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1 Introduction

1.1 About C-Roads Antwerp-Helmond

C-Roads Antwerp-Helmond has the ambition to integrate cooperative intelligent transport systems (C-ITS) with advanced driving assistance systems (ADAS, especially intelligent speed assistance (ISA)), urban vehicle access regulations (UVAR), and (urban) mobility services (buffering of trucks, prioritisation, and multi-modal information). The combination of these services should lead to better road-safety and liveability.

Both cities, Antwerp and Helmond are convinced that C-ITS deployment is not a stand-alone service and certain integration in other ITS solutions will be needed, especially in the mindset to achieve autonomous driving in the near future. The pilot will deploy, test, and evaluate the combined services. The pilot will include development of services to align with both city and regional priorities whilst recognising EU standards and regulations. Certain C-ITS Day 1 and Day 1.5 services will be made available and integrated in other services. They will be made available for different types of users like private drivers, professional truck drivers, and active mobility users.

C-Roads Antwerp-Helmond will be part of the C-Roads platform, which emphasises cooperation on a holistic level in order to cover all the dimensions linked with the deployment of C-ITS. The pilot will test and evaluate the combined services on the Flemish TEN-T Network near Antwerp and also along the urban nodes of Antwerp and Helmond. The duration of the pilot will be six months in total.

The C-ITS information will be provided by hybrid communication and will comply with the C-Roads requirements and specifications. It will be made available in the vehicles through (i) the use of on-board units (OBU), which also allows the combined implementation of C-ITS and ISA, and through (ii) smartphone applications whereby one specific for truck drivers.

The C-Roads Antwerp-Helmond consortium consists of 9 partners: Tractebel Engineering (coordinator), Transport & Mobility Leuven, Lantis, V-Tron, Be-Mobile, the municipality of Helmond, the city of Antwerp, Hogeschool PXL, and Yunex. The project started end of 2022, and runs for two years.

1.2 Purpose of this document

In this document we will present the C-ITS infrastructure, the common back-end and the data supply and the architecture per pilot site and per use case.

Within the project, the use cases will be implemented in both Belgium (Flanders) and the Netherlands, specifically in Antwerp and Helmond. The TEN-T road network will also be utilized, and the cross-border aspect will be carried out on the A67 and E34 highways.

1.3 Structure of this document

In the next chapter we will first describe the C-ITS infrastructure by zooming in on the various components: ISA, road site units and mobile applications. By combining these technologies, we focus on interoperability and facilitate hybrid communication. Next, we will explain the common back-end, followed by an overview of the data supply and the architecture per pilot site and per use case. The use cases are divided into the following sub-sections: C-ITS & ADAS, C-ITS & UVAR and C-ITS & (urban) Mobility Services.

1.4 Glossary

ADAS	Advanced Driver Assistance Systems
APR	Animal or Person on the Road
AWV	Agentschap Wegen & Verkeer (Agency Roads & Traffic)
AWWD	Alert Wrong Way Driving
AZ	Accident Zone
CAM	Cooperative Awareness Message
CEF	Connecting Europe Facility
C-ITS	Cooperative Intelligent Transport Systems
DENM	Decentralized Environmental Notification Message
EC	European Commission
EPVA	Emergency or Prioritized Vehicle Approaching
ERVI	Emergency or Rescue/recovery Vehicle in Intervention
FTC	Flemish Traffic Center
GIPOD	Generiek Informatieplatform Openbaar Domein (Generic Information platform Public Domain)
GLOSA	Green Light Optimal Speed Advisory
GPS	Global Positioning System
HMI	Human-Machine Interface
I2V	Infrastructure-to-vehicle
ISA	Intelligent Speed Assistance
ITS	Intelligent Transport Systems
IVI	In-Vehicle Infotainment

iVRI	Intelligente Verkeersregelinstallatie (Intelligent Traffic Regulation Installation)
IVS	In-Vehicle Signage
KPI	Key Performance Indicator
LTC	Local Traffic Control
MOW	Mobiliteit en Openbare Werken (Mobility and Public Works)
NDW	Nationaal Dataportaal Wegverkeer (National Data portal Road traffic)
NWB	Nationaal Wegenbestand (National Road file)
OBU	On-board units
OHLN	Other Hazardous Locations Notification
OR	Obstacle on the Road
P+R	Park and Ride
PTVC	Public Transport Vehicle Crossing
PTVS	Public Transport Vehicle at a Stop
RLX	Railway Level Crossing
RSU	Road-Side Unit
RWW	Road Works Warning
SPAT	Signal Phase and Time
SV	Stationary Vehicle
TEN-T	Trans-European Transport Network
TJA	Traffic Jam Ahead
TSR	Temporarily Slippery Road
UBR	Unsecured Blockage of a Road
UDAP	Urban Data Access Platform
UVAR	Urban Vehicle Access Regulations
V2I	Vehicle-to-infrastructure

V2V	Vehicle-to-vehicle
VMS	Variable Message Sign
WP	Work package

2 C-ITS Infrastructure

In this section, we start with a summarized overview of the C-ITS infrastructure in Antwerp and Helmond. In the next sections, the infrastructure is further explained by providing more details for each part.

As a first step, we created an inventory of the available data sources of the City of Antwerp and evaluated the usability. For this pilot location we can make use of the Mobilidata architecture. To make sure the data sources of the City of Antwerp are available for all other technical parties, the data sources are connected to the Public Information Provider, which is connected to the Mobilidata Interchange. This interchange is then connected to the Be-Mobile C-ITS Cloud, V-tron Infrastructure and Yunex Cloud Infrastructure. The traffic lights controlled by Yunex are connected to the TLEX platform and subsequently to the Mobilidata Interchange. This connection is needed for the use cases with a focus on traffic lights, such as traffic light prioritization for cyclists and trucks. The Yunex Road Side Units communicate to the V-tron On Board Units over ITS-G5. In a final step, the C-ITS information is exchanged with the applications for the road users such as ISA and the mobile applications Flitsmeister, Truckmeister and Sway.

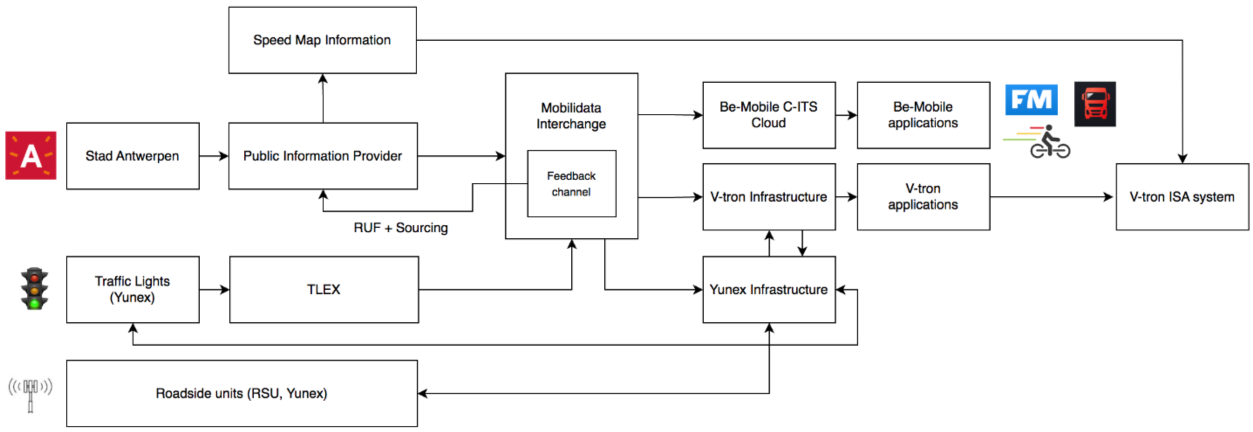

Figure 1: C-ITS infrastructure in Antwerp

For Helmond we also made an inventory of the available data sources and evaluated the usability of these data sources. We noticed that many data sources of Helmond are connected to the national data portal NDW. A connection between the C-ITS infrastructure and NDW is therefore essential. For this pilot location we cannot make use of the Mobilidata Interchange. This means that the technical parties will connect directly to the following components: NDW and Helmond specific data, the Urban Data Access Platform (UDAP) for the traffic lights and the Road Side Units of Yunex. Be-Mobile connects with Talking Traffic Netherlands ecosystem via the UDAP for the intelligent traffic lights use cases. All traffic lights of Helmond that are connected to the UDAP are supported in this project. For the Road Side Units of Yunex, V-tron connects directly with the infrastructure of Yunex. In a final step, the C-ITS information is exchanged with the applications for the road users such as ISA and the mobile applications available in Helmond: Flitsmeister and Truckmeister.

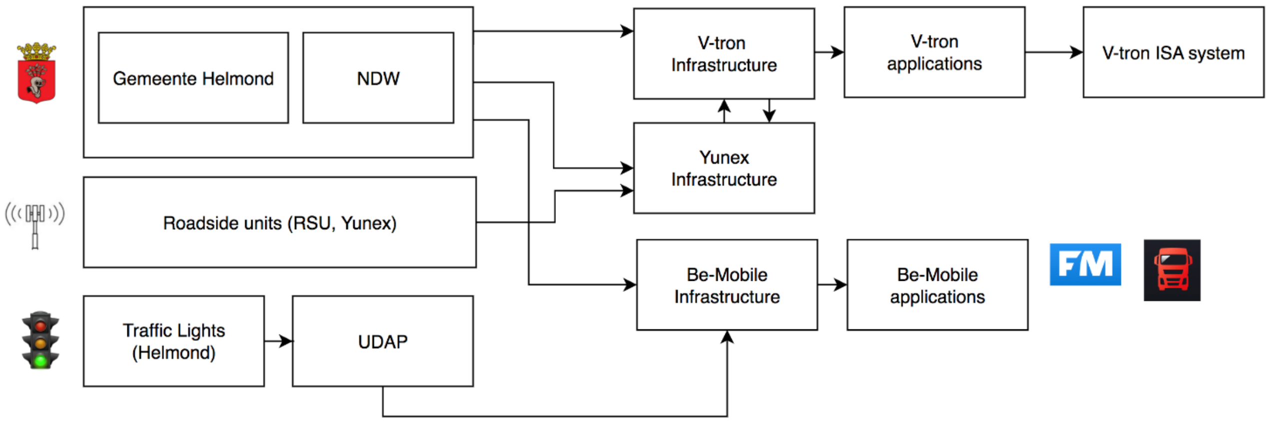

Figure 2: C-ITS infrastructure in Helmond

2.1 ISA

The V-tron ISA system introduced and further developed within the project is a system that can be retrofitted into almost any vehicle. The system relies on a speed limiter, installed in the vehicle and capable of limiting the maximum speed based on dynamic input.

The input is derived from two systems:

1) A vision sensor, placed on the windshield of the vehicle, scans the red-bordered traffic signs on the road. These include, among others, the maximum speed signs installed on the road. No images of the road are captured or stored; only the traffic signs are logged, which serve as input for the speed limiter.

2) Additionally, there is a processing and logging unit containing the digital map of the area where the vehicle is deployed. In the Netherlands, this comes from the NWB, and in Flanders, from the Open Data Portal. However, the latter is found to be of insufficient quality to use during the pilot. Therefore, an alternative speed map provided by the City of Antwerp has been chosen.

This data is accessed and processed into usable data for the ISA system. The system compares its own location using a GPS sensor with the location on the digital map and thus knows the corresponding maximum speed at that location. A smart algorithm then determines whether the input should come from the vision sensor or the digital map as input for the limiter.

Throughout the project, investigations are conducted into the possibilities of providing the ISA system itself with an internet connection to possibly implement map updates or retrieve vehicle logging. Additionally, a connection with V-tron's hybrid OBU is established during the project. This enables the system to display warnings on the HMI of the system in addition to the digital map and vision sensor warnings, alerting the driver to messages from various C-ITS use cases. Moreover, investigations are underway to explore whether the C-ITS (received via both short- and long-range communications) can be used to limit the vehicle to an alternative speed, for example, in roadwork zones or school zones.

The system logs various parameters during use, such as a timestamp, maximum speed, at the location according to the vision sensor and the digital map, GPS location, and the driven speed. This data also enables the discovery of discrepancies between the physical traffic signs on the road and the applicable maximum speed at that location on the digital map. V-tron has developed a feedback loop whereby this information can be sent back to the administrator of the digital map. This way, data collected during the system's use can improve the digital speed map.

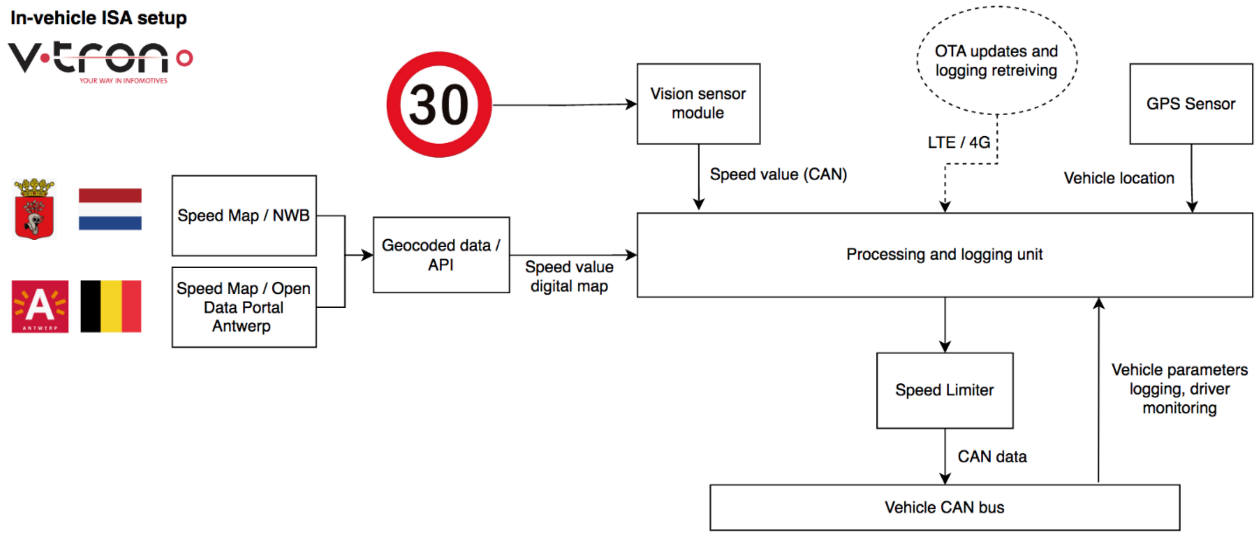

Figure 3: In-vehicle ISA setup

2.2 Road Side Units

For the ADAS and UVAR use cases, the C-ITS short-range ITS-G5 communication will be also set up. Yunex provides Road Side Units which are connected to the Yunex Cloud Infrastructure The Yunex Cloud Infrastructure is connected to the Mobilidata Interchange as data source. The Yunex Cloud Infrastructure will be used during the tests to facilitate the test flow with simulated messages. The Yunex Road Side Units will broadcast the specific DENM and IVIM messages at the respective locations. The V-tron On Board Units, installed in normal vehicles and trucks will pick up these ITS-G5 signals when driving in the vicinity of the Road Side Units and will notify the users accordingly via the interface.

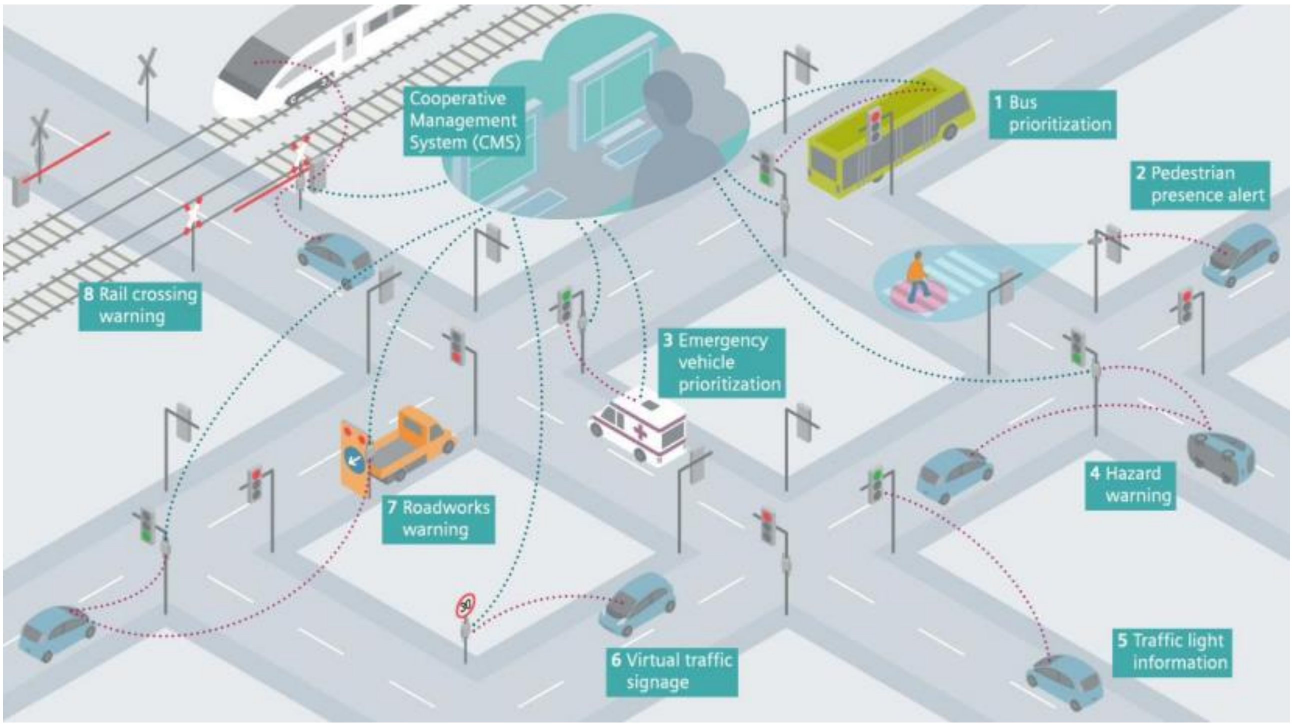

Figure 4: Typical C-ITS Short Range ITS-G5 RSU use cases

2.3 Mobile applications

Be-Mobile will rely on their own mobile applications to support the C-ITS use cases and facilitate information exchange with the road users via long range communication. In this project we will use the following mobile applications: Flitsmeister, Truckmeister and Sway. We will provide more information for each application below.

Flitsmeister is a mobile navigation companion app, available for both Android and iOS. The application has a strong community of more than 3 million active users in the Netherlands and Belgium. A large part of the shared traffic information is gathered and validated by the large user base. Flitsmeister always shows the maximum speed allowed and warns users during their route for speed cameras, incidents (stationary vehicles, accidents, obstacles, ...) and other dangerous traffic situations. Users can report dangerous traffic situations as well. These reports are translated into notifications for other users after various validation checks. The users can configure their vehicle type: car or truck. When 'truck' is selected as vehicle type the speed limits and route navigation are adapted. The mobile app can be used by private drivers and professional drivers. Furthermore, the app can be used with or without route navigation. In both cases, the Flitsmeister user will receive notifications when approaching specific traffic situations. The route navigation is always calculated based on the actual travel times by relying on Floating Car Data collected and precisely processed by Be-Mobile. For this purpose, the GPS-positions of Flitsmeister users are also anonymously collected and processed as an additional data source. In this project we will further expand and improve the functionalities of this mobile app by supporting different C-ITS use cases.

Figure 5: Flitsmeister mobile application

As a truck driver, you can choose between the mobile app Flitsmeister and **Truckmeister**. The mobile app Truckmeister is developed specifically for truck drivers. The application is available for both Android and iOS. In this project, the Truckmeister app is used for the truck traffic light prioritization use case.

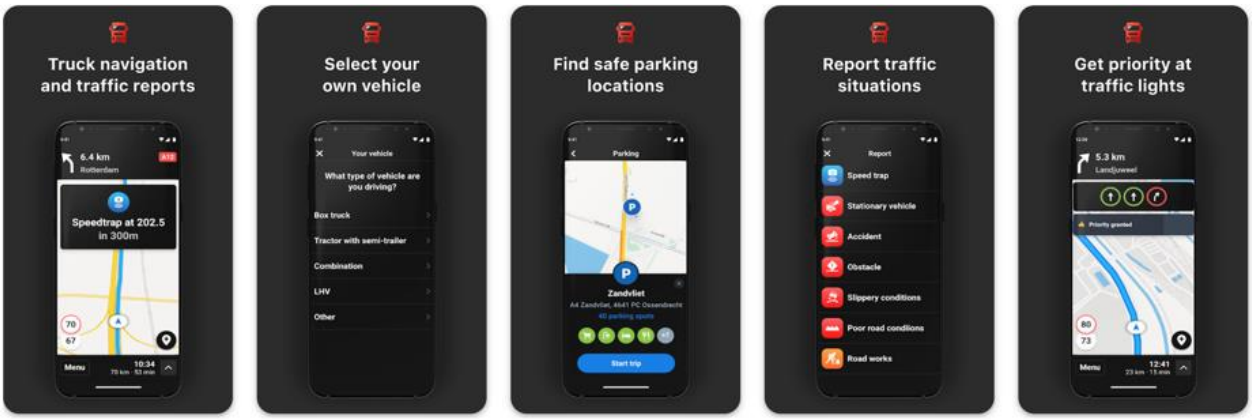

Figure 6: Truckmeister mobile application

The third mobile app of Be-Mobile that will be used is **Sway**. Sway is the newest mobile app for pedestrians and cyclists. The goal of the app is to decrease the waiting time for cyclists and pedestrians at traffic lights. In this project we will connect multiple traffic lights in Antwerp to reach this goal. Pedestrians and cyclists are typically only registered at a traffic light after pressing a button installed on the traffic light to request green light. By using the mobile app your presence as a pedestrian or cyclist at an intersection can be registered sooner by the traffic lights. Besides registering the vulnerable road users sooner, the mobile app will also predict in which direction the pedestrian or cyclist wants to go at the intersection based on historical GPS-positions of this user.

Figure 7: Sway mobile application

2.4 Hybrid communication and interoperability

The C-ITS information will be gathered and exchanged via hybrid communication. The services will be made available in the vehicles by (i) the use of on-board units (OBU), which also allows the combined implementation of C-ITS and ISA; and (ii) by mobile applications. The hybrid communication accommodates both short-range and long-range communication. This combination implies certain challenges, which are also addressed in this project. The hybrid communication set-up of this project is visualised in the figure below.

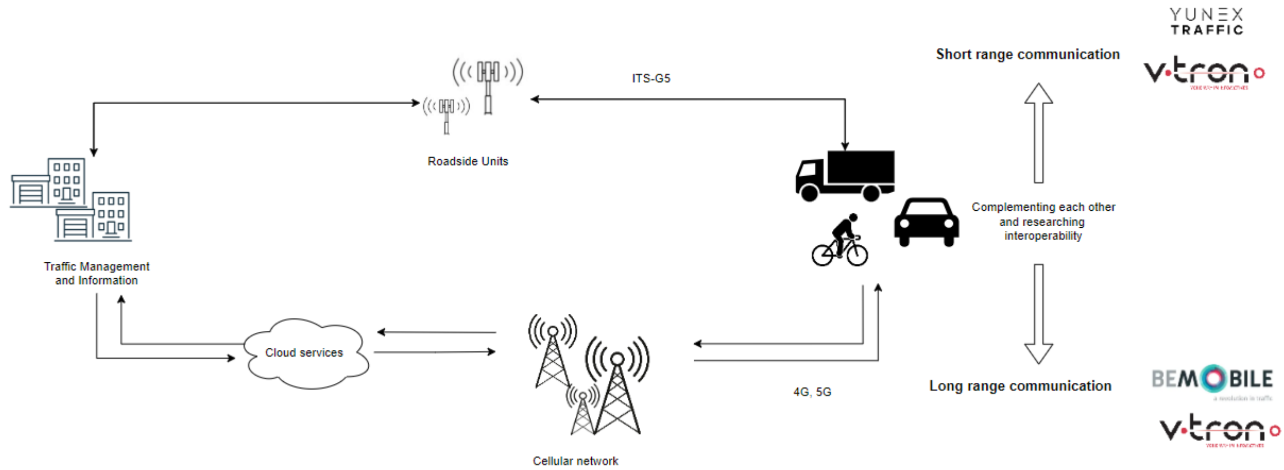

Figure 8: Visualisation of hybrid communication

3 Common backend

3.1 Intro

Building further on the functional description of the C-ITS use cases, we have discussed with all partners the different input data sources and defined the common backend architecture. The C-ITS infrastructure is set-up and ready to use as a common backend.

3.2 Technical implementation

The figure below illustrates the architecture for the use cases which will take place in Antwerp. For this pilot location we can make use of the Mobilidata Interchange. Next to Be-Mobile, the two other technical parties V-tron and Yunex are also connecting with the Mobilidata Interchange. Once the legal agreements are made and signed, the technical integration is initiated and completed. The integration with the Mobilidata architecture enables the technical parties to retrieve access to the needed data sources and C-ITS messages that are already pre-processed and made available in C-Roads standards, ready for direct application for the various defined use cases.

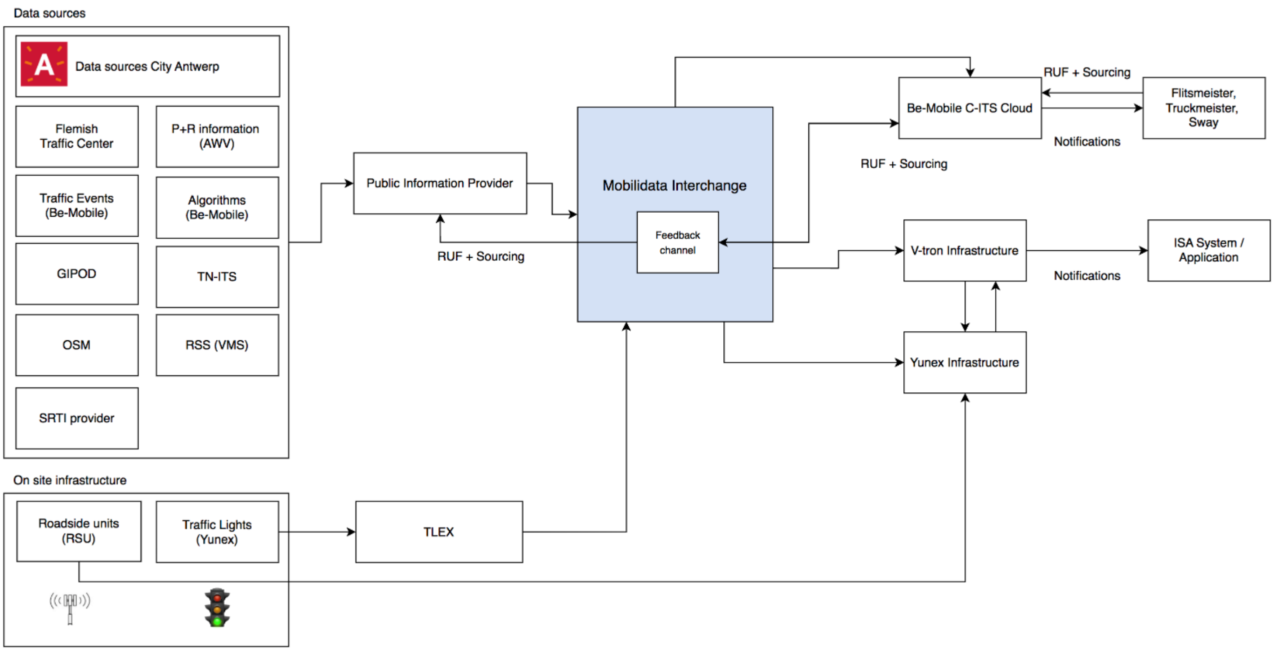

Figure 9: Architecture backend in Antwerp

The architecture scheme lists all data sources. However, the data sources that are effectively used differ between the technical parties. For this reason, the next chapter of this document presents tables listing the used data sources per party and provides more detail per use case and per pilot location.

The figure below shows the architecture for the use cases which will take place in Helmond. For this pilot site, the technical parties will connect directly to the required data sources, national platforms, and on-site infrastructure for the different use cases, as opposed to the pilot site in Antwerp, where the Mobilidata

Interchange plays an essential role. Be-Mobile will connect with Talking Traffic Netherlands ecosystem via the Urban Data Access Platform (UDAP) for the intelligent traffic lights use cases and will also support C-ITS use cases in Helmond that are implemented directly in the backend of the Flitsmeister application.

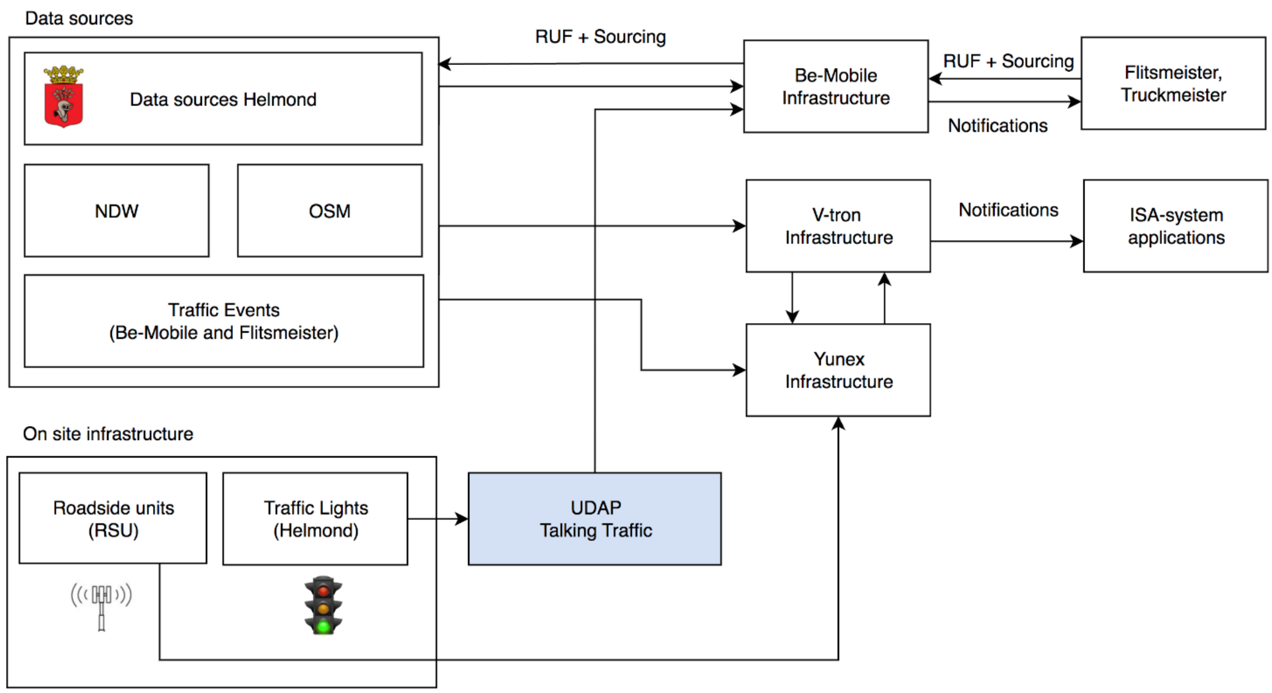

Figure 10: Architecture backend in Helmond

Be-Mobile also connects to various other data sources of NDW. Due to data issues, V-tron had to develop an alternative for Helmond, as described in Table 4.

4 Architecture and data supply

The use cases are grouped in different sub-sections: C-ITS & ADAS, C-ITS & UVAR and C-ITS (urban) Mobility Services. Each sub-section elaborates further the locations and technical specifications of the use cases related to the architecture and data supply.

4.1 C-ITS and ADAS

The Cooperative Intelligent Transport Systems (C-ITS) and Advanced Driver Assistance Systems (ADAS) use cases are described in the following sections.

4.1.1 Road works Warning (Static & Dynamic)

"A service whereby the road operator can communicate with drivers through I2V communication about road works, restrictions and instructions"

For the pilot site in Antwerp, V-tron will collaborate with Yunex to investigate which DENM messages can be used and received via short-range communication in order to display a warning to the end user in the vehicle through the ISA HMI. Currently, this information is mainly provided within the project as simulated. Additionally, a connection will be established with the Mobilidata platform to determine if this information could be useful for future implementation in the ISA/C-ITS system.

For the pilot site in Helmond, V-tron is researching the usability of information from the NDW. Due to the lack of participants and the execution of the alternative demonstration week, this will only be done conceptually.

For the pilot site in Antwerp, Be-Mobile combines the collected data of the Flanders Traffic Center, own traffic events, data from AWV and GIPOD to share the needed information. These data sources are converted to C-roads compliant messages that are available via the Mobilidata Interchange. These messages are used for warnings in Flitsmeister.

For the pilot site in Helmond, Be-Mobile connects to the available data sources of NDW to share valuable road works warning to the users of the Flitsmeister mobile app.

Antwerp:

Table 1: Description Road works Warning, in Antwerp

Party	Description	Data
Be-Mobile	Static road works warnings: roll-out with participants. In Flanders, Be-Mobile uses the data from the Flemish Traffic Center (FTC, in DATEX II), own traffic events, AWV and GIPOD. The different data sources are converted to C-roads compliant messages. Moreover, we apply several additional rules and filtering to these data sources to validate the data and maximize data quality. In this way, we ensure that users of the Flitsmeister mobile app only receive valuable notifications. We also make use of feedback from road users using Flitsmeister. Users can indicate whether the warning was useful and still applicable. We rely on the C-roads standards and supplement the DENM messages with a few extra properties (alert-c codes). We decided to use extra subtypes to make the alerting run more granular than the current DENM version supports. Moreover, for closed roads, we adapted the C-roads standards to fill in the lane codes if this information is made available. These changes can be considered as improvements to the standards based on insight and experience. Dynamic road works warnings: conceptual or functional roll-out according to C-roads standards. We use DENM messages with the corresponding cause and sub-cause codes. Next to this, additional vehicle types are added to the sent DENM messages to provide a more granular indication of which road works vehicle will be encountered. This again allows for more granular alerting to the end users than the DENM standard currently supports. The logged GPS positions of the service vehicles from local authorities and related service providers are converted to events that entirely follow the C-Roads standards.	FTC, Be-Mobile traffic events, GIPOD, AWV

V-tron	V-tron establishes the connection with the Mobilidata platform to receive information about both static and dynamic roadwork warnings in Antwerp via long-range communication. Within the project, the information is only used via desktop setup by V-tron to conceptually determine how it can be implemented in the ISA system in conjunction with the hybrid OBU in order to display warning messages to the driver through the ISA system's HMI. We are investigating how the Roadworks Warning use case messages can be received via the Yunex RSU installed in Antwerp. Based on this information, we may combine this C-ITS service with the ISA system in V-tron's test vehicle and display a warning on the ISA HMI in the vehicle. For both channels, the received messages comply with the C-Roads specifications.	Mobilidata / Yunex RSU
Yunex	Yunex will broadcast the same static and dynamic road work warnings (ETSI DENM messages) over short-range ITS-G5 transmitted by RSUs placed at urban or interurban locations.	Mobilidata & simulated messages via Yunex Cloud Infrastructure for ease of testing as only a few RSUs will be installed.

Helmond:

Table 2: Technical description Road works Warning, in Helmond

Party	Description	Data
Be-Mobile	Static road works warnings: roll-out with participants. In the Netherlands, Be-Mobile has its own developed methodology to warn road users about road works. We use the data from NDW for this purpose. Additionally, we will support this use case conceptually according to C-Roads standards. Dynamic road works warnings: in Flitsmeister, we can warn users of dynamic road works. Roll-out with participants is possible as soon as this data is available via NDW and is sufficiently reliable. We will also implement a proof of concept where the quick service teams of Helmond will share their GPS-positions with a track and trace app of Be-Mobile. The GPS positions are	NDW, Helmond

	collected and processed to warn users in Flitsmeister on the road when they are approaching these service vehicles. The implementation follows the C-roads standards.	
V-tron	For both static and dynamic Roadwork Warnings in Helmond, V-tron has investigated which data sources can be used. While this information is made visible by Helmond in the platform linked to the NWB, V-tron has not established a direct link with the NWB because this data does not appear to be of sufficient quality to be used in their system. This is partly due to the lack of participants for a rollout with end users, but an alternative was chosen with a demonstration week. Conceptually, we explored how messages could be received via short-range communication and RSUs by the V-tron OBU and displayed in the vehicle on the HMI of the ISA system. However, no RSUs are provided within the project in Helmond, resulting in a lack of actual implementation.	NDW
City of Helmond	The static road works are known in LTC. Major road works can be found in the MELVIN system, which is linked to the NWB. As for the dynamic road works, it still needs to be determined how they can be disseminated and through which platform or C-ITS channel they can be delivered to the end user.	

4.1.2 In-Vehicle Signage (Static & Dynamic)

"Via V2I communication, information on relevant road signs is given to the driver. Roadside units may be mounted on traffic signs and key points along roads, informing drivers of potentially dangerous road conditions ahead, speed limits and upcoming junctions"

For both Antwerp and Helmond, V-tron will focus on maximum speed and vehicle limitation through the ISA system. In the Netherlands, and thus in Helmond, we focus on the data provided through the National Road Database (NWB), where we also provide valuable data feedback to improve the mapping material through a feedback loop. In Antwerp, we use the data provided through the Open Data Portal and Data Portal City of Antwerp. Furthermore, in Antwerp, we are investigating which IVI use cases can be further combined with the ISA system, with data initially being a simulation provided by Yunex via an RSU.

For both Helmond and Antwerp, Be-Mobile will focus on the traffic signs showing speeds limits. In Helmond, we rely on the open data of OpenStreetMap and combine this data with an additional data layer that is made available by NDW. In Antwerp, we also combine multiple data sources in order to maximize the data quality. More specifically, we combine again the open data of OpenStreetMap with an additional data source: the speed limit information of AWV (this is the Agency Traffic and Roads in Flanders). This data source is available via the common backend of Mobilidata. Next to this, the variable messages signs on highways and near school zones, which are sent in IVI format, are incorporated to show dynamic speed limits in the Flitsmeister and

Truckmeister apps. Roadworks with additional speed limit information, available via the Mobilidata Interchange in DENM format, will also be taken into account to dynamically lower the max speed shown to the end users.

Antwerp:

Table 3: Technical description In-Vehicle Signage, in Antwerp

Party	Description	Data
Be-Mobile	We will focus on the traffic signs showing the applicable speed limits. Static in-vehicle signage: roll-out with participants. For static speed limits Be-Mobile uses its own developed methodology and data format, more specifically we work with an entire basemap with up-to-date static speed limits that are linked to road segments (made available via a static data API). Dynamic in vehicle signage: roll-out with participants. The dynamic speeds displayed on the Variable Matrix Signs are exchanged via the Mobilidata Interchange. The implementation is according to the C-Roads standards (data stream in IVI).	OpenStreetMap, open data and data from AWV (TN-ITS feed and variable message signs) via Mobilidata
V-tron	V-tron's focus will be on the speed information. V-tron will install Intelligent Speed Assistance (ISA) systems in the participants' vehicles. These systems, equipped with a vision sensor, digital speed map (obtained from the Open Data Portal MOW and Antwerp), and GPS system, determine the maximum permitted speed on the road being driven. This is also the focus of V-tron in this use case. Additionally, the system is capable of limiting the vehicle's speed to this maximum permitted speed. In the dynamic form, the implementation of information from Variable Message Signs (VMS) in Antwerp and Flanders into the ISA system is explored, or alternative methods of informing drivers about these variable messages. One of the topics that are of particular interest are the school zones with variable maximum speeds based on timing. In terms of evaluation, V-tron is primarily interested in user experience with the system and whether the information is accurate. This can be later verified with the digital road map, physical signage, and system logging.	Open data portal MOW and Data Portal City of Antwerp

Helmond:

Table 4: Technical description In-Vehicle Signage, in Helmond

Party	Description	Data
Be-Mobile	We will focus on the traffic signs showing the speed limits. Static in-vehicle signage: roll-out with participants. Be-Mobile will use its own developed methodology and data format. The main data source is OpenStreetMap. We combine this data with the open data from NDW for maximum speeds as an extra data layer to maximize data quality. We work with an entire basemap with up-to-date static speed limits that are linked to road segments. Dynamic in-vehicle signage: roll-out with participants. As NDW applies a different format of data, Be-Mobile will use its own developed methodology and data format to show these dynamic speeds to users in the mobile app. For dynamic speeds we will also support this use case conceptually according to C-Roads standards.	OpenStreetMap combined with open data from NDW
V-tron	V-tron will deploy a test vehicle equipped with an ISA system in Helmond for a demonstration week with end users. These systems, equipped with a vision sensor, digital speed map (obtained from the NWB), and GPS system, determine the maximum permitted speed on the road being driven. This is also the focus of V-tron in this use case. Additionally, the system is capable of limiting the vehicle's speed to this maximum permitted speed. In the dynamic form, V-tron will explore methods to inform drivers about variable messages, mainly through the implementation of information from VMS in Helmond into the ISA system. In terms of evaluation, V-tron is primarily interested in user experience with the system and whether the information is accurate. This can be later verified with the digital road map, physical signage, and system logging.	NDW speed map, no additional C-ITS sources are foreseen.

4.1.3 Other Hazardous Locations Notification

"The road operator can communicate with drivers through I2V communication about road works, restrictions and instructions"

V-tron is exploring the possibilities of accessing Mobilidata in Antwerp and relaying this data as warnings in the vehicle, but only through desktop setup. Additionally, they are investigating the potential to receive such messages via the Yunex RSU and display them in V-tron's test vehicle as a functional test. In the Netherlands, research has been conducted on which NDW data is usable for displaying such messages in the vehicle. However, within the project, this is only being developed conceptually.

Be-Mobile can make use of its own collected data (by traffic editors of Be-Mobile and the collected road users feedback in Flitsmeister), the data of Mobilidata, the data of the Flemish Traffic Center and the data of NDW.

Antwerp:

Table 5: Technical description Other Hazardous Locations Notification, in Antwerp

Party	Description	Data
Be-Mobile	Be-Mobile will support a large part of the number of notification types and will follow the C-Roads standards (DENM messages with corresponding cause and subcause codes). For a few traffic incidents, we believe that the C-Roads standards are in practice sometimes too restrictive, therefore, we add some extra parameters in a way to improve these standards.	Be-Mobile data (traffic editors Be-Mobile, feedback from Flitsmeister users), data from Mobilidata, data from Flemish Traffic Center
V-tron	Conceptually, it is being explored whether the information from the Mobilidata platform is usable for V-tron to implement in their system and thus warn the driver in the vehicle via the ISA HMI. Furthermore, investigation is ongoing regarding the possibility of receiving such messages (according to C-Roads specifications) via a Yunex RSU (short-range), which will contain simulated data only within the project. The specific use cases encompassed by this will be added later.	Mobilidata, simulated data via Yunex RSU

Helmond:

Table 6: Technical description Other Hazardous Locations Notification, in Helmond

Party	Description	Data
Be-Mobile	Be-Mobile will support a large part of the number of notification types as a roll-out. In the Netherlands, we will make use of our own developed methodology and data format, starting from our own data and the open data of NDW. Additionally, we will support this use case conceptually according to C-Roads standards.	Be-Mobile data (traffic editors Be-Mobile, feedback from Flitsmeister users), NDW

V-tron	V-tron will not roll out any OHLN use cases in Helmond due to a lack of usable qualitative data. However, conceptual research is being conducted to determine if and which data from the NDW could be useful for future implementation. Data could then be received via the hybrid OBU and displayed on the ISA HMI in the vehicle.	NDW

4.1.4 Traffic Light Manoeuvres Road and Lane Topology

"Traffic lights are connected to a roadside unit. Via this connection, information can be broadcast to nearby vehicles informing them of the traffic light phase schedule. This will enable vehicles to calculate optimal speed of approach. Time to green information may also be presented to drivers."

V-tron is exploring the possibility of integrating GLOSA (Green Light Optimal Speed Advisory) information with the ISA system. This way, the driver can be informed about time-to-green and the potential to limit vehicles speed via the ISA system based on the suggested maximum speed to catch the green light.

Be-Mobile will include traffic light information in their mobile app Flitsmeister by connecting traffic lights via the common backend of Mobilidata in Antwerp and via UDAP NDW in Helmond.

Antwerp:

Table 7: Technical description Traffic Light Manoeuvres Road and Lane Topology, in Antwerp

Party	Description	Data
Be-Mobile	Roll-out with participants. Be-Mobile will support the color mode and time to green in Flanders in the Flitsmeister app. Format of the data stream: SPAT and MAP messages. We will support this use case for all iVRIs that are connected to the Mobilidata interchange via the TLEX platform. The use case follows the C-roads standards.	Mobilidata (TLEX)
V-tron	V-tron will not support this use case in Flanders.	-

Helmond:

Table 8: Technical description Traffic Light Manoeuvres Road and Lane Topology, in Helmond

Party	Description	Data
Be-Mobile	Roll out with participants. We will show the color mode of the iVRI in Flitsmeister for all the traffic lights in Helmond that are connected to the public interchange of UDAP NDW. Recently, we have also implemented time-to-green countdown for this pilot site. Format of the data stream: SPAT and MAP messages. Currently, we have already connected many traffic lights to our mobile application. This information is available in the Flitsmeister app. However, we rely on the Urban Data Access Platform (UDAP) where the current implementation of the communication channel deviates from the C-Roads standards. The exchanged SPAT and MAP messages follow a "Dutch Profile" of the ETSI ITS specifications.	UDAP Talking Traffic
V-tron	V-tron will conceptually implement the SPAT and MAP messages in the ISA system. This combination of ISA and GLOSA (GLISA) will advise the driver with 'time-to-green' information as well as the current status of the traffic light on the ISA HMI. For now, it is not possible to actually receive messages via short-range communication from traffic lights in Helmond. However, it has been functionally tested and demonstrated as operational using a test setup.	Short range communication with traffic lights

4.1.5 Traffic Jam Ahead

"The Traffic Jam Ahead use case aims to warn road users via I2V and V2V messages when approaching a traffic jam, reducing the risk of rear-end collisions"

Be-Mobile will support this use case in Antwerp. For this use case we have developed an algorithm that excels in early identification of traffic jam tails, leading to a significant increase in road safety by providing this information to mobile app users of Flitsmeister. These messages are also made available to other parties via the common backend.

Antwerp:

Table 9: Technical description Traffic Jam Ahead, in Antwerp

Party	Description	Data
Be-Mobile	Roll out with participants. For the detection of jam tails Be-Mobile uses its own developed algorithm. The implementation follows the C-Roads standards via the Mobilidata interchange. Data stream: DENM messages.	Generated by the algorithms of Be-Mobile and shared via Mobilidata Interchange.
V-tron	V-tron will not support this use case other than what is available for OHLN.	-

Helmond:

Be-Mobile supports warnings for traffic jams in Helmond via the use case: Other Hazardous Locations Notification (OHLN).

4.1.6 Slow or Stationary Vehicle

"A slow or stationary vehicle can signal its presence to other vehicles. This improves traffic fluidity by encouraging other vehicles to take an alternative route"

Description: The Slow or Stationary Vehicle use case, as defined by C-Roads specifications, aims to enhance road safety and traffic efficiency by providing real-time warnings to nearby vehicles about the presence of slow-moving or stationary vehicles on the road. This use case utilizes Cooperative Intelligent Transport Systems (C-ITS) technologies to enable vehicles to exchange information and alert drivers of potential hazards ahead. By promptly notifying drivers of the presence of slow-moving or stationary vehicles, this use-case helps prevent rear-end collisions, enables smoother traffic flow, and improves overall road safety.

Objective: The Slow or Stationary Vehicle use case within the CEF Antwerp-Helmond project aims to provide safety benefits by alerting approaching pilot drivers of slow-moving or stationary/defective vehicles ahead, which can act as obstacles on the road. The warning helps prevent dangerous manoeuvres as drivers have more time to prepare for the hazard. This improves safety and efficiency, and the information can be shared via vehicle-to-vehicle (V2V) communication. By issuing timely warnings, the Slow or Stationary Vehicle use case enhances driver awareness and allows them to take necessary precautions, ultimately reducing the risk of accidents and promoting smoother traffic flow in the project area.

Antwerp:

Table 10: Technical description Slow or Stationary Vehicle, in Antwerp

Party	Description	Data
Be-Mobile	<u>Stationary vehicles</u>: roll-out with participants. The implementation of warnings for stationary vehicles is according to C-Roads standards. Data stream: DENM messages. <u>Slow-moving vehicles</u>: notifications for slow-moving vehicles are being developed functionally. We follow the C-roads standards for this use case. Data stream: DENM messages.	DATEX II feed Vlaams Verkeerscentrum for stationary vehicles, Flitsmeister and other connected users for slow moving vehicle warnings

Helmond:

Be-Mobile supports warnings for stationary vehicles in Helmond via the use case: Other Hazardous Locations Notification (OHLN).

4.1.7 Rail-road crossing

"The rail-road crossing use case involves implementing intelligent transport systems to enhance safety and efficiency at railway crossings. V2I communication technologies provide real-time information to road users approaching the crossing"

The rail-road crossing information can be made available in C-ITS over short range or long range communication. As the railway infrastructure operator is not part of this project to share this data and there is not yet a data source provider in the Mobilidata ecosystem providing static or dynamic rail-road crossing information as open data, we will focus in this project on the role of the traffic light controller for making this information available.

Antwerp:

Table 11: Technical description Rail-road crossing, in Antwerp

Party	Description	Data
Yunex	Conceptual. Yunex describes how traffic controllers that receive the Open / Closed information from nearby railroad crossings could upload this information in real time towards C-ITS ecosystems.	Yunex Traffic Controller

4.2 C-ITS and UVAR

The Cooperative Intelligent Transport Systems (C-ITS) and Urban Vehicle Access Regulations (UVAR) use cases are described in the following subsections.

4.2.1 Tunnel Height Warning

"The Tunnel Height Warning use case aims to prevent collisions between vehicles that are too tall and tunnels by alerting approaching traffic about the tunnel height through I2V and V2I messages"

In this use case, we will identify the messages that can be broadcasted in the different zones when approaching a tunnel with height restrictions. The messages depend on the location of the vehicle and the availability of alternative (escape) routes. We will analyse the data quality of the static tunnel height data in the Mobilidata ecosystem, which incorporates the TN-ITS data stream, compared to specific tunnel data provided by the City of Antwerp. Yunex will broadcast IVIM messages for the different zones over short range ITS-G5 by means of an RSU, installed close to the tunnel entry.

V-tron will functionally test this use case using its own test vehicle in Antwerp. The V-tron OBU will receive IVIM messages from the Yunex RSU and process them into a warning message to the driver on the ISA HMI. Additionally, V-tron is conceptually investigating whether the vehicle can indeed be limited via the ISA system based on the IVIM message. It will also be explored whether the notifications and vehicle limitation can be made vehicle-specific based on the CAM messages broadcasted by the V-tron OBU via ITS-G5 communication.

Antwerp:

Table 12: Technical description Tunnel Height Warning, in Antwerp

Party	Description	Data
Yunex	Functional roll-out. Yunex provides the ITS-G5 short range RSU at location and will broadcast the IVIM messages containing the exact tunnel height and warning zones. A back end will be in place for enabling the functional tests and providing a technical concept for future integration in C-ITS ecosystems. We warn drivers for upcoming height restrictions in the vicinity of tunnels.	TN-ITS feed via Mobilidata platform or dedicated tunnel data from City of Antwerp, depending on availability and required quality. Short range broadcasting. Aim to get personalised / individualised messages in the vehicles depending on their height.
V-tron	The objective of V-tron within this use case is to (conceptually and functionally) determine whether drivers in the vehicle	Short-range / T.B.D.

	can be alerted about approaching tunnels that their vehicle may be too tall to pass through. This will be investigated for the short-range communication, based on CAM and DENM and IVIM messages. The information may be displayed on the HMI of the ISA system.	

4.2.2 Temporary Speed Restrictions near School Areas

"The Temporary Speed Restrictions near School Areas use case aims to enhance traffic safety by implementing temporary speed limits in the vicinity of schools during specific times of the day"

In Antwerp, Be-mobile provides temporary speed restrictions near school areas in the mobile app of Flitsmeister and Truckmeister via the common backend. For Helmond, we will provide the same information as soon as this data is available via NDW.

V-tron is investigating how (reliable) information about school zones and alternative maximum speeds can be accessed and used as input for the ISA system in both Antwerp and Helmond. This is aimed at both warning the driver through a notification on the HMI and exploring the possibility of limiting the vehicle to an alternative speed in these zones.

Antwerp:

Table 13: Technical description Temporary Speed Restrictions in School Areas, in Antwerp

Party	Description	Data
Be-Mobile	This use case will be supported via the use case "in-vehicle signage" where we will share the speed signs for a number of school zones.	Data from AWV via Mobilidata in IVI format.
V-tron	V-tron is exploring how data regarding school zones and opening hours can be accessed through AWV (the Agency for Roads and Traffic) and Mobilidata for Flanders and Antwerp, respectively, and implemented in V-tron's test vehicle. The aim is to display these school zones and possibly alternative speeds on the ISA HMI in the vehicle. Conceptually, it is also being explored whether the vehicle can actually be limited to an alternative speed.	Data Portal City of Antwerp, Mobilidata

Helmond:

Table 14: Technical description Temporary Speed Restrictions in School Areas, in Helmond

Party	Description	Data
Be-Mobile	This use case will be supported via the use case "in-vehicle signage" where we will share the speed signs for a number of school zones as soon as this data is available via NDW.	NDW
V-tron	V-tron is investigating how data regarding school zones and opening hours can be accessed through the NDW for the Netherlands and implemented in V-tron's test vehicle. The aim is to display these school zones and possibly alternative speeds on the ISA HMI in the vehicle. Conceptually, it is also being explored whether the vehicle can actually be limited to an alternative speed.	NDW, school zones information via primary education council

4.2.3 Access regulation for truck drivers depending on time and place (time-slots, access restrictions, …)

"The Access Regulation for Truck Drivers use case involves implementing time and location-dependent restrictions for truck drivers, ensuring controlled access based on specific regulations"

Description: During the European project Scale-Up, Be-mobile, in collaboration with the city of Antwerp and Lantis, developed a freight route planner for trucks. Depending on different variables such as the street category, school environment etc, the route planner calculates the least dangerous route for trucks.

Objective: Originally, the integration of access regulation in the route planner was also planned. Unfortunately, due to a number of problems, information on access regulation could not be fully integrated. Therefore, the objective within C-Roads is to go a step further and analyse the shortcomings that came to light in Scale-Up. The focus will be on how to overcome the problems and focus for example on data availability and data standards.

Helmond will follow up this use case as well and share their challenges and insights.

Antwerp:

Table 15: Technical description Access regulation for truck drivers, in Antwerp

Party	Description	Data
Be-Mobile, Lantis	Be-Mobile and Lantis will support this use case conceptually. Analysis of the insights and problems within Scale-Up and possible ways to overcome these problems with a focus on data availability and data standards. We will research which tools and standards could be useful for cities to configure and publish access regulations in general.	This is a conceptual study. We can focus on some examples of existing access regulations.

4.2.4 Speed restrictions for micro mobility users, depending on time and place (active users)

"The Speed Restrictions for Micro Mobility Users use case involves implementing time and location-dependent speed limits for users of micro mobility vehicles, ensuring safer and controlled speeds based on specific regulations"

Antwerp and PXL will focus on a functional evaluation of this use cases by observing and counting traffic and analysing historical trip data.

Antwerp:

Table 16: Technical description Speed restrictions for micro mobility users, in Antwerp

Party	Description	Data
Antwerp, PXL	**Functional evaluation** by PXL and Antwerp to learn if the slow-speed-zone and its borders work without complications. Evaluation of **historical trip data** of shared electric scooters to discover the impact on route choice of scooter drivers and amount of trips made that cross the slow-speed-zone. **Observation** and **traffic counting** in slow speed zone by PXL and Antwerp to observe the interaction between pedestrians and faster active road users. **Interviews** to determine what causes discomfort and (possible) conflicts between faster micromobility users and pedestrians.	Trip data from shared mobility providers

4.2.5 Cut-through traffic measures

"Evaluate C-ITS CAM data for cut-through traffic measurements"

Description: There are a lot of ways to discourage cut-through traffic, but good measurements are needed to evaluate the change in behaviour. We test how C-ITS can be used to provide meaningful cut-through traffic data.

Objective: Test if CAM data can be used for creating cut-through traffic statistics & evaluate the quality.

Note: It is still unclear at what location the test will take place.

Tabel 17: Technical description Cut-through traffic measures

Party	Description	Data
Yunex	CAM data will be collected via long range C-ITS by means of an RSU. We will define a cut-through traffic zone, match station-id's & create statistics.	ETSI CAM data collected by ITS-G5 RSU.

4.3 C-ITS and (urban) Mobility Services

The Cooperative Intelligent Transport Systems (C-ITS) and (urban) mobility services use cases are described in the following subsections.

4.3.1 Truck buffering by providing specific information to avoid traffic jams

"The Truck Buffering use case aims to prevent traffic congestion by providing specific information to truck drivers, allowing them to adjust their routes and avoid traffic jams"

Description: Due to the road works around Antwerp during the following years, more traffic jams are expected. Next to a modal shift, an active traffic management is needed to decrease the impact of the traffic jams.

Antwerp:

Table 18: Technical description Truck buffering, in Antwerp

Party	Description	Data
Be-Mobile, Lantis	Be-Mobile and Lantis will support this use case conceptually. We will give an overview of truck buffering methods and gather feedback from truck sector organizations. For the proposed truck buffering methods, we will map the technical requirements and evaluate the feasibility.	We will gather information and valuable insights during interviews with relevant stakeholders.

4.3.2 Traffic light prioritization for different active mobility users and trucks

"The Traffic Light Prioritization use case involves prioritizing traffic lights for various active mobility users (e.g., pedestrians, cyclists) and trucks, ensuring efficient and safe movement through intersection by granting priority based on specific user categories"

Description: Traffic light prioritization aims to change the status of the traffic lights for a specific vehicle type (car, truck, bike, pedestrians) in such a way that they can move quickly through traffic in order to shorten waiting times, encourage active mobility and lower emissions due to braking and acceleration of trucks. When the road users request priority for an intersection, the traffic light control is adjusted according to the priority level and situation.

Objective: The objective of this use case is to test the possibility for traffic light prioritization and to see which technical specifications work. The focus will be on traffic light prioritization of (cargo and regular) bike traffic and truck traffic. For this, a conceptual analysis is made, together with a first test on a crossroad in the north of Antwerp.

The selected traffic lights in Antwerp are connected to TLEX. TLEX is connected to the common backend.

Helmond will not participate in this use case.

Antwerp:

Table 19: Technical description Traffic light prioritization, in Antwerp

Party	Description	Data
Be-Mobile	The aim is to support this use case for a functional test or a roll-out with participants for the selected traffic lights in the City of Antwerp. Both the app Truckmeister and Sway will be used for this use case. This means that we will test prioritization for both truck drivers and active vulnerable road users (with a focus on cyclists). The implementation is compliant with the standards described by the Dutch Profiles (CROW).	Traffic lights connected to the common backend. SRM, CAM and SSM messages.
Yunex	Yunex will upgrade existing (non iVRI) traffic controllers to allow for ETSI based C-ITS priority handling in their traffic actuation programs. Separate signal plans will be made available for supporting the tests, showing the possibilities of C-ITS priorities on intersections equipped with traffic lights.	Yunex will connect to the MobiliData TLEX and will deliver SPATEM data of the connected intersections. It will 'subscribe' for CAM and SREM messages, generated by the applications of Be-Mobile. SSEM feedback from the intersections will be available.

4.3.3 P+R information for drivers on the highway

"The P+R Information for Drivers on the Highway use case aims to provide drivers on the highway with relevant information about Park and Ride (P+R) facilities, allowing them to make informed decisions regarding parking and commuting options"

Description: This use case is a further development of a use case from the European project Scale-Up. For the use case within Scale-Up, pre-trip advice is given to car drivers heading to Antwerp to use the P+Rs around Antwerp. However, with sudden traffic changes and increasing delays, there might also be a need for on-trip advice. In this situation, the Flitsmeister app can therefore calculate a reroute via P+Rs, taking into consideration the difference in travel time.

Objective: The objective for this use case is to nudge drivers on their way to Antwerp to use P+Rs and to continue their travel with public transport. On first sight, we see two options: to show the information of P+Rs in route navigation apps or to give specific advice to car drivers driving to Antwerp.

Concerning the occupancy of the P+Rs, two options will be analysed: the option to only show when a P+R approaches maximum occupancy or to also reroute cars to alternative P+Rs.

Helmond will not participate in this use case due to the unavailability of P+Rs in the area surrounding the city.

Antwerp:

Table 20: Technical description P+R information, in Antwerp

Party	Description	Data
Be-Mobile	Be-Mobile will only support this use case in Flanders. The implementation of both static information (such as P+R locations) and dynamic information (such as occupancy rates of P+R's) will deviate from C-Roads standards. C-Roads standards are indeed less suitable to show this kind of information. If the occupancy rates of P+R's are available, we will make this information available via the Mobilidata interchange in DATEX II format, which better meets the requirements of a production environment.	Mobilidata in DATEX II format
Lantis	Deliverable (for Lantis and Be-Mobile): analysis of the lessons learned from earlier projects, with identification of possible remedies. Analysis of the possibilities for on-trip travel advice via P&Rs and re-routing due to full P+Rs.	

4.3.4 Traffic Management Portal to monitor and analyse KPIs for (i)VRIs

"The goal is to dashboard typical traffic engineering KPI's based on ITS-G5 short-range and cellular long-range C-ITS messages"

Description: Until now, many traffic engineering KPI's are not based on C-ITS. For example, vehicle counting is done manually, or is based on temporary or permanent detection loops. Waiting times and delays for public transport are calculated based on data available in traffic controllers. ETSI messages such as CAM and SREM provide meaningful data for creating traffic management KPI's.

Objective: The objective of the traffic management portal is to explore the use of ETSI messages such as CAM and SREM to provide traffic engineering insights based on C-ITS messages.

Table 21: Technical description Traffic Management Portal

Party	Description	Data
Yunex	Based on the ETSI messages used in the different use cases, Yunex will create dashboards for typical traffic engineering KPI's. In the traffic light priority use case, SREM and CAM data as well as SPATEM data will be available for analysis. Also the short range RSUs broadcasting DENM and IVIM messages will be able to collect publicly available CAM data.	ETSI CAM, SREM, SPATEM as available in the MobiliData TLEX for the connected intersections. Plus CAM messages picked up by the ITS-G5 RSU's.