a straightforward ‘yes’! Was the pudding already perfect? I would not say that. But then again, that is not something you can expect from a new recipe. We laid the foundation, tested in practice. On top of that, there are many issues road authorities should be aware of when further realizing C-ITS. So, cooperation with international industry partners and road operators is the way to move ‘Smart Forward’!

With this booklet I want to share our experiences with you. I hope you find it enjoyable!

Fred Verweij
Senior Advisor Rijkswaterstaat
C-ITS Corridor project team


FUTURE PROOF TRANSPORT AND MOBILITY SYSTEM
GREEN
SMART
CO2 EMISSION LOW / ZERO
SUSTAINABLE
SMART & SAFE
SECURE

Introduction

Green and smart: the key components of a future proof Dutch mobility system!

The Dutch Minister of Infrastructure and Water Management summarizes the transition to a green and smart mobility system in the very appropriate acronym ACESSS: Automated, Connected, Emission free, Smart, Safe, Secure. Innovative, scalable new generation smart mobility solutions can provide an important contribution to the improvement of road safety, traffic flow and sustainability. And, ultimately, improve your experience as a road user.

Cooperative
ITS Corridor
Joint deployment

InterCor

Cooperative ITS Corridor

The C-ITS Corridor project is a cooperation of road operators in the Netherlands, Germany and Austria. Together with industrial partners, the road operators are working towards the introduction of C-ITS services in Europe. The project became a major building block for other international initiatives and contributes to standardization, harmonization and implementation of new cross-border services for international road users.

InterCor

InterCor (Interoperable Corridors) is a European project, co-financed by the European Union under the Connecting Europe Facility. The project aims to enable vehicles and road infrastructure to communicate data through cellular or ITS-G5 networks, or a hybrid combination, on road corridors within France, Belgium, the United Kingdom and the Netherlands.
In this project technical specifications are being developed and validated in a broad context to enable the rollout of interoperable C-ITS services.
The results of the InterCor project contribute to the formulation of joint specifications within the C-Roads Platform.

Services

Initially, the C-ITS Corridor project focused on two services:

- Road Works Warning (RWW);
- Sensor data from vehicles (Probe Vehicle Data, PVD).

Additionally, the Netherlands also developed:

- Collision Risk Warning (CRW);
- In-Vehicle Signage (IVS).

As part of a collaboration with the Dutch team of the European Concorda (Connected Corridors for Driving Automation) project, the following services were tested in 2019 and 2020:

- Road Works Warning;
- Dynamic Speed Limit Information (IVS-DSLI);
- Dynamic Lane Management - Lane status information (IVS-OSI);
- Signalized Intersections - Green Light Optimal Speed Advisory / Time to green/Time to red (SI-GLOSA).

In addition, two additional use cases are being developed:

- Hazardous Location Notification - Stationary Vehicle (HLN-SV);
- Hazardous Location Notification - Traffic Jam Ahead (HLN-TJA).

Collaboration

Collaboration between the Dutch C-ITS Corridor project and the Dutch team of the European Concorda project started early 2019.

Concorda will prepare the road infrastructure in Europe for automated driving and high-density truck platooning with adequate connected services and technologies. The main objective of Concorda is to assess performances of the hybrid communication under real traffic situations. To this aim, the Dutch teams of the C-ITS Corridor and Concorda projects cooperate closely with one another and with national and international project partners and market parties. The collaboration focuses mainly on the use and extension of the integral ITS system (Back end –Central Unit (CU) – Roadside Unit (RSU) – In-car systems) as developed within the C-ITS Corridor project.

The Dutch part of the C-ITS Corridor project is also the technical core of the Rijkswaterstaat contribution to the InterCor project. Besides sharing data, resulting in harmonized European specifications, the Dutch team also delivered input for the completion of InterCor deliverables such as Technical Evaluation, Impact Assessment and User Acceptance. The majority of the input data was collected during the InterCor Pilot Operation.


Cooperative
ITS Corridor
CONCORDA
Praktijkproef
Amsterdam

1 InterCor Pilot Operation

Increasing road transport volumes in the European Union are the primary cause of growing congestion and rising energy consumption and represent a major environmental and social challenge. Improving road safety, traffic flow and sustainability: a goal on European level as well.

The InterCor Pilot Operation, a period of extensive and long-term testing, provided insights into the effects we can expect from the utilization of C-ITS systems. Subsequently, through thorough evaluation proven cumulative, real-life benefits of C-ITS applications will promote investments in these systems by public and private stakeholders.

1.1 Member states Pilot Operations

The InterCor Pilot Operation consisted of conducting aligned pilots in the four Member States. During the pilot operation the Member States were required to collect data for evaluation purposes.

1.2 Pilot Operations in the Netherlands

In the Netherlands an incremental approach was chosen for the InterCor pilots, building on work already carried out in the C-ITS Corridor project and other national projects. The pilot activities can be seen as a process growing from first trials with ITS-G5 communication in 2016 to full pilot operation with all services with cellular and ITS-G5 communication in 2018/2019. In this incremental approach extra services were gradually added over time. And this approach also allowed to adapt to changes in the (international) specifications of systems during the first years of the InterCor project and to work in a 'learning by doing' way.

The Dutch pilot area is situated in the southern part of the country and near Utrecht. 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.

The following services were operational:
- In-Vehicle Signage (IVS);
- Road Works Warning (RWW);
- Probe Vehicle Data (PVD, sensor data from vehicles);
- Green Light Optimal Speed Advisory (GLOSA);
- Truck Parking (TP);
- Multimodal Cargo Transport (MCTO);
- Tunnel Logistics (TL).

1.3 Dutch Pilot activities on the C-ITS Corridor test site

From September 2018 to August 2019 extensive data regarding the services IVS and RWW was collected for the InterCor Pilot Operation evaluation, using the final common InterCor specifications. During this period, over 2,700 test drives on the state of the art, hybrid test bed on the A16 motorway near Dordrecht were logged.

The A16 is a very complex part of the Dutch motorway network with numerous gantries for traffic management, tunnels, viaducts and parallel lanes. This makes it a very suitable section for complex testing and acquiring knowledge about the functional working of the technology.

The last four months of testing also included naturalistic user tests and controlled tests during live road works. Data collection started with several tests towards the InterCor Cross-border Interoperability TestFest.

C-ITS Corridor, a bird's-eye view

2013

June 2013
Signing of the Memorandum of Understanding by the ministers responsible of Austria, Germany and the Netherlands

2014

January 2014
Project plan discussed by the RWS Board of Directors

November 2014
Start preparations RWS phase 1 of the Dutch part of the Corridor

2015

May
Approval to commence project activities

October
First Corridor market day: Re-action Day, sharing views on the ITS Corridor

LIVE EVENT #1
November
Field test RWW on the A16 motorway near Dordrecht

LIVE EVENT #2
November
Interoperability test RWW in Germany
The first Dutch interoperability test in Germany

LIVE EVENT #3
December
Field test RWW on the A58 infrastructure of the Shock-wave traffic jams project

2016

LIVE EVENT #4
March
Second Dutch inter-operability test RWW in Germany

April
Participating in Innovation Expo Amsterdam

July
Second Corridor market day: Recap RWW field tests and interactive workshops

LIVE EVENT #5
November
Field test RWW from lane closure trailers
The first time RWW messages were automatically generated by a Central Unit

LIVE EVENT #6
December
Field test Sensor data from vehicles (PVD), based on the 3rd party infrastructure for the A58 Shockwave traffic jams project

2017

LIVE EVENT #7
February
Field test CRW
For the first time a Flister message was converted to a DENM message, in accordance with international standards

LIVE EVENT #8
March
Field test RWW on a typical Dutch motorway with variable message signs (motorway management system)
The first demonstration in Europe of the transmission of IVI messages based on information from the back-end systems

April
First version of RSU Positioning Guidelines: guidelines to determine the position of cooperative roadside ITS stations

June
Press release Volkswagen: 'With the aim of increasing safety in road traffic, Volkswagen will enable vehicles to communicate with each other as from 2019'

LIVE EVENT #9
July
Organizing Dutch InterCor ETSI-G5 TESTFEST: validating the common set of specifications for existing services using ITS-G5
The first InterCor TESTFEST

LIVE EVENT #10
July
Field test ('Probebetrieb') in Germany: validating the interpretation of the ETSI-G5 signals from German safety trailers

September
Publication by the C-roads platform of the first release of a harmonized specification for cooperative services, the internationally aligned Dutch C-ITS Corridor Profile

November
Corridor NL event 'Accelerating Corridors': presenting results en lessons learned so far

2018

March
Participating in InterTraffic Amsterdam

July
Nomination for the Dutch Computable Awards in the category 'Digital Innovation of the Year'

LIVE EVENT #11

April
InterCor PKI Security TESTFEST in France: validating the interoperability of PKI solutions

September
Participating in ITS World Congress Copenhagen
RWS Special Interest Session

LIVE EVENT #12

June
Cooperating with the Province of Noord-Holland for testing on the N205
The N205 is the first 'smart road' in the Netherlands, fully equipped with smart traffic lights

LIVE EVENT #15

October
Participating in Experience Week Connected Transport: RWW test runs on the C-ITS Corridor, the A16 motorway

LIVE EVENT #16

October
InterCor Hybrid TESTFEST in the UK: testing I2V services operating in a hybrid combination of ITS-G5 and cellular communication systems
The cross-border interoperability of these services was tested by means of crossing a virtual border

LIVE EVENT #13

June
Participating in SMART & Safe Convoy & Parking event

LIVE EVENT #14

June
InterCor pre-TESTFEST in Helmond: validating the interoperability of ITS Hybrid GLOSA services

November
Participating in ITS Forum Utrecht

June
Organizing international workshop Hessen: exchange of experiences amongst the Corridor partner countries

December
Start up-scaling test vehicle fleet for InterCor pilot operations
Objective is to analyse elements and issues that influence the penetration and effective use of relevant C-ITS hybrid services

2019

January
Participating in InfraTech Rotterdam

June
Thirteenth ITS European Congress
Contributing to the making of the 'Smart Mobility Dutch Reality' film and an informative InterCor film
Hosting an 'Experience Visit' to the A16 testbed during live traffic for a group of international visitors

LIVE EVENT #17

February
Participating in collaboration with Fiat Italy in a pre-test event for the Concorda project: testing on the Corridor test bed A16 motorway

July
Executing ESB-DENM tests with safety trailer on the A16 test bed

July
Up-scaling testbed A16 with LTE-V
Testbed prepared for next level live pre-testing

LIVE EVENT #18

March
InterCor Cross-border Interoperability TESTFEST organized by Belgium: validating interoperability of all deployed C-ITS hybrid services
A three-week event of testing in the Netherlands, France, the UK and Belgium

March
Allocation of test vehicles to Rijkswaterstaat test drivers

August
Evaluation of InterCor Pilot Operation

LIVE EVENT #29

March - August
Naturalistic driving tests on the A16 testbed by Rijkswaterstaat test drivers

September
Organization of Concorda Amsterdam pilot test session 1

LIVE EVENT #19-28

April - July
Nine controlled driving test events with external drivers on the A16 testbed during road works

LIVE EVENT #30

November
Organization of Concorda Amsterdam pre-test for pilot test session 2

2020

LIVE EVENT #31

January
Concorda Amsterdam pilot test session 2

April
(Inter)national launch of C-V2X

LIVE EVENT #32

July
Concorda Amsterdam Interoperability cross-border testing IMEC Leuven

LIVE EVENT #33

September
Concorda Amsterdam Interoperability testing Brabant

October - December
- Launch PKI 1.3.1 on A16 & A5/A9
- Concorda evaluation data collection
- Discharge C-ITS Corridor and transfer Buildingblocks to C-ITS Next

2 Test, test, test!

Through testing we verify and validate that the system meets the various requirements, including functionality, performance, reliability, security, usability and so on. Verification and validation are necessary to ensure that the system and use cases are built correctly. In addition, testing validates that the system being developed is what the user needs.

We found out that the gap between theory and practice can only be narrowed by testing, testing and more testing, in live traffic and with international partners.

2.1 InterCor Cross-border Interoperability TestFest

Twelve teams from InterCor Member States France, Belgium, the United Kingdom and the Netherlands participated in the InterCor Cross-border Interoperability TestFest. In preparation of this TestFest, the Dutch C-ITS Corridor project team performed extensive pre-tests over a period of two weeks in the UK, France and Belgium.

The objective of the TestFest was to validate the interoperability of the deployed C-ITS hybrid services RWW, PVD, IVS and GLOSA across national borders, based on the common set of specifications developed in the InterCor project. Validation was to be achieved by testing the interoperability of user devices [Vehicle ITS stations or On-Board Units (OBUs)] from the four member states at each other's pilot location(s).

In the Netherlands, Rijkswaterstaat and the Province of Noord-Brabant hosted the tests, which were performed on the test sites on the A16 near Dordrecht and in Helmond. Tests on the A16 focused on RWW and IVS, tests in Helmond focused on GLOSA. The participating Dutch road operators performed their tests with two dedicated test vehicles. Those vehicles were equipped with ITS-G5 as well as cellular capabilities and could be switched to either 'ITS-G5 only', 'cellular only' or 'hybrid' (both). Each vehicle was able to verify digital signatures (Public Key Infrastructure, PKI), but could also be switched to a setting without verification.

By participating in this TestFest we learned that in principle the overall C-ITS concept functions and allows for cross-border interoperability, but that there is also still a lot of work to be done with regard to fine-tuning of testing, specifications and documentation.

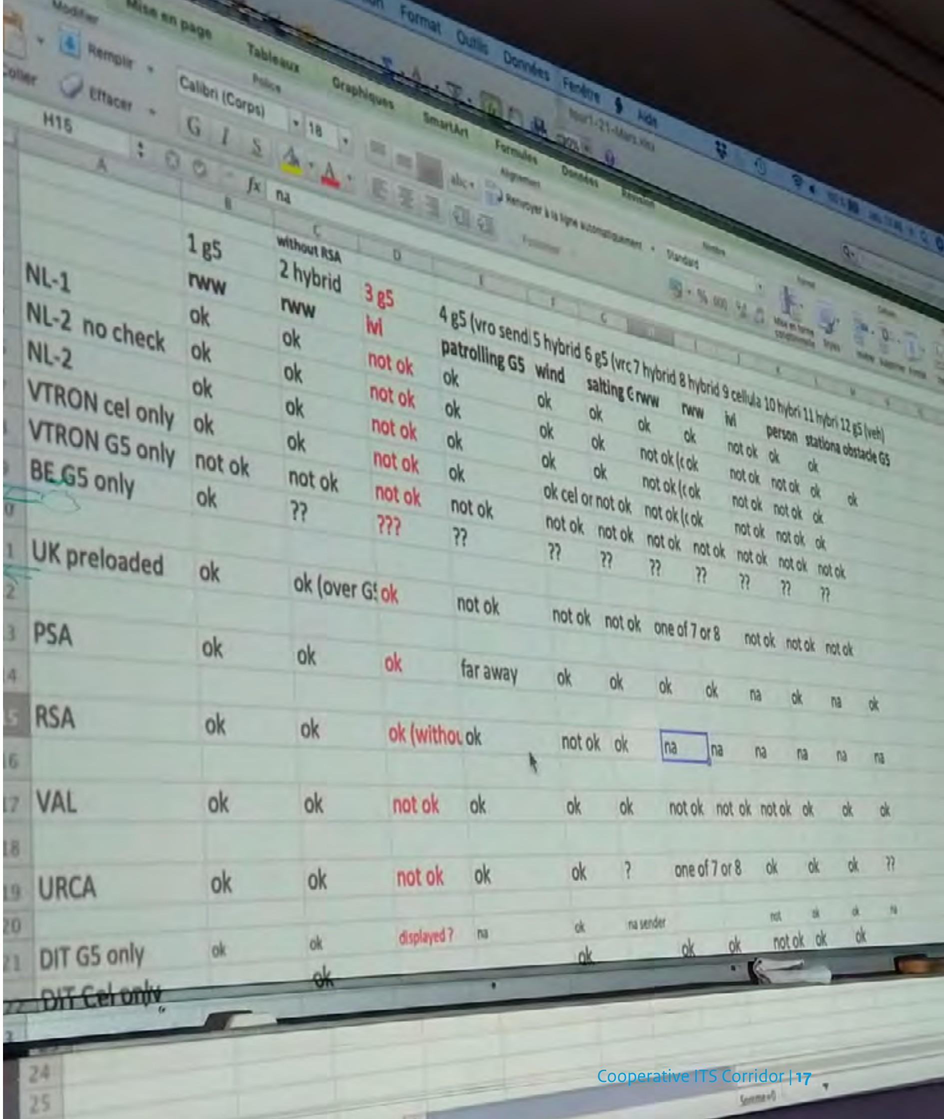
Participation in this TestFest also resulted in a number of Lessons Learned, some of the key Lessons Learned were:

The number of tests necessary with regard to various complex technical aspects of the associated services is underestimated.

Having a ‘developer’s playground’ as provided by the InterCor TestFests creates major opportunities for networking between all private and public parties.

The unavailability of an independent international validation body poses a challenge.

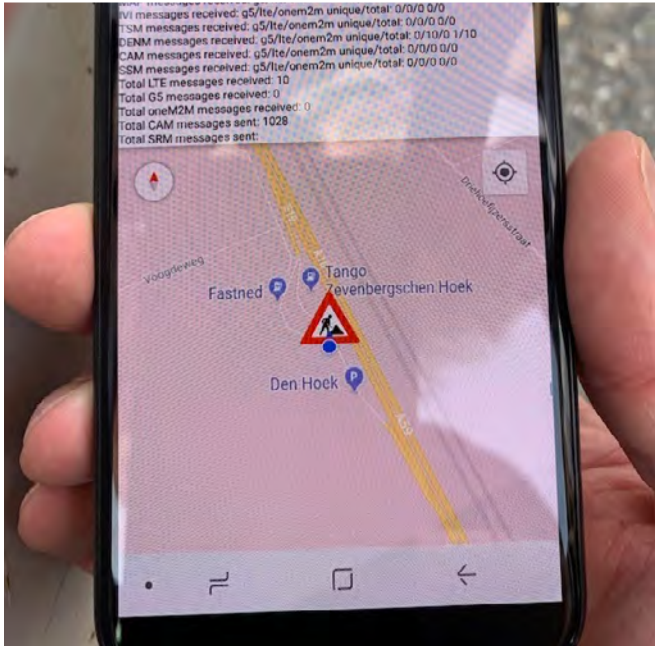
International, unambiguous agreements about specifications, profiles and methods of collecting log data still need to be further improved, for even better results and for evaluation purposes.



2.2 ESB-DENM tests

In July 2019, ESB-DENM testing took place in order to test reception of DENMs (Decentralized Environmental Notification Messages) in a controlled test environment. Communication of the DENMs was established via the cellular channel only, from a lane closure trailer connected via the existing Flister app.

This was the first time this type of testing took place. Eventually, it will be possible to provide the RWW service via long range communication.



2.3 Concorda test events

A large part of the cooperation between the Dutch teams of the C-ITS and Concorda projects involves testing, validating and verifying the hybrid C-ITS system, with a clear focus on and contribution to the next step of connected and automated driving. For this purpose, a series of open road tests was performed with Concorda Amsterdam partners Fiat Chrysler Automobiles (FCA-CRF), NXP and the Amsterdam Practical Trial, during real live traffic as well as with virtual scenarios. Also, a state-of-the-art test site was established on the A5 and A9 motorways near Amsterdam. However, because this test location was not yet operational, the initials test events were held on the A16 motorway.

February 2019. Pre-test event with Concorda project partners
Objective: to test security and whether or not the information from the intelligent traffic lights on the N205 test location and the intelligent RSUs on the A16 test location was correctly received and displayed in the test vehicles. As a result various adaptions were made to the systems, test vehicles and security protocols.

September 2019. Concorda Amsterdam pilot test session 1
Objective: to verify ETSI ITS-G5 V2X (Vehicle-to-Everything) and LTE/4G communication. Testing focused on cooperative driving with a number of GLOSA use cases and on cooperative driving with Road Management Information.
The tests were performed on test locations on the N205 and the A5-A9/A16.

November 2019. Concorda Amsterdam pre-test for pilot test session 2
Objective: to test cooperative driving with new use cases HLN-TJA and HLN-SV. Testing took place on the A5-A9 test location.

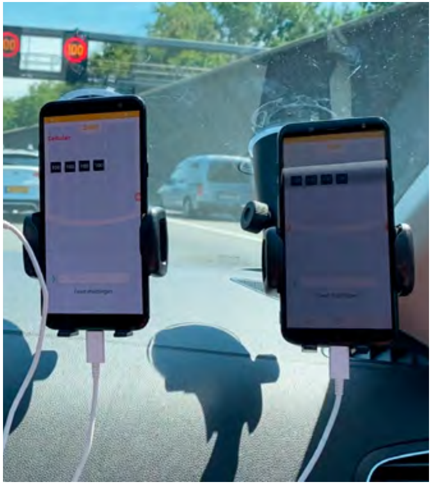
January 2020. Concorda Amsterdam pilot test session 2
Objective: Twofold, verifying both ETSI ITS G5 V2X communication and LTE/4G communication, collecting real live data for the purpose of subsequent in-vehicle control system verification. Successful testing took place on the A5/A9 including first live tests of HLN-TJA.

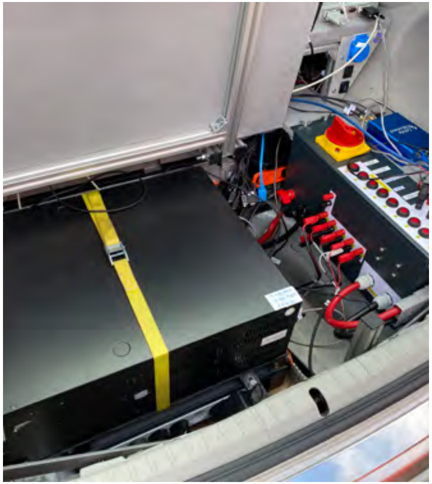
April 2020. Launch of C-V2X
Objective: International introduction of C-V2X (Cellular Vehicle-to-Everything) on roadside infrastructure. Verifying Concorda use cases through C-V2X Dedicated Short Range Communication. Successful tests and introduction were performed on the A5/A9.

July 2020. Concorda Amsterdam Interoperability cross-border testing with IMEC University Leuven
Objective: Verifying interoperability between the Concorda test sites MRA and Flanders. Successful tests were performed on the E313 near Antwerp and the A16 south of Rotterdam.

September 2020. Concorda Amsterdam Interoperability testing Brabant
Objective: Verifying interoperability between the Concorda test sites MRA and North-Brabant/Helmond by performing cross-site testing on the N273.

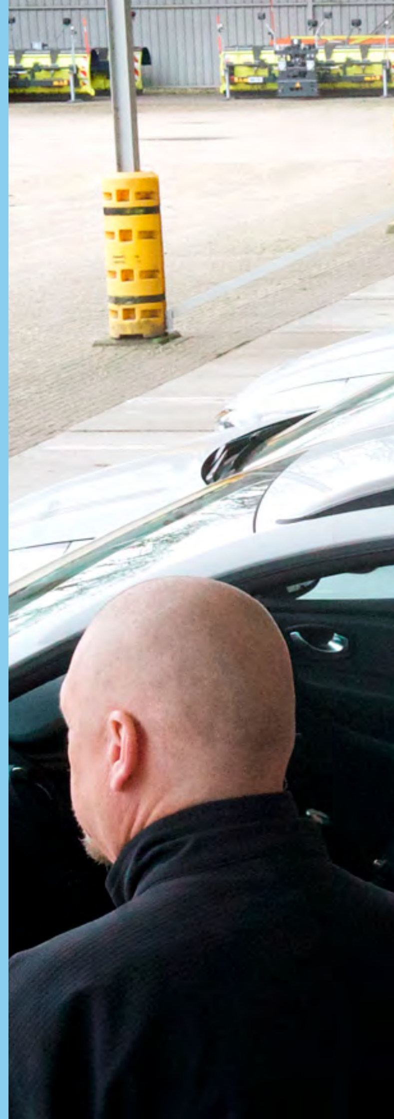
Due to Covid-19 restrictions, the main test sessions scheduled for Q2 – Q4 2020 were either postponed or executed in an alternative way. During this period, tests were performed not only with regard to interoperability but also around cooperative driving with HLN-SV and HLN-TJA, C-V2X and PKI 1.3.1 security. Furthermore, in December a large number of data collection runs took place on the N205, the A5/A9 and the Amsterdam IJtunnel area.
With those alternative tests and data collected we generated sufficient input for a solid evaluation program.





3 InterCor Pilot Operation on the C-ITS Corridor test site

The Dutch C-ITS project team, the technical core of the Rijkswaterstaat contribution to InterCor, made significant efforts towards successful execution of tests and data collection. The team put together a test fleet including voluntary test drivers. The HMI (Human-Machine interface) that was initially deployed was improved and the functionality of the OBU was updated with the requirements specified for the InterCor Cross-border Interoperability TestFest and Pilot Operations.



3.1 Approach

As mentioned in paragraph 1.2, intensive testing took place on the Corridor test bed on the A16 motorway for the purpose of data collection for the InterCor Pilot evaluation of the services IVS and RWW. In the last four months also with focus on naturalistic user tests and controlled tests during live road works.

For the IVS service, two scenarios were run: speed limits and lane deviations. Variable message signs were replicated in IVS messages during road works and for incident detection during congestion and traffic jams. The RWW service was delivered simultaneously with the IVS service. Decentralized Environmental Notification Messages (DENM) based on Flister data were also used to warn drivers for safety trailers blocking lanes during road works. The RWW service was tested in several scenarios in combination with and without IVS.

3.2 Test fleet

To enable the execution of the controlled and naturalistic user tests, the Dutch C-ITS Corridor project team set up a test fleet. This meant upscaling from one Rijkswaterstaat test vehicle to fifteen vehicles, fully equipped to fulfil the requirements for evaluation:

- One Rijkswaterstaat test vehicle for general use;
- Ten Rijkswaterstaat company cars driven by Rijkswaterstaat employees;
- One private car of a Rijkswaterstaat employee;
- Two Rijkswaterstaat road inspector vehicles. The participating road inspectors work on incident management and maintenance inspections and were often active on the test site;
- One vehicle of a Rijkswaterstaat subcontractor, working on the maintenance of the IT road infrastructure in the test site area.

3.3 Test drivers

The test drivers were recruited in different ways. Drivers for the naturalistic driving tests were found within Rijkswaterstaat. Ten employees - not directly involved in the project - volunteered to drive an equipped test vehicle as part of their regular commute for a period of five months. For the controlled drives, a specialised company was asked to supply 140 test drivers. All test drivers were briefed and completed a survey, both before and after the test drive. Every driver received a participant ID so they complete the questionnaires anonymously. Through the ID, the questionnaire results were linked with the data from the vehicle used by the participant. The outcome of these questionnaires was presented in the InterCor report 'Technical evaluation, Impact assessment and User acceptance finalised'.

3.4 Data collection

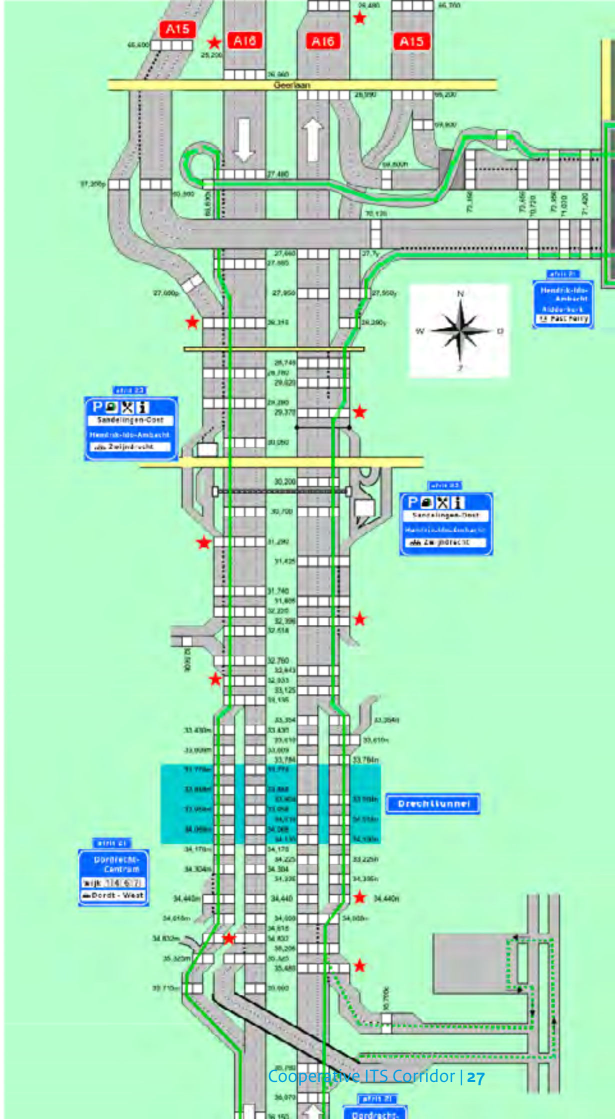
The combination of naturalistic driving (study into driver behaviour during regular everyday trips) and controlled driving was an approach, designed to answer the InterCor main evaluation questions. This combined approach made it possible to collect data on IVS and RWW within a limited period of time. Naturalistic driving took place during peak hours, when the dynamic speed signs are the most active. This provided much data on the performance, impact and behaviour related to IVS.

The naturalistic driving made it possible to test the system, not only over a longer period of time but also in many different situations. However, a disadvantage of naturalistic driving was that it was unsure how many times the equipped cars passed a location with for instance road works warning. Since road works on motorways in the Netherlands mainly take place during off-peak hours, it was less likely that test drivers would encounter road works during regular driving. To ensure sufficient 'hits' during actual road works, it was decided to also organize controlled tests on the A16 test location during selected evenings with actual road works. These controlled drives provided the data on RWW.

The project team selected nine evenings with actual road works on the A16 test site:

- April 5, 8 and 9. Each evening one of the four tubes of the Drechttunnel was closed. The tests were executed with fifty test drivers;
- May 10, 11 and 12. These evenings were chosen because of works at the Van Brienenoord bridge. The tests were executed with sixty test drivers;
- July 16, 17 and 18. These evenings were selected for more detailed technical tests on the DENM and the IVS messages. The tests were executed with thirty test drivers.

Selecting road works that provided interesting test circumstances was done using the Rijkswaterstaat tool 'SPIN'. Rijkswaterstaat uses the 'System Planning and Information Netherlands' tool to plan road works. This also includes the application procedure for traffic measures, for instance road closures, by contractors.

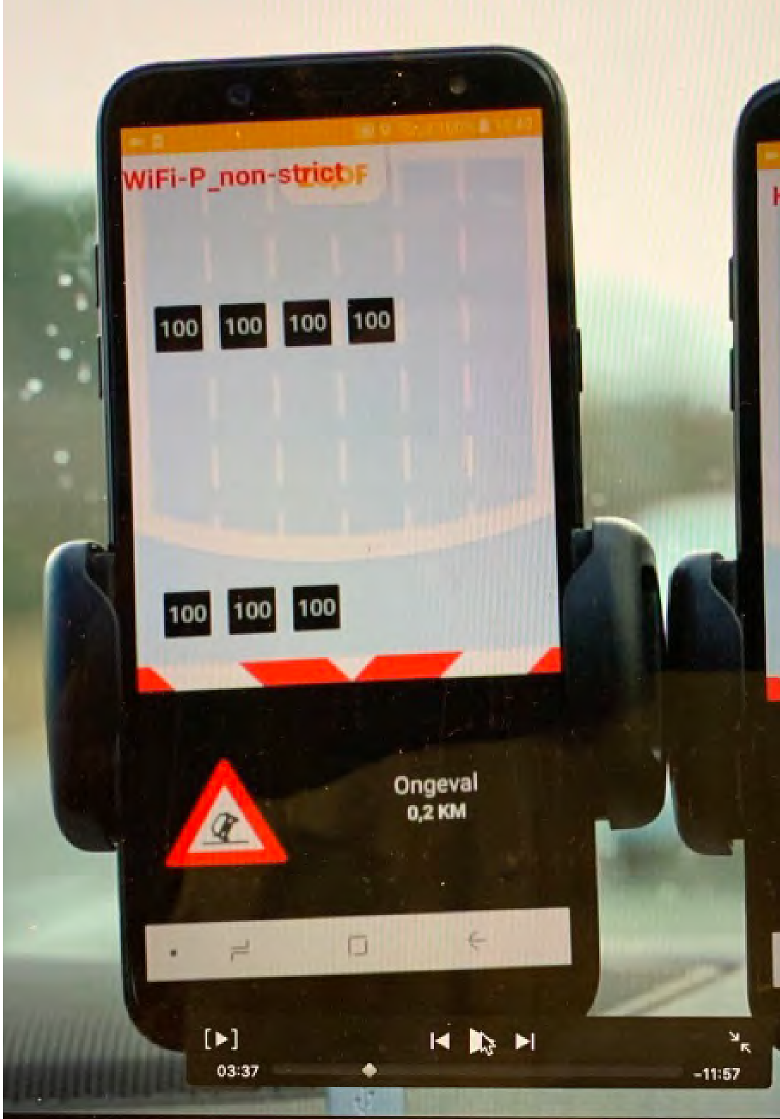


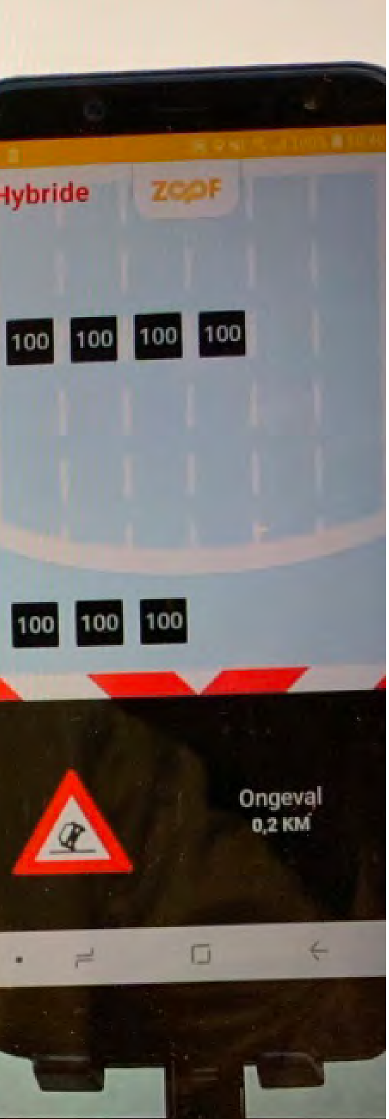
3.5 HMI

The HMI is a crucial part of the system and crucial for test and evaluation purposes. During a workshop with Human Behaviour experts a lot of information was collected to improve the HMI.

Improvements to the HMI were:
- Horizontal orientation of the HMI, for optimal use of the available space on the screen;
- Perspective was used to display information on portals further downstream;
- A black background to prevent distraction and an overly bright surface when driving in the dark.

The current version of the HMI does meet a great deal of the demands set by InterCor and also contains improvements suggested by our test drivers. However, one has to keep in mind that the final design, development and production of in-car C-ITS equipment for daily use, is up to the automotive industry.




Hybride
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Ongeval
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4 InterCor Pilot evaluation of IVS and RWW on the C-ITS Corridor test bed

Evaluation is an important tool for the development and introduction of safe, secure, efficient and sustainable C-ITS services.

The technical evaluation measures the effects of implemented technologies on system performance and quality of services. Impact assessment of applications and services includes the identification of the proper periodicity of advice, follow-up and their impact on indicators such as speed adaptation, route choice, travel times and traffic efficiency and safety. And, finally, user acceptance is crucial for widespread deployment of services.

4.1 Evaluation of IVS

Technical evaluation

Technically, the IVS service works excellently in conveying variable message signs to drivers. IVS works using either ITS-G5 with security, the IF2-interface data provisioning to service providers with cellular communication and the hybrid system as piloted. More than 96% of IVI (In-Vehicle Information) messages received from the roadside is presented to the driver on time and in the exact area where the IVI is valid (relevant), and revoked promptly when leaving this area.

Impact evaluation

When analysing the impact of IVS on user behaviour, speed data indicated that there are little to no differences in adapting speeds to the given in-car device speeds, compared with the baseline situation without in-car device. In case of speed limits of 50 and 70 km/h, results show that the median speeds are above the speed limit. For the case of 90 and 100 km/h there is compliance and the average speeds are equal or lower than the displayed limit.

User acceptance

Regarding the IVS of speed and lane information, most of the participants indicated to have seen, understood and used the information, either in every ride or mostly during disruptions. Participants mentioned that they found it useful to have specific emergency information in the vehicle. In general, the participants indicated a positive effect on their driving behaviour, related to the reaction to the information presented and to feeling more secure and at ease while driving. However, many participants were more negative after the test with respect to being distracted. Their comments for improvements mainly concerned the interface of the HMI but also the timeliness of presenting the information.

4.2 Evaluation of RWW

Technical evaluation

Technically, the RWW service works excellently in warning drivers for lane closures and other road hazards. RWW works using either ITS-G5 with security, the IF2 data provisioning to service providers with cellular communication and the hybrid system as piloted. More than 98% of DENM warnings received from the roadside is presented to the driver on time and throughout the area approaching the crash barrier (event location), and revoked promptly when passing this location.

Impact evaluation

For the DENM warnings, the impact evaluation found no effect at all on driving speed. From the moment a DENM warning was received by the OBU, no change in speed could be found, either from 30 seconds before to up to 30 seconds after the moment of receiving the DENM.

User acceptance

Regarding the RWW service, there was a considerable number of participants who indicated that they were actually not able to observe the information presented. This is most probably because during the second series of tests, much fewer roadworks were actually in progress than expected. Thus, there were no relevant messages for the drivers. As a result most of the participants indicated that, regarding the frequency, they never or almost never saw or used the presented information. Those who claimed to have seen and used the information, did it either in every drive or mainly during disruptions. No significant effect was noticed with respect to their reaction to the message presented for increasing the distance to the car in front of them or for their speed adaptation. In general, participants were positive about the usefulness and trustworthiness of the service. Some participants found the differences in the provided information regarding the speed limit, lane restrictions and road works unclear.

4.3 Research questions

For the user acceptance evaluation two questionnaires were used: one for user acceptability and one for user acceptance. The acceptability was assessed before the driving tests, the acceptance was assessed after the driving tests. This allowed for a comparison between the acceptability and acceptance of the tested services. Additionally, the general attitude of the group of users was also assessed by posing statements about their attitude towards speeding, their perception of the relation between speeding and other traffic aspects (for instance increased possibility of accidents), and how speeding influences their environment. Below you will find an overview of the research questions used for the user acceptance evaluation.

Human behaviour

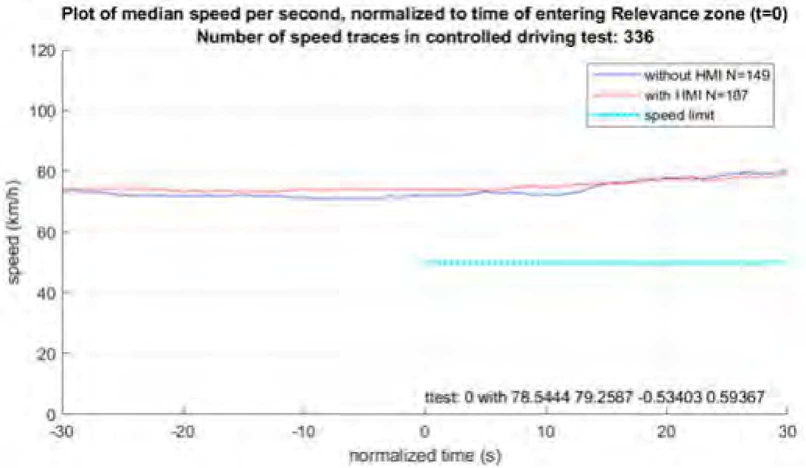
- Do drivers perceive, understand and value the information presented?
- How do drivers change their behaviour?
- Does the behaviour differ from those without the services?
- What demands does the current HMI place on drivers?

User acceptance

- Do drivers report perceiving and using the information presented?
- Do drivers feel like the services influence their behaviour? If so, how?
- How do drivers value the services?
- Do drivers believe the services improve their overall trip quality? If so, how?
- How do drivers value the HMI and could it be improved? (distracting/easy to use)
- How would drivers rank the services on key indicators like reliability and confidence in the data presented?

4.4 Main conclusions and key Lessons Learned

Technical evaluations proved the technical maturity of the roadside units and in-vehicle systems in place. Overall, the system worked very well with a reliability rate of over 96% of HMI presentations and an accuracy rate of over 94% of trace/relevance in ITS-G5 and hybrid mode. The roadside units provided (almost) complete coverage of the pilot site trajectory. Cellular and ITS-G5 both proved to be reliable communication layers with no substantial differences found in the use of 4G, ITS-G5 or hybrid communication.



With regard to impact and user acceptance findings, in general drivers were positive about both services. That being said, the measured impact on their speed and speed adaptations was not significant.

During the pilot a number of valuable Lessons Learned were collected. Some key items were:

The performance of the ITS-G5 services IVS and RWW was excellent.

Active involvement of OEMs and/or first tier suppliers is a must for road authorities in order to realize robust development of the services.

Road authorities need to constantly test, validate and verify their C-ITS systems. Investment in test vehicles and on-board systems is therefore crucial.

Testing with a variety of on-board units is valuable, comparing data from the various communication channels leads to a better understanding of the technology.

The HMI requires much attention. Both the quality of the HMI and its location in the vehicle are crucial for the outcome of a pilot.

Further research is still necessary to get a better understanding of the actual impact of the services. The pilot did not show a significant difference in behaviour with or without HMI, although the drivers stated that the services had a positive effect on their driving.

5 Meanwhile

In the midst of preparing for upcoming test events, the project team also organized and participated in several communication activities and events.

In February, C-ITS Corridor project manager Abraham Bot featured in an episode of the Dutch television series ‘Fight against traffic congestion’ (view here). Abraham was filmed giving an interview while driving on the A16 test bed in busy traffic.


avrotros
ABRAHAM BOT / PROJECTMANAGER RIJKSWATERSTAAT
die rechtstreeks communiceert
met de auto.

During the thirteenth ITS European Congress, which took place in the Eindhoven Brainport region in June, the project team was involved in several activities. In collaboration with various Dutch Smart Mobility parties the 'Smart Mobility Dutch Reality' film (view here) was produced. The team contributed to this film by showing some cross-border use cases integrated in trucks. And to an informative InterCor project film that was published (view here) around the same time.

In the context of the ITS European Congress, we hosted an 'Experience Visit' to the Corridor test site near Rotterdam. A group of international experts visited us at the Rijkswaterstaat location 'Steunpunt Dordrecht'. We presented our guests with the latest information about the realization and evaluation of the InterCor TestFests and Pilot Operations on the A16 test bed. After that, our guests went for extensive demo drives on the test bed, so they could experience the latest developments in Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) hybrid communication. In-car, by means of a mix of virtual scenarios and real live road works.

Germany, Austria and France have started preparations for deployment and operation of the day-1 C-ITS services. Road operators, industry partners and knowledge institutes are involved in these preparations for roll-out. An international Taskforce Operations, led by Hessen Mobil, was established to coordinate and handle upcoming issues in this process. The Dutch Corridor team is participating in this Taskforce.

Last but not least, in September the Technical University in Delft invited the C-ITS Corridor project to give a lecture to their 'Dispuut Verkeer', a student association of several master programs at the faculty of Civil Engineering. Two of our Corridor team members presented the students with hands-on information about the project and smart mobility in the Netherlands and initiated a discussion on statements regarding challenges in this field.

6 Key Project Results and Lessons Learned

The end of another phase of the ITS Corridor project! As always, this reminds us to focus on what we learned and achieved so far - and the key results we have to show for. Since this is also true for our project partners, we asked them to share their thoughts with us on some relevant subjects. These interviews have been incorporated in this and the next chapter. The interviewees:

- Freek van der Valk, Managing Director at Swarco Nederland B.V.;
- Ron de Waard, Operational Manager at Compass;
- Wim Vossebelt, CEO / Managing Partner at V-tron.

Firstly, we would like to present you with the overview of our key project results.

Key project results

The project started with just two day-1 use cases, the number of developed and evaluated use cases has grown to six.

A robust set of specifications which are internationally adopted:

- System Specifications;
- Profiles;
- PKI subscriptions;
- Customer Requirements Specifications.

A state-of-the-art cooperative test site, seventeen kilometres long, on the A16 motorway between Rotterdam and Dordrecht. A developers playground for international industry partners and road operators for making the next steps.

Two state-of-the-art test vehicles, equipped with hybrid OBUs and HMIs. These are compliant with and can be used on several European C-ITS test beds, based on the C-Roads platform specifications.

In-depth knowledge of cooperative hybrid systems, including a good understanding of its functionality from a traffic management and a road user point of view.

Access to an international network of key players: national road operators in Germany, Austria, Belgium, France and the UK as well as industry partners.

Interview question: ‘In your view, what are the most significant results of the C-ITS Corridor project and what is the major yield for your business from your collaboration with the project?’

‘Cooperation with the various actors involved has been of major importance when it comes to producing results. The term ‘Cooperative’ definitely applies to the organizational level as well
The outcomes and standards achieved were or are being harmonized at European level. For Swarco, being an international business, they are a way forward to standardized products and services.’

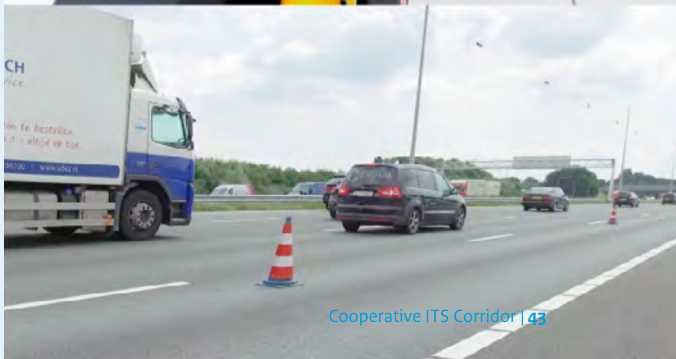
Freek van der Valk

‘I think as a country we have shown that we want to move forward and that we are not afraid to experiment. I believe we have proven that we are capable of being a ‘living lab’. Furthermore, we have become aware of the fact that there is a lot we do not know yet and that the automotive industry chooses its own path. In my view, that is a major yield. Last but not least, the role of Rijkswaterstaat as the driving force has proven to be of key importance.
As a business, we acquired a lot of knowledge and experience and expanded our network with interesting and relevant partners. Within the agreed communication frameworks, it has also generated positive PR.'

Ron de Waard

‘Understanding each other’s field, working together towards a common goal. This is not just the domain of the OEM or the road authority or the... No, this project has demonstrated that this supersedes the traditional pillars. The mayor yield for V-tron is, without a doubt, the knowledge we acquired in the field of integral cooperation, with parties we do not usually have as clients. This really was an opportunity for us to learn and understand the challenges that lie ahead.’

Wim Vossebelt



Projects can accelerate their development and decrease their costs by learning from earlier phases. We can do so by implementing past successes and avoiding past mistakes. To this end, the Corridor project team has collected over 400 Lessons Learned so far. Explicit priority was also given to incorporating lessons learned from all partners.

Next we would like to present our key Lessons Learned on generic project management topics.

Key Generic Lessons Learned

Plan and execute test events
They serve as an accelerator for development and international cooperation. They provide direction to the project team, operating in a setting of maximal insecurity.

Test and validate in live traffic as much as possible
The learning curve is much steeper when testing developments in live traffic. You will find challenges that will not show up in a lab or test circuit setting.

Involve the OEM and/or first tier
These parties represent the end user. It is crucial to know what the needs and expectations are. Also, by involving them, standards become industry standards.

Road authorities need their own OBU/HMI implementation
Without an own OBU/HMI it is not possible to release the test site for testing parties. It is also crucial when testing third party test results. And finally, essential for HB evaluation.

The achievements from one C-ITS technology are reusable in another C-ITS technology
Message formats and functional descriptions from ITS G5 solutions are reusable for the cellular domain.

Invest in the cooperation with good, international partners and nurture these relationships
They are hard to find. And when found, these relationships demand a lot of time, energy and attention. Facilitate test request from abroad.

Large-scale market introduction of C-ITS vehicles is on the horizon
This will drastically change traffic and traffic management.

International harmonization and standardization are tough but crucial
Without European aligned protocols cross-border interoperability is not feasible.

Trusted partners that can quickly and easily adapt are crucial for successful test events
These market parties fill in the technology.

Hybrid solutions have been proven to work, they are what we need to focus on in the coming years
Technology neutral, don’t exclude any solution.

As a road authority, focus on the traffic management benefits of the technology
And thus do not focus on the technology push.

Finally, below an overview of our key Lessons Learned on technical topics.

Key Technical Lessons Learned

Joint profiles
It is not just important but also critical to have EU-wide harmonized profiles and that every country adheres to them. Give profiles more attention and status. Suggestion: transfer C-Roads results to the European Committee for Standardization (CEN) and elevate them to European standard.

Hybrid communication
ITS G5 and cellular (short and long range) communication work well together. Thanks to the use of exactly the same data and the exact same format over ITS G5 and cellular no serious integration problems arise in-car. The advantages of the one compared to the other are still unclear. More research needs to be conducted, in a much more focused way using solid research questions and international, stable infrastructures.

TestFest are great for in-depth discussions
During briefings and debriefings relevant topics were being addressed. But sometimes participants were downplaying their issues. Plenary (de)briefings are not really suited for expert interaction. It is preferable to organize one-on-one technical sessions to discuss issues experienced in-depth.

GLOSA speed advice
A maximum speed must be included in the advice speed calculation so that the in-car speed advice does not exceed the maximum speed. If this is not the case, the speed advice should not be given. Time synchronization is also crucial for the service.

The Dutch MTM-ESB chain
The ESB client specification should contain a warning regarding the method used in combination with a firewall/proxy, with a reference to the specification RFC6202.

Lane sequence
In some countries, the lane sequence may be mirrored compared to what is common in continental Europe. As a result, the lane sequence does not correspond to reality and warnings are sometimes displayed in the wrong lane.

Extensive, long term testing in live traffic
The gap between theory and the practical reality can only be narrowed by testing, testing and testing, in live traffic with international partners. Intensive short-term testing is great, extensive long-term testing is indispensable in finding the real issues.

Infrastructure design guidelines
The costs of one-off / stand-alone C-ITS infrastructural deployment are very high. Combining C-ITS deployment with existing works can drastically reduce the deployment costs.

Interview question: ‘What is your key Lesson Learned?’

‘The standards require a very detailed knowledge. That means that knowledge of the domain is very relevant when aligning with other parties. This principle was well demonstrated in the inter-operability test events with multiple participating parties.'

Freek van der Valk

‘We learned that we are a flexible partner and that we can achieve a lot in a setting like this one. We navigate well - and with positive energy - between government, ‘externals’, software companies and automotive. Finally, we learned that political decision-making processes are more complicated than the technology.’

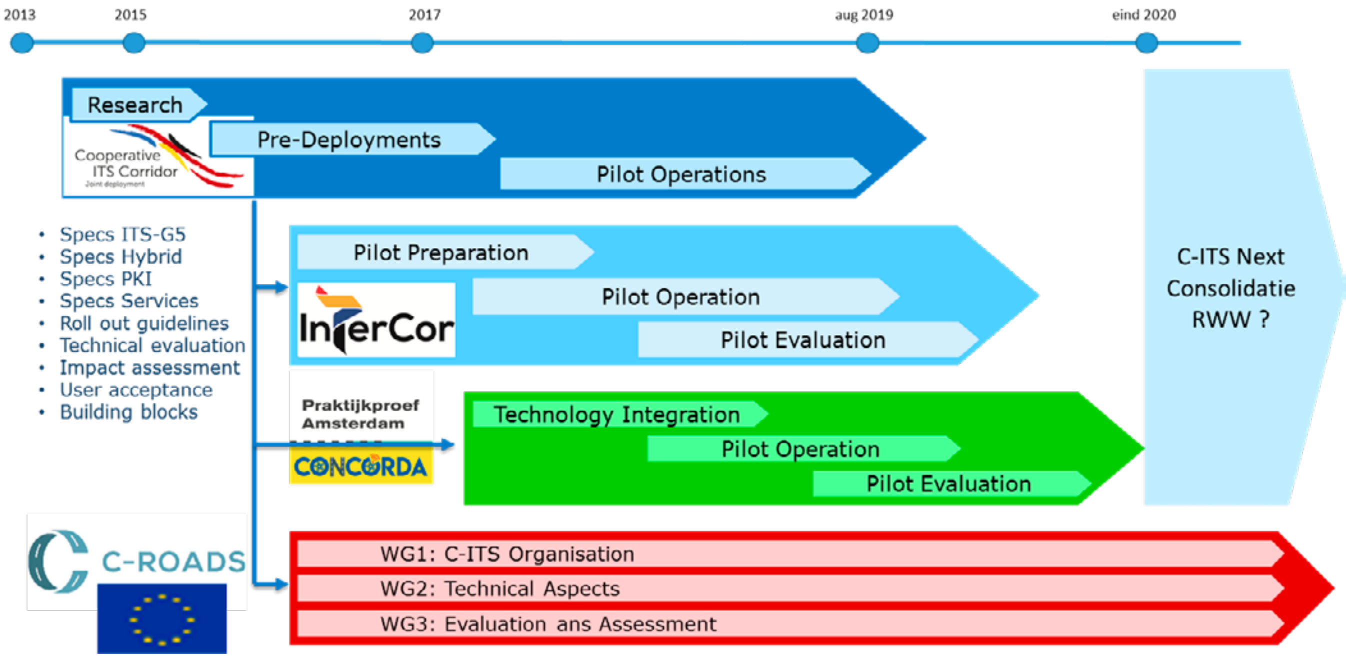
Ron de Waard

'This is not about technology, an excuse often used. It is more about traditional market conditions, market parties and government bodies holding one another to ransom. That is the hardest challenge! Finally, I truly believe that international coordination is crucial, this cannot be done at country level.’

Wim Vossebelt

The Corridor project has brought us numerous Lessons Learned, new solutions and new ways of working together. Understanding the value of road operators and industry partners working together is key for achieving joint successes in the Dutch C-ITS projects which will come next.
If you would like to find out more, please visit our website.
We have published a large number of knowledge carriers in our documents section, such as technical specifications, reports, animations, factsheets, films and so on.

Below an overview of the realization processes of the C-ITS Corridor, InterCor and Concorda projects, also in relation to C-Roads.



7 Looking ahead

'Looking ahead is quite difficult, especially when it concerns the future' a Dutch comedian once said. However, considering the developments in the field of C-ITS, a number of converging patterns can be seen:

- In the fall of 2019 Volkswagen introduced its new Golf Mk8. This is the first European high-volume vehicle equipped with cooperative technology. This Golf is standard-equipped with Car2X technology so it is able to communicate with other vehicles and with the infrastructure. The first Golf Mk8 was delivered in March 2020. The project team already performed some tests with it on the A16. This introduction by the Volkswagen group will certainly accelerate the deployment of C-ITS services;
- Based on our international contacts, it is expected that Renault will follow as the second-high volume OEM deploying cooperative technology in its vehicles;
- Germany and Austria are currently deploying cooperative technology. Germany on 3000+ safety trailers, Austria on its gantries along the corridor Vienna - Salzburg;
- The introduction of C-V2X, being the cellular short range 5G equivalent, and already successful tested by Rijkswaterstaat, will also help to speed up deployment of C-ITS;
- The ETSI-defined message structure to support various use cases has evolved to a solid industry standard, independent of the communication technology used.


Stilstaand voertuig vooruit
300 m
94
km/h
170 km
93 km/h
D


Stilstaand voertuig vooruit
50 m
94
km/h
170 km
93 km/h
D


Test-site
Prov. Noord Holland
Test-site
City Amsterdam
Test-site RWS A5/A9
ITS G5, C-V2X, cellular (4G)
RWS A4-A13-A20
Cellular (4G)
Test-site RWS A16
ITS G5 + cellular (4G)
Testsite Vlaanderen
ITS G5 + cellular (4G)
Haarlem
Amsterdam
Amstelveen
Lisse
Leiden
Alphen aan den Rijn
Den Haag
Delft
Hoek van Holland
Rotterdam
Brielle
Spijkenisse
Dordrecht
Gorinchem
Nationaal Park De Biesbosch
Steenbergen
Roosendaal
Breda
Tilburg
Antwerpen

Interview question: ‘We would be interested to find out which short term developments you expect regarding the roadside infrastructure along the primary road network.'

‘The need for an infrastructure related technology in order to adequately support the driving tasks of autonomous vehicles is evident. And also, to support high quality road marking and safety related use cases. The experience we gained does certainly contribute, especially in the migration process. However, we may have to change our expectations about when the introduction of fully autonomous vehicles will take place.’

Freek van der Valk

Interview question: ‘As a system integrator, how does Compass prepare for future roadside developments and the uncertainties in this field?'

‘We prepare by realizing that change is the only constant factor! And by keeping up to date with the developments and building a network of relationships we can move forward with.’

Ron de Waard

Interview question: ‘What is your view with regard to the future development of in-car possibilities?'

‘For V-tron, the challenges are infinite. The biggest challenge however is to keep the Dutch fleet, consisting of newer and older vehicles, on a relatively equivalent level. In our vision drivers will still play an important role, but how are we going to support that role in such a way that we can help prevent errors? Also, when it comes to older vehicles! Besides the fact that road accidents cause human suffering there is a financial consequence of fourteen billion euro a year. An unacceptable situation! The biggest challenge is the development of valuable services drivers can understand and utilize.’

Wim Vossebelt

I am very curious to see further developments in C-ITS! I strongly believe that short range V2X communication will become reality in the next decade.

Abraham Bot

Project Manager

C-ITS Corridor project

Cooperative
ITS Corridor
Joint deployment

Co-financed by the European Union
Connecting Europe Facility

Published by

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For further information visit
www.its-corridor.nl

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