Rethinking transport
27–30 April 2020

TRA 2020 HELSINKI

Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland

C-ROADS GERMANY

Fazin Godarzi[a], Tobias Reiff[a], Stephanie Cheung[b], Marcus Hirschberger[b], Yihong Pei[c]

[a] *Federal Highway Research Institute (BASt), Brüderstr. 53, 51427 Bergisch Gladbach, Germany*
[b] *Hessen Mobil – Road and Traffic Management -, Westerbachstraße 73-79, 60489 Frankfurt am Main, Germany*
[c] *NORDSYS GmbH, Mittelweg 7, 38106 Braunschweig, Germany*

Abstract

C-Roads Germany, as part of the European C-Roads Platform, aims to test and implement cooperative Intelligent Transport Systems (C-ITS) in a real traffic environment. C-ITS encompass services based on data exchange via wireless communication systems among road users and among infrastructure entities and road users. These technologies enable a new generation of services.

C-Roads Germany has two pilot sites where the following eight C-ITS Services are developed and tested: Emergency Vehicle Approaching, Green Light Optimal Speed Advisory, In Vehicle Signage, Maintenance Vehicle Warning, Probe Vehicle Data, Road Works Warning, Shockwave Damping and Traffic Jam Ahead Warning. All services aim to reduce the number and severity of accidents (Safety), minimize the emissions of noise and exhaust (Environment) and increase the efficiency of the road system (Efficiency). The road user receives the information to react accordingly.

The Federal Highway Research Institute fosters the European-wide harmonization of C-ITS and promotes their interoperability.

Keywords: C2C;C2I;C-ITS;Testing;Safety

1. Introduction

The infrastructure in Europe is facing an increasing volume of passenger and freight traffic. The demand for individual mobility is accompanied by a simultaneous increase in goods transportation. To ensure the individual mobility and supply reliability innovative technologies are indispensible. New and enhanced technologies are needed to increase road safety, improve traffic flow and reduce emissions. Even if these goals are partly in conflict with each other, Cooperative Intelligent Transport Systems (C-ITS) offer substantial potential for improvements in every respect. C-ITS are based on a wireless data exchange between road users and infrastructure (V2I) and between road users among each other (V2V). C-ITS enable the road user to be reached directly. Through C-ITS warning services like Traffic Jam Ahead or Road Works Warning can be sent to the appropriate road user and help to avoid accidents. Information messages like speed recommendation can be sent to improve the traffic flow and reduce waiting times. On the other side the infrastructure can be supported with additional single vehicle data to improve traffic management decisions and actions.

To establish C-ITS the infrastructure and the road users have to be equipped with the appropriate technology. In section 2 the relevant services and messages types are outlined. To ensure a seamless interoperability Europe-wide of these technologies the C-Roads Platform aims to harmonize the appropriate interfaces. The methods and challenges of the C-Roads Platform are characterized in section 3. C-Roads Germany has to pilot sites to implement and test C-ITS Services which are described in section 4. The results gained out of the pilot sites are substantial to foster the connected mobility and raise the degree of automation.

2. Cooperative Services

The cooperative services are based on a wireless communication. To understand the basic idea a few main message types have to be distinguished: the Cooperative Awareness Message (CAM), the Decentralized Environmental Notification Message (DENM) and the Infrastructure to Vehicle Information (IVI).

The CAM is a status message which vehicles send periodically with a relatively high frequency. Depending on the station type (e.g. passenger car, bus, motorcycle, trailer) and the situation described in a CAM, the message typically contains information about the position, dimensions (for example vehicle dimensions), motion state and activated systems. Through this message type the road users are informed about each other. Additionally, also infrastructure operators can obtain information about the situation on the road [1].

The DENM is a warning message. It can be sent to the relevant road users to warn them of a detected hazardous situation. The DENM can be used to alert of example from traffic jams ahead, roadworks, emergency vehicles approaching or maintenance vehicles. In comparison to the CAM the DENM is just sent out, if a defined event has been detected [2].

The IVI message is sent out from the infrastructure to the road user. It contains for example information about static or variable roads signs, like speed limits information [3]. This message type has an informative character.

To explain the use case Green Light Optimal Speed Advisory (GLOSA) two additional message types need to be introduced: Signal Phase and Timing (SPAT) and Map (MAP) [4]. Both message types are sent out by a traffic signal controller to the approaching road users. The SPAT message contains information about the current traffic light phase. The MAP message provides topological information about the relevant intersection.

Based on the described message types following C-ITS Services are implemented and tested in a real traffic environment.

2.1. Traffic Jam Ahead Warning (TJW):

The aim of this service is to increase the road safety. The road safety will be increased by sending warning messages (DENM) to vehicles and road users which are approaching an end of a traffic jam. This enables the drives to adapt their driving behaviour accordingly. The driver's awareness can be improved, allowing the driver to reduce the driving speed in time. Especially, in situations of a bad visibility, caused by weather conditions or road layout, the end of a traffic jam can be a dangerous situation.

The detection of a traffic jam needs to be done in the Traffic Control Centre (TCC). By combining traditional information gathered for example by detection loops and single vehicle data (CAM) an intelligent algorithm will process the data and create the desired output. The accuracy of the data may be increased by the penetration rate of vehicles which are sending CAMs. The DENMs will be sent out to the road users by Intelligent Roadside ITS Stations (R-ITS-Ss). The R-ITS-S will receive the information from the TCC. Fig. 2 illustrates the wireless communication in example of TJW.

In general this service could also be performed by V2V without the infrastructure. It would be necessary to ensure that an accurate traffic situation is calculated within the vehicles on the basis of the CAMs received from the other vehicles. In the pilots of C-Roads Germany this service is only

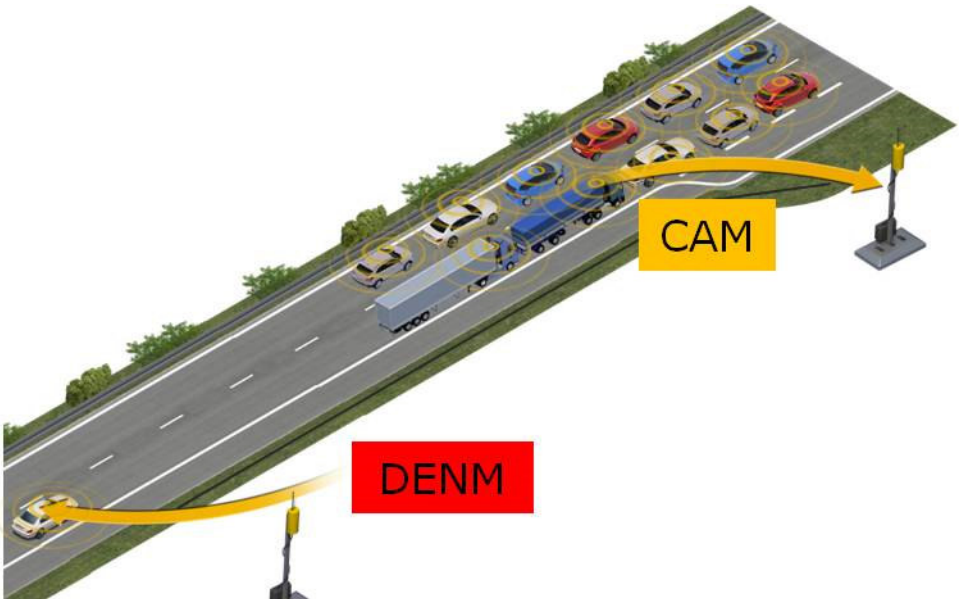


Fig. 1 schematic representation of TJW [5]

tested with the infrastructure. So the already existing and established TCCs are used to calculate an exact traffic situation before sending DENMs.

2.2. Road Works Warning (RWW):

In the frame of the RWW Service the roads user who is approaching a stationary or mobile roadworks site receives a warning message in advance. Mobile roadworks includes for example road marking and road cleaning activities on the motorway which require a closure of a lane or several lanes. These situations have a great potential for danger, for the road agents and for the road user. Similar to the TJW the DENM, which is sent to the road user, aims to increase the vigilance of the road user and enables him/her to adapt their driving behaviour. So the road user is able to reduce the speed, change lanes if needed and draw the necessary attention to the situation.

2.3. In Vehicle Signage (IVS):

In comparison to static road signs or already widespread variable message signs the IVS Service offers the possibility to provide more accurate, timely guided, customized and dynamically presented signage information to the road user. The information contains for example traffic regulations, danger warnings or general relevant information. The information can be presented continuously compared to the short visualization of static or variable signs. Depending on the implementation and the availability of appropriate technology, the information might be directly presented to the driver or incooperated into driving assistant technologies. With this service the road user's awareness can be improved and the road safety increased.

2.4. Maintenance Vehicle Warning (MVW):

Maintenance vehicles represent a special traffic situation, as they often travel particular slowly during duty. To improve the road safety for the road users and agents, the maintenance vehicles can send a DENM to road users nearby and warn them about the traffic situation. A MVW message may for example be sent due to winter operation activities. In this example, the relevant DENM is sent from the equipped Maintenance Vehicle to the road users nearby as soon as the salting mechanism or the snow plough is activated. Therefore the road users are enabled to adapt their driving behaviour according to the situation, sufficiently in advance.

2.5. Emergency Vehicle Approaching (EVA):

A DENM can be sent out from an emergency vehicle to road users nearby to minimize the risk of collisions and to reduce the emergency vehicle's travel time. Obstructions in connection with an emergency vehicle often occur due to road users, which receive the information about an approaching emergency vehicle on very short notice. Additionally, the high driving speed difference between the emergency vehicle and the road users increases the risk of accidents. A well informed road user can help to minimize the risks of collisions. The road user, who has received the information about an approaching emergency vehicle in advance, is able to adapt the driving behaviour and also to form an emergency corridor if needed.

2.6. Probe Vehicle Data (PVD):

On the basis of CAMs sent by different road users the service PVD provides the basis for many other applications. The CAMs are received by the R-ITS-Ss and transferred to the TCC. In the TCC the received data can be analyzed, combined, aggregated and result in different actions. With the help of PVD traffic flow conditions, the location of traffic jams and current road conditions can be analyzed and calculated. The extent to which the information can be used depends largely on the level of detail of the CAMs. If the CAMs provide for example information about the activation of windscreen wipers and fog lights this information could be used to calculate the road condition and trigger more traffic management actions.

2.7. Green Light Optimal Speed Advisory (GLOSA):

The service GLOSA has the goal to improve efficiency and driving comfort in an urban environment. In order to run this service, the traffic light controller of the intersection has to be equipped with an R-ITS-S which sends the SPAT and MAP messages to the approaching roads users. Based on the SPAT and MAP message the device of the road user, for example an on board unit, is able to calculate the optimal speed which is needed to pass the intersection without stopping. This service supports on the one hand the reduction of emissions by minimizing acceleration and deceleration manoeuvres, on the other hand it helps to improve the urban traffic flow by reducing the number of stops.

3. C-Roads Platform

The European Commission has adapted a European Strategy on C-ITS “COM (2016) 766” on 30th of November 2016, a milestone initiative towards cooperative, connected and automated mobility [6]. The objective of the C-ITS Strategy is to facilitate the convergence of investments and regulatory frameworks across the EU, in order to see deployment of mature C-ITS services.

Member States and the European Commission launched the C-Roads Platform in December 2016 to link C-ITS deployment activities; jointly developing and sharing technical specifications and verifying interoperability through cross-site testing. The C-Roads Platform started with eight Member States and raised this number to 18 in the meantime. Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Greece, Ireland and UK jointly work on harmonising specifications and the necessary measures for a Europe-wide deployment of C-ITS with seamless experience for the end user. The Governance structure of the C-Roads Platform is visualized in Fig. 3:

Recently two Working Groups has been established within the C-Roads Platform, therefore it includes five Working Groups (WG) at the moment as following:

- WG1: C-ITS Organisation
- WG2: Technical Aspects
- WG3: Evaluation & Assessment
- WG4: Urban C-ITS Harmonization
- WG5: Digital Transport Infrastructure (DTI)

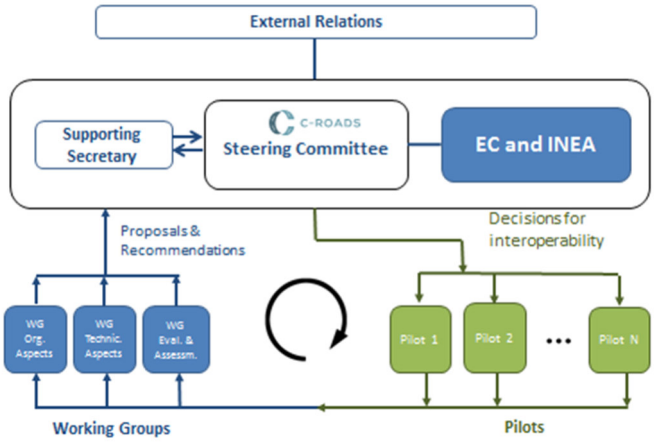


Fig. 3 Governance structure of the C-Roads Platform [7]

WG 1 - C-ITS Organisation - the main goal of this working group is to provide the needed cooperation between different organisational environments such as public actors and private entities to realize the roll-out of C-ITS under consideration of the legal framework and investigate solutions to overcome known and newly identified legal barriers and obstacles (including privacy issues) related to C-ITS. WG 2 - Technical Aspects - is the key group to fulfil the harmonized standardisation as like as functional, technical and process specifications of the C-Roads platform. This includes specifications for procurement, operations and qualification of those parts of C-ITS to ensure C-ITS service consistency and interoperability for users of the services supported and being deployed throughout Europe. Therefore 5 Task Forces (TFs) have been established to manage the work in WG2. The following TFs are defined at the moment:

- TF1: Security
- TF2: Service Harmonisation.
- TF3: Infrastructure Communication
- TF4: Hybrid Communication
- TF5: Cross-border testing and validation

WG 3 - Evaluation and Assessment - focuses of this working group is to evaluate and transfer achievements and results from all the Working Groups to practical environments with the goal of interoperability and harmonisation of C-ITS Services.

WG 4 - Urban C-ITS Harmonization - The aim of this new established WG is to inform cities on the current status of the C-Roads activities and support cities in setting their desires for C-ITS deployments.

WG 5 - Digital Transport Infrastructure (DTI) - concentrates on the infrastructure required for a digital infrastructure as well as Traffic Management and HD maps. The main tasks are to reflect the existing standards and elaborate the recommendations to infrastructure operators for the data provision for HD maps.

As first important results, C-Roads have released the harmonised C-ITS specifications for services with infrastructure involvement in Europe and furthermore, reports on legal and organisational structures [8] as well as on the European security mechanism for C-ITS [9] have been published.

4. Implementation in Germany

4.1. Pilot Lower Saxony

As Fig. 4 shows the Lower Saxony pilot site is mainly on the section of the A2 motorway, about 6 km in length. The main task is to implement three Day 1 C-ITS services, MVW, IVS and PVD. To provide the IVS and PVD services, three R-ITS-Ss, an intelligent Central ITS Station (C-ITS-S) and a virtual TCC will be established. The interface / protocol between R-ITS-Ss and intelligent Vehicle ITS Stations (V-ITS-Ss) have already been standardized.

4.1.1. Functional and Technical Aspects

Fig. 4 Lower Saxony Pilot Site [10]

The system architecture is based on the requirements of the agreement and is combined with the situation in Lower Saxony. Some specific details are still under discussion, e.g. the data format for the data exchange between TCC and C-ITS-S. Implementation and installation will be completed in December 2019.

Three use cases are defined for the MVW Service:

- Slow Moving Road MaintenanceS
- Snowplough
- Short Term Stationary Roadworks

The maintenance vehicle is additionally equipped with an ITS station, so that the DENM can be sent out while working. The maintenance vehicle will be provided by the Lower Saxony state authority for road construction and traffic (Niedersächsische Landesbehörde für Straßenbau und Verkehr).

The objectives of the IVS and PVD Services are that the road users can be informed in advance about the dynamic traffic signs and the vehicle data can be collected and forwarded to the TCC. To achieve these services, three R-ITS-Ss will be installed on three gantries, a C-ITS-S and a data converter system will be developed in order to provide data between the R-ITS-Ss, the C-ITS-s and the TCC. Two use cases of the PVD Service and Four use cases of the IVS Service are defined based on traffic signs that can be displayed by the selected gantries.

A certificate management protocol will be implemented for communication between the C-ITS-S / R-ITS-S and the Public Key Infrastructure (PKI). The new V2X PKI instance with the latest ETSI certificate formats (TS 103 097 v1.3.1) and with the ETSI based request protocol (TS 102 941 v1.2.1) are provide by ESCRYPT GmbH.

4.1.2. Test concept

A test concept was created in order to ensure harmonisation and interoperability of the services in Germany and focuses on three levels:

- Integration tests of service providers
- Communication tests on system test level
- Functional tests on system and acceptance test level

Currently the service MVW is successfully implemented. In order to verify the consistency of the executed MVW Service with the technical specification defined by Lower Saxony pilot site, the integration test in the laboratory was executed, namely correctness of the transmission between maintenance vehicles and other vehicles. In total 17 test cases for three use cases were carried out.

The MVW Service is a service between maintenance vehicles and other vehicles. Thereby the integration test focused on the transmission between sender and receiver. When the maintenance vehicles are in operation, DENMs are sent as broadcast to all road users, which are located inside an area of relevance. For this reason, a simple laboratory test could be set up. Verification of the 17 test

cases was completed in this test environment. The integration of the maintenance vehicle is simplified by use of a switch box that provides input signals for the status of the light bar and parking brake without requiring access to the vehicle's internal systems (e.g. CAN bus).

In addition, the receiving range of the antenna was also tested. To verify the receiving range of the multiband antenna, a test vehicle and a maintenance vehicle are each equipped with a V-ITS-S. In this case, the V-ITS-S is a waveBEE®plus developed by NORDSYS GmbH with a multiband antenna. The only wired connection between the test vehicle and the waveBEE®plus was the power supply. To be able to send or receive DENMs, the test vehicle have been equipped also with an ITS-Station (waveBEE®plus with a multiband antenna). The range of antenna reception depends on multiple factors, such as weather, topography, surrounding environment etc. It can vary according to single situation. In this case, the antenna receiving range has been measured on the stretch of the A2 with the equipped maintenance vehicle and test vehicle.

4.1.3. First Results

A total of 17 laboratory integration test cases were designed for the 3 use cases represented. Each test case has been tested 3 times. Pass rate is 100%. Based on this test results, the MVW Service has been successfully implemented and is consistent with the defined test specification.

The antenna receiving range in total was about 670m. Upstream and downstream depend on the drive direction. The reason why the receiving distance from point A to point 1 (270m) is less than the distance from point 1 to point B (400m) is probably because of the conditional terrain, surrounding environment or obstacles such as fences, buildings, curve and other factors. Thereby, no direct connection could be established. The purpose of this test was to measure the receiving rage of the multiband antenna installed on the roof of the maintenance vehicle. Whether other external facilities (e.g.foldable warning sign) of the maintenance vehicle will cause interference to the antenna. The result shows no negative effects. Communication can be established as long as there is a direct line of sight between the sender and the receiver vehicles.

By implementing the new services, it is expected that the awareness of road users can be increased and driving behaviours can be accordingly adapted. At the same time, traffic accidents can be greatly reduced or even avoided, thereby increasing traffic safety and reducing congestion. This makes it more comfortable to drive.

4.2. Pilot Hessen

Hessen Mobil established a good surrounding for all kinds of developmental work for development of cooperative traffic information/control services as well as road- and central side equipment. The

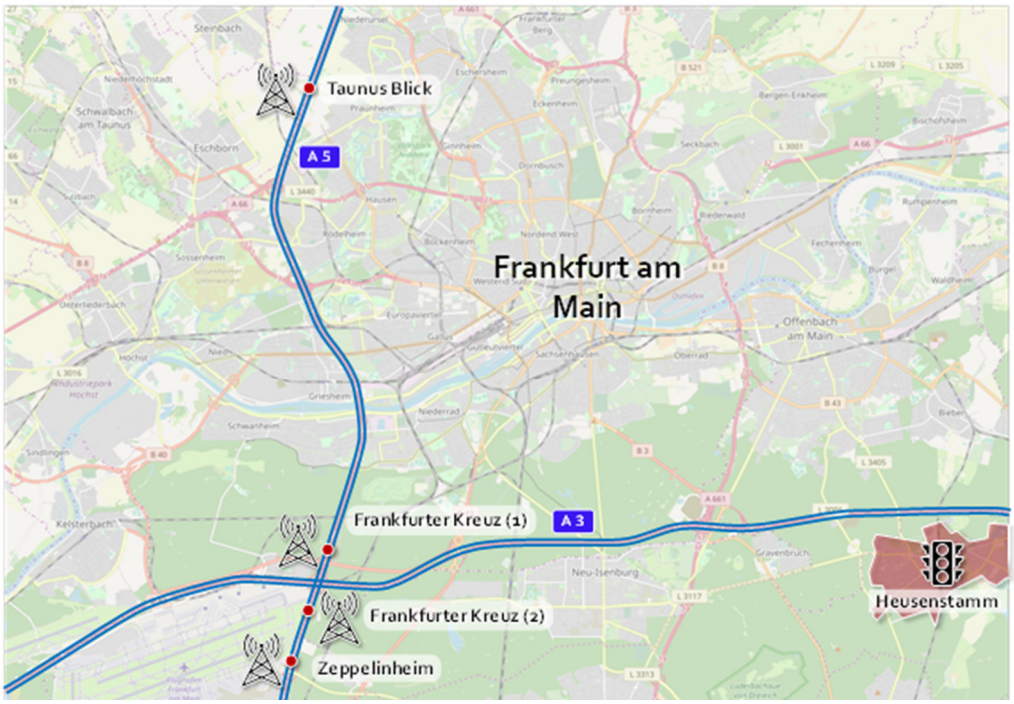
DRIVE Test Site Hessen for connected and automated traffic (cooperative roadside test site in the Frankfurt Rhine-Main metropolitan region) on motorways and the federal roads around Frankfurt (total length of already covered network: 200 km) has been established. In addition, a special test gantry on the motorway A 5 with access from the TCC Hessen site for the development of accompanying device testing was built.

4.2.1. Functional and Technical Aspects

By implementing four R-ITS-S on the motorway A 5, the RWW Service is operational since this year.Fig. 5 shows the location of the implemented R-ITS-S for RWW and the location for the GLOSA Service, where a reception of the messages via a mobile smartphone app has already been implemented. Around Frankfurt, 13 warning trailers are already in use to send RWW for short-term roadworks. The five winter maintenance vehicles are also equipped for sending messages and are operating in the south of the Rhine-Main metropolitan area.

Recently, the existing service RWW has been extended, PVD and MVW have been implemented. The mobile RWW Day 1 Service have been extended by an extension of communication mediums like DAB (Digital Audio Broadcast) and the functionality has been expanded by integrating a stationary roadworks service to get a comprehensive Road Works Warning Service.

Furthermore, Hessen Mobil has implemented five V-ITS-S on maintenance vehicles and will implement two V-ITS-S on rescue vehicles each. In addition, Hessen Mobil and Continental each provided two vehicles to receive the ETSI ITS G5 messages. In more detail, Continental will expand its



development to activate the Adaptive Cruise Control (ACC) in the event of a speed recommendation by the service SWD or a TJW.

In addition, in 2019, the four new C-ITS services EVA, TJA, SWD are going to be implemented in the framework of C-ROADS.

In the frame of the Hessian Pilot,

- 15 stationary R-ITS-S mounted on gantries,
- four temporary stationary R-ITS-S for long-term works,
- four R-ITS-S mounted on warning trailer and
- twelve stationary R-ITS-S connected with traffic signal controllers

have been implemented already or will be installed in the near future.

4.2.2. Test procedure

Within the C-ROADS project, the existing DRIVE Test Site Hessen will be enlarged to the south of Frankfurt.

The evaluation of all implemented C-ITS Services will include several tests, based on requirement catalogues considering the appropriate C-ROADS specifications and already the proposed Delegated Act on C-ITS.

The general test conditions are currently in discussion and will be aligned with WG 2 TF 5, which prepares compliance test scenarios on C-ROADS platform level. The Hessian pilot has implemented the test cases and enlarged the portfolio by additional test scenarios. Therefore, requirement catalogues are developed to prepare the test case specifications.

In summer 2019, the overall system test of RWW, MVW and PVD has started. The focus hereby is on conformance testing. The testing of all other services has begun in October 2019.

4.2.3. First Results

Fig. 6 shows an exemplary RWW message in a real time environment. Additionally, the DAB-end user communication channel for the existing short-term RWW Service (additional to the existing ITS G5 end-user communication) is operational.

Fig. 6 RWW Service displayed on the prototype HMI [12]

First tests showed that the DENM of RWW and MVW are received correctly. It can also be guaranteed that the already implemented R-ITS-S can receive CAM. By now, the preparations for the overall system test are ongoing with these, different uses cases.

5. OUTLOOK

To ensure a seamless implementation of C-ITS all over Europe, C-Roads plans cross border tests with all member states. Vehicles equipped with the necessary technology will drive through different C-Roads pilots and will test the services. These activities have not been completed yet and need to be continued to implement all test results including the cross border ones until the end of this project by 2020.

With the help of the described activities, elementary foundations for a connected mobility are anchored within the framework of C-Roads Germany. These are indispensable in order to meet the increasing demands on individual mobility with a simultaneous increase in (freight) traffic.

References

[1]EN 302 637-2 V1.3.2 (2014), European Telecommunications Standards Institute, page 11, *https://www.etsi.org › etsi_en › en_30263702v010301v*

[2]EN 302 637-3 V1.2.1 (2014), European Telecommunications Standards Institute page 13-15, *https://www.etsi.org › etsi_en › en_30263703v010201v*

[3]TS 103 301 V1.2.1. (2018), European Telecommunications Standards Institute, page 21-23, https://www.etsi.org › 103301 › ts_103301v010101p

[4]. Amsterdam Group White Paper, SPAT/MAP V1.1, 2015, page 6-8

[5]CAR 2 CAR Communication Consortium

[6]. EUROPEAN COMMISSION, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A European strategy on Cooperative Intelligent Transport Systems, a milestone towards cooperative connected and automated mobility, COM(2016)766 , (2016)

[7] C-Roads Platform, https://www.c-roads.eu/platform/about/about.html, (last access 22-Feb-2019)

[8]Report on Legal and Organisational Structures for C-ITS Operation, https://www.c-roads.eu/platform/documents.html (last access 5-Jun-2019)

[9]Draft Report on European Security Mechanism Version 1.4, https://www.c-roads.eu/platform/documents.html (last access 5-Jun-2019)

[10] Source map: OpenStreetMap-participant www.openstreetmap.org/copyright

[11] Source map: OpenStreetMap-participant, Hessen Mobil, CC-BY-SA 2.0 www.openstreetmap.org/copyright

[12] Continetal Teves AG/ HessenMobil