THE SOCRATES$^{2.0}$ PILOT IN CITY OF ANTWERP

Version	1.2
Date	14-6-2021
Status	Final

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Antwerp

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Published by	SOCRATES$^{2.0}$
Information	Info@socrates2.org
Activity	7
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Date:	14-6-2021
Status:	Final public version
Version no.:	1.2

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0. INTRODUCTION

This document presents the final report of the pilot in the region of Antwerp within the Socrates $^{2.0}$ project.
It is a combined report on the operational period (7.7), together with the actual final report (7.6).
The Socrates $^{2.0}$ Use Cases that were deployed in the Antwerp region are:

- 'Optimizing Traffic Network Flow' in two variants with different cooperation models. In these Use Cases, following partners are involved: Flemish Traffic Centre, Be-Mobile, BMW, and MAPtm;
- 'Speed and Lane Advise', in which Flemish Traffic Centre and Be-Mobile are involved;
- 'Road Works' with participation of Flemish Traffic Centre, MAPtm, Be-Mobile and TomTom.

1. ORGANISATIONAL SET-UP

Originally in the work plan at the start of the Activity, there was a subdivision into tasks and each partner was supposed to work within his/her own premises and to report to the Task Leader. The task leaders then would form the Activity Management Team
Given the fact that the number of partners and the number of staff involved from the various partners was rather limited, in practice there was no strict division into tasks nor working groups. Parts that needed to be organized by partners internally were arranged accordingly, cross partner interaction was tackled in regular Pilot site meetings with all partners directly involved. Communication and interaction with Liefkenshoektunnel, who was an important partner, but was not part of the Socrates $^{2.0}$ project, was done bilateral by the Flemish Traffic Centre. For the use case Road Works, a different approach was decided since this use case was largely similar in the three pilot sites (Antwerp – Amsterdam – Munich) concerned, it was developed somewhat separately from the other use cases in the pilot sites as a combined use case for all three of them.

1.1. Planning

There is no fixed planning made upfront. Most use cases will be executed in one phase. Only for the ONTF Toll Reduction use case, it is foreseen that during the pilot the settings of the different thresholds for activation and the distribution of vouchers can be adapted, largely depending on the amount of users. The aim is to build up a substantial user base by making the use cases easily accessible to as many potential users as possible. This is done by broad settings for the thresholds. The plan was that once a sufficient amount of users recruited, these settings could be adapted. Due to the Corona pandemic and the measures taken in response, a sufficient amount of users to go to a next phase with different settings was never reached

2. USE CASES OPTIMIZING TRAFFIC NETWORK FLOW

2.1. Use case description

On the Antwerp motorway network, there are two tunnels that can be used to cross the river Schledt. In the north there is the Liefkenshoektunnel (A), which is a toll tunnel and in the south there is the Kennedytunnel (B) which is free of charge.

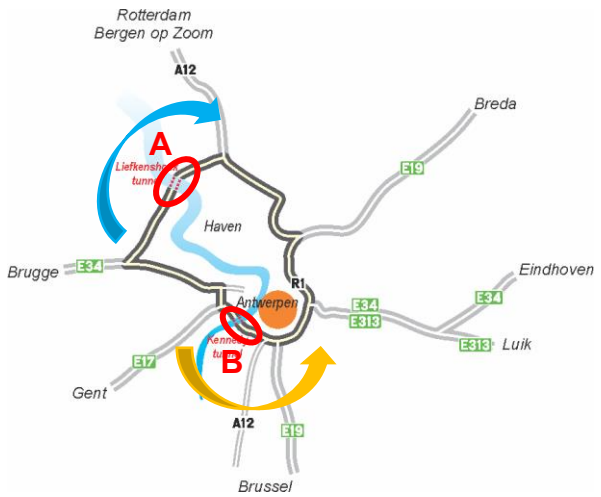

FIGURE 1: ANTWERP MOTORWAY NETWORK

In normal traffic conditions, there is an unbalance in use between those two tunnels. Where the Kennedytunnel has an average daily traffic volume of 160.000 vehicles, the Liefkenshoektunnel only gets around 40.000 vehicles a day.
Since 2002, the Flemish Traffic Centre has the ability to suspend tolling at the Liefkenshoektunnel in case of incidents that seriously affect the throughput on the southern part of the Antwerp ring road. In such a case, toll is suspended for every road user that passes through the Liefkenshoektunnel. The toll booths are being closed, and all traffic is diverted to the outside of the toll plaza, around the toll booths. All passages through the Liefkenshoektunnel during toll suspension are registered and invoiced to the Flemish Road Administration.
When the toll suspension measure is activated, this is communicated to the road user via VMS, website, radio broadcast, …. However, up till now, there was no machine-readable message (e.g. in DatexII) send out about toll suspension, and also navigation devices couldn't handle temporary toll suspension. For most navigation devices, toll is a static map-feature, which cannot be adapted dynamically. The first ONTF Use Case for the Antwerp region thus was to realise a machine readable message whenever toll suspension is activated. This message than could be interpreted by service providers that could incorporate the message that toll has been suspended temporary in their services (Toll Suspension A). The same machine readable message could also be used to adapt navigation services in a way that during toll suspension, they don't consider Liefkenshoektunnel as a toll tunnel (Toll Suspension B).

Building on this, the ‘toll reduction’ variant (Toll Reduction) of the ONTF use case was developed. This Use Case aims to get a better balance of traffic between both tunnel in normal day to day traffic conditions. The idea is to get a dedicated part of the traffic out of the Kennedytunnel and shift it towards the Liefkenshoektunnel in order to only redistribute the excess on traffic. This is done by constantly monitoring the traffic conditions in both tunnels. Whenever the Kennedytunnel tends to become saturated and at the same time, there is sufficient capacity let in the Liefkenshoektunnel, the toll reduction measure is to be activated. At that time, service providers will target road users that are on the road, using their navigation device and actually are following a route that passes through te Kennedytunnel. They will be offered an alternative route through the Liefkenshoektunnel, and if they accept, they get sent a voucher on their smartphone, containing a QR-code that they can use to get a free ride through the Liefkenshoektunnel. The amount of users that are to be persuaded to shift from the Kennedytunnel towards the Liefkenshoektunnel depends on the actual traffic state in both tunnels. The idea for this use case is that also the amount of toll reduction offered to the road user would depend on the actual traffic state in both tunnels and the amount of traffic to be shifted. For practical reasons, the toll reduction for this pilot will always be 100%, avoiding some practical financial issues that would make it too complicated to achieve.

2.2. Active Partners

Partners active in this use case are the Flemish Traffic Centre, MAPtm as an intermediary party and two parties providing end user services: Be-Mobile with the Flitsmeister app and BMW. Brandmkrs finally decided not to operate an end user service. As for the Toll Reduction UC, an external partner (nv Tunnel Liefkenshoek) had to be involved as they are the operators of the Liefkenshoektunnel and collect the toll. A separate contract between Flemish Traffic Centre and nv Tunnel Liefkenshoek was established.

2.3. Description of end user services

2.3.1. End user service by Be-Mobile

Be-Mobile's Optimizing Network Traffic Flow services aim at providing routing advice to travellers crossing the river Scheldt in Antwerp. The route advice is given in the Flitsmeister navigation driver companion application.
When toll in the Liefkenshoektunnel is suspended globally, this information is shown in the Flitsmeister application to travellers for whom this information is relevant (travellers in a geofenced area around the tunnel or travellers on a route that is crossing the Scheldt). The routing algorithm in the navigation service takes into account that toll is suspended, when providing routing guidance.
When the measure 'toll reduction in Liefkenshoektunnel' is activated, Be-Mobile's end user service will contribute to the objective of improving the distribution of traffic over the 2 tunnels, by shifting specific travellers from Kennedytunnel to Liefkenshoektunnel. When a Flitsmeister user requests a route to his/her destination, and this route goes via the Kennedytunnel, then the service will first check whether the toll reduction measure is activated by the traffic manager.

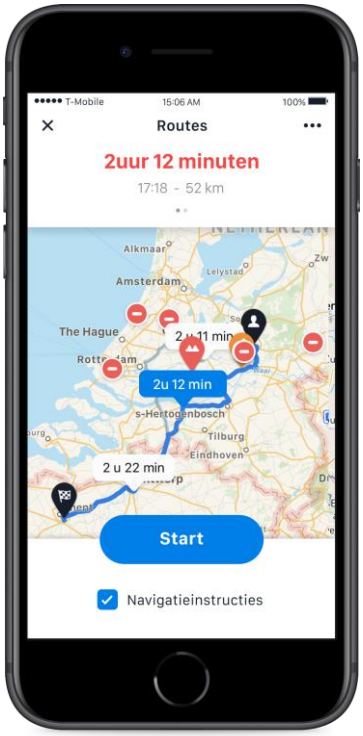

FIGURE 2: USER REQUESTING A ROUTE IN THE FLITSMEISTER SERVICE

If the toll reduction measure is activated, the routing engine in the navigation service will calculate an alternative route via Liefkenshoektunnel. Expected travel time on this alternative route is compared to the expected travel time on the original route via Kennedytunnel. If travel time on the alternative route is not much longer compared to travel time on the original route, the end user will be presented with the option to shift to this alternative route. A pop-up will be shown that informs the traveller on the alternative route, thereby offering a voucher to pass the Liefkenshoektunnel for free. By offering toll reduction vouchers, road users are incentivised to follow up the re-routing advice. When accepting the alternative route, the voucher is sent to the user.

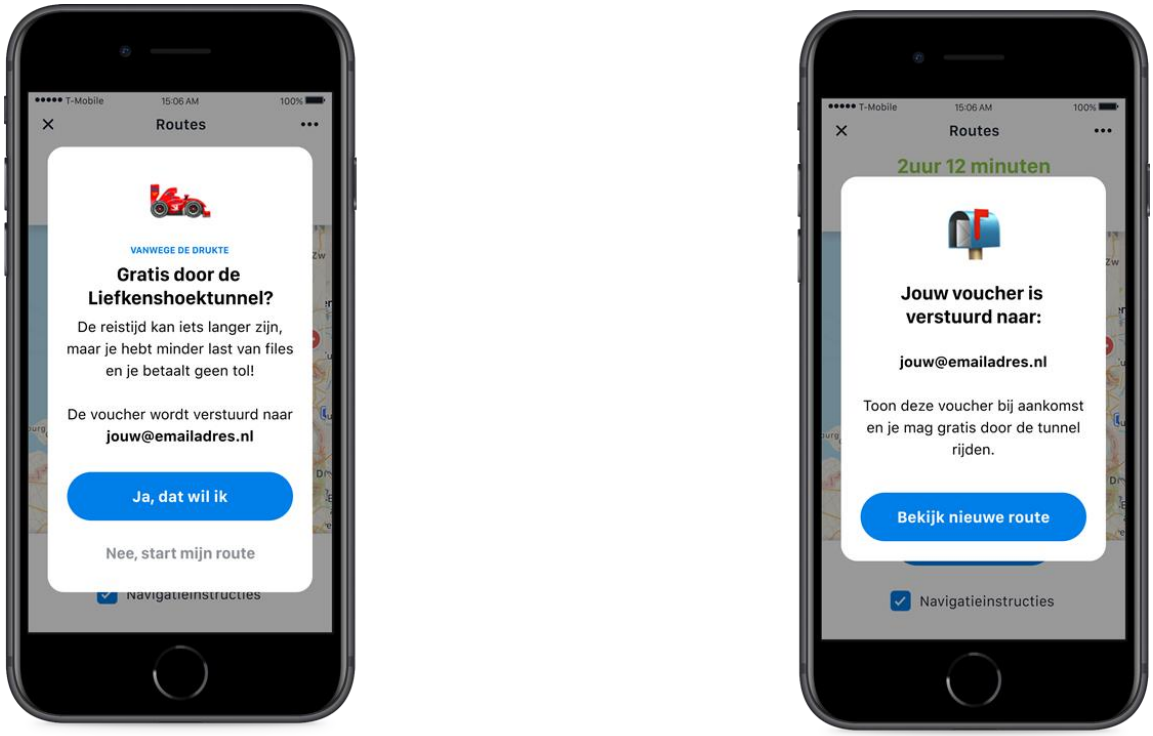

FIGURE 3: RE-ROUTE ADVICE IN THE FLITSMEISTER SERVICE

When the traveller arrives at the Liefkenshoektunnel, he/she can have his voucher scanned by a toll booth operator and he/she can continue his route without paying a toll. To avoid mis usage, the QR code is presented together with i/ information on the applicable driving direction (towards Ghent vs towards the Netherlands) and ii/ information on the expiration date and time.

FIGURE 4: VOUCHER FOR FREE PASSAGE THROUGH LIEFKENSHOEKTUNNEL IN THE FLITSMEISTER SERVICE

2.3.2. End user service by BMW Group

The approach taken to realize the Socrates vehicle prototype is an “Offboard-Routing”, meaning the route for the vehicle is no longer calculated by the internal navigation system of the vehicle, but by an external server. The communication is done via a built-in mobile phone connection. This approach is a common realization which is also already in use in series production vehicles. This is an essential fact, as the prototype was used by normal series production vehicles of customers.
The normal setup was extended by a so called “vehicle app”, which is essentially only an application running on the vehicle’s onboard unit. Those vehicle apps can be pushed to defined vehicles via over-the-air updates and only need to be downloaded by the vehicle to get the prototype ready.

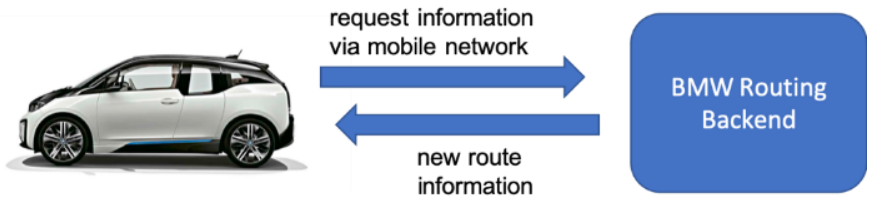

FIGURE 5: BMW VEHICLE – BACKEND INFORMATION EXCHANGE

This described vehicle application is used to send detailed and personized information to a vehicle and display it instantly in the car. The implementation is realized via a pull mechanism, where all information is kept in the backend and vehicles make requests for new information to be displayed. The backend decides conditionally when to release new information. When asking for new information the vehicle transmits its current position, enabling the backend to decide geographically when to send new information.

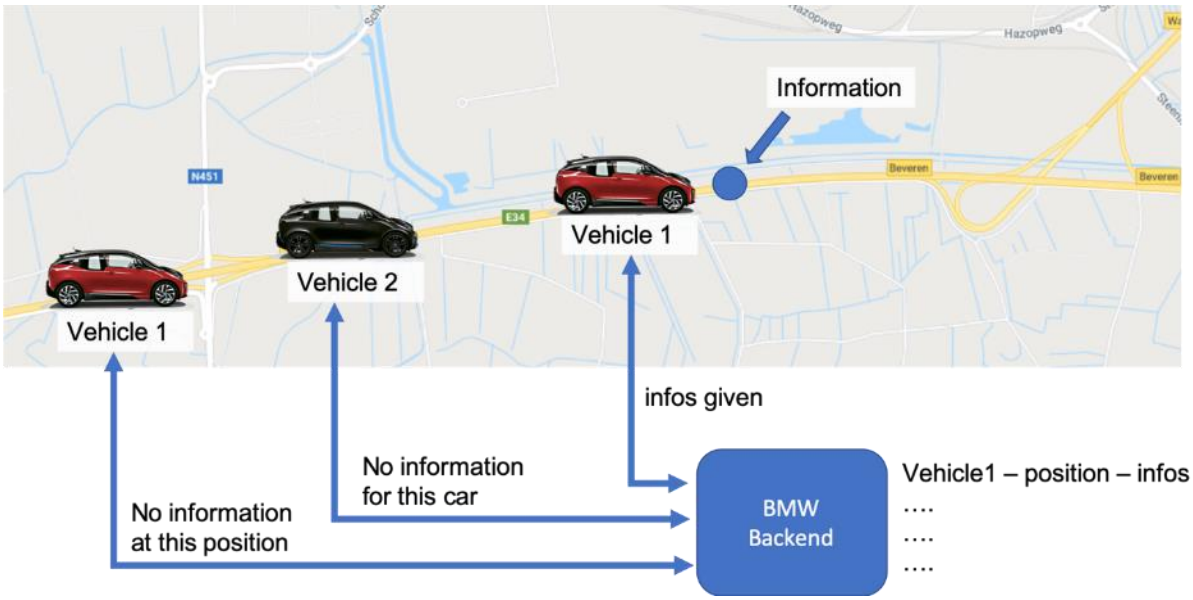

FIGURE 6: VEHICLE APP AND BMW BACKEND COMMUNICATION TRIGGERED BY GEO LOCATION

The picture above shows how the developed vehicle app and the backend work together. The backend service only gives information to specific vehicles and only if they are near a specific location. Information can also be broadcasted to all vehicles, or can be send to a specific vehicle independent from its position.
The combination of these two services – the router running on backend servers and the vehicle app to display additional information in the car are the two core components used to realize all prototypes and demonstrators in all Socrates2.0 pilot cities.

BMW Backend
The BMW backend itself can be structured into several subcomponents again. The picture below shows those different components

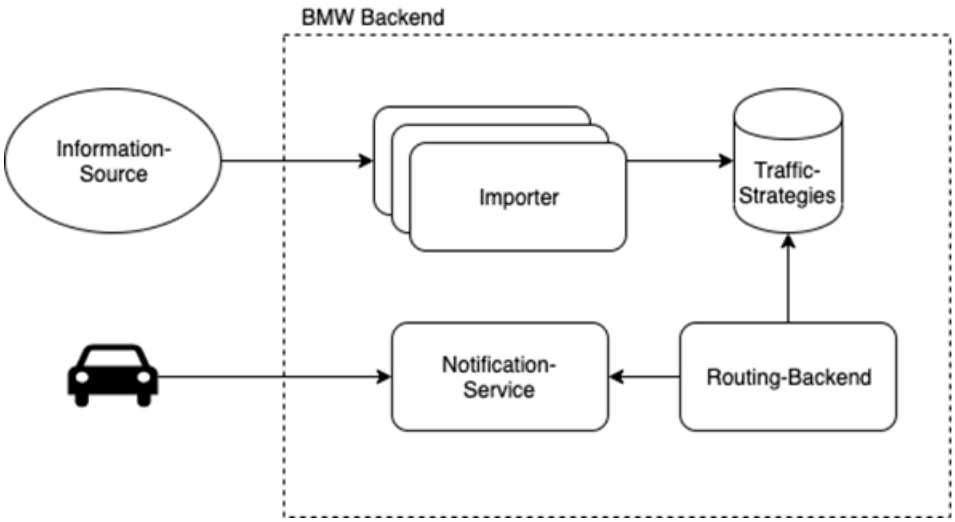

FIGURE 7: COMPONENTS OF THE BMW BACKEND

The importer is responsible for fetching or receiving information from 3rd party information sources, such as intermediaries or authorities. As shown in the picture above there are several importers, as different protocols or publishing strategies are being used. To have a clean and maintainable infrastructure, separate importers have been created for different protocols.
After receiving the information, the importer passes it on to the strategy store. This store holds all currently active strategies, from all different sources in a unified format. The importer can also update or invalidate strategies if this is applicable.
The BMW routing backend checks the strategy store for active strategies. Based on this information it calculates alternative routes and gives information about the intended behavior for the fleet to the notification service. Whenever there is an active strategy, the routing backend produces a so called “trigger-screen”. The trigger-screen is a message which is sent to the car, via the notification service, to ask the driver, if he wants to take an alternative route. The appearance and content of this trigger-screen is dependent on the strategy.
The notification service is responsible for the communication with the vehicles as they constantly ask if there is any information that should be displayed to the driver. The notification service also receives the answers from the drivers, e. g. when they were asked if they would like to take a strategic alternative route. If they acknowledge, this

information is passed on to the routing backend. The routing backend then calculates an alternative route based on the currently active strategies. The details of this route, including information that needs to display to the vehicle are passed back to the notification services. The notification service now creates vehicle specific information screens which are provided along the route.
This overarching architecture has been implemented for all of the Socrates2.0 pilot cities. The notification service and the strategy store could be kept generic from the specifics of the pilot sites. The routing backend was fed with some configuration for each pilot site, but its core logic was independent and identically for all pilot sites. Whilst most of the components could be used without adaptation for all pilot sites, especially the importer had to be tailored to the specific use case. The fact that the information from many different sources could not be collected in the same fashion, is not very surprising. However, during the implementation of the pilot sites, the usage of standardized protocols and national distribution hubs was always favored, to ensure a scalability from single suppliers to a larger extent.
The BMW car of registered users to the BMW Smart Tunnel Drive Service was set up over the air with the specific vehicle App. Interface ANT-ONTF-CM4-TRM3 was processed by the BMW Socrates Backend: In case of heavy traffic in the Kennedytunnel and activated service request, the vehicle App triggers relevant users based on their actual position in pre-defined geofences when to change their route to the Liefkenshoektunnel to spread traffic best and to reduce congestion, as described in the following chapter.

BMW Frontend
The Service of BMW Group provides the information via a vehicle app. A pop-up occurs in the main display if the user passes specific geofence areas in the surroundings of the tunnels and the main and ring roads towards the tunnels. This is triggered by the BMW Backend as described before.
The user receives an active Service notification via a pop-up when:

- He is driving in defined trigger areas of the Antwerp ring and;
- the Flemish Road Authority (Vlaamse Overheid) has activated a Service request to switch to the Liefkenshoektunnel:
    - when toll is suspended in general (information is also broadcasted on radio and shown on road signs) or (= Toll Suspension);
    - if they monitor that the traffic needs a redistribution to balance the traffic flow in the two tunnels (= Toll Reduction).

Approaching the main relevant decision points, the user is asked whether he wants to follow the alternative towards the Liefkenshoektunnel. If he accepts, further in car pop-ups occur and guide him on the strategic streets towards the Liefkenshoektunnel, as follows.

Case A: **Toll is suspended for everyone** by the Flemish Road Authority (Vlaamse Overheid).

- In case you are driving in defined trigger area of the Antwerp ring, you will receive a pop-up with information of general toll suspension and a recommendation of a detour via Liefkenshoektunnel.

- You may accept or decline the alternative route suggested in the Service App:
  - **If you accept**,
    1. Pop-ups will advise you when to change in direction to Liefkenshoektunnel.
    2. After passing the Liefkenshoektunnel we kindly ask you to vote the Smart Tunnel Drive.
  - **If you decline**, follow your initial route via the Kennedytunnel.

How this is communicated via the BMW in car frontend pop-ups, shows figure 7.

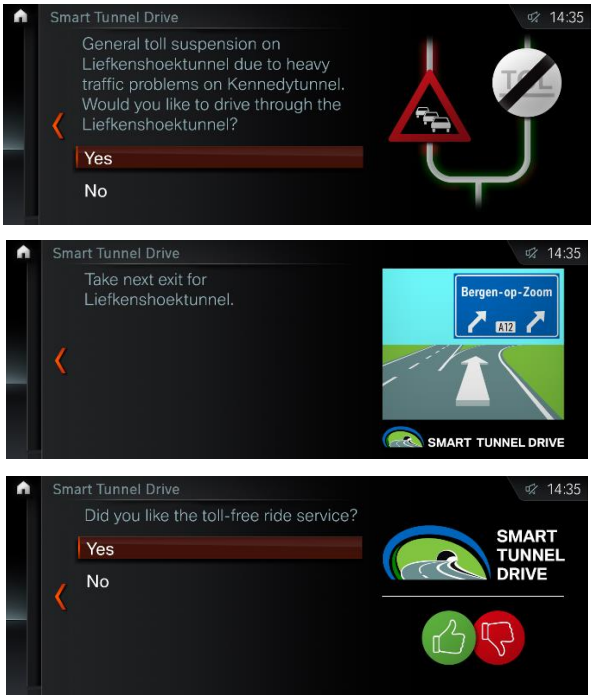

FIGURE 8: CASE A: TOLL SUSPENSION IN GENERAL: SERVICE SCREENS SEQUENCE TOWARDS THE LIEFKENSHOEKTUNNEL OF THE IN VEHICLE END USER SERVICE OF THE BMW GROUP

Case B: If the Flemish Road Authority (Vlaamse Overheid) monitors that the traffic needs a redistribution to **balance the traffic flow** in the two tunnels, the Service will inform you:

- If you drive in the area of the Antwerp ring, a pop-up offers you a **toll-free drive** through the Liefkenshoektunnel.
- You may accept or decline the suggested alternative via Liefkenshoektunnel in the Service App.
  - **If you accept**,
    1. you receive a QR-Code by email to your registered email address and a notification is shown in the main display that the QR code has been sent to your registered email address.
    2. Pop-ups will advise you when to change in direction to the Liefkenshoektunnel.

3. A pop-up will remember you to take a “green arrow” toll booth.
4. After passing the Liefkenshoektunnel we kindly ask you to vote the Smart Tunnel Drive.

- **If you decline,** follow your initial route via the Kennedytunnel

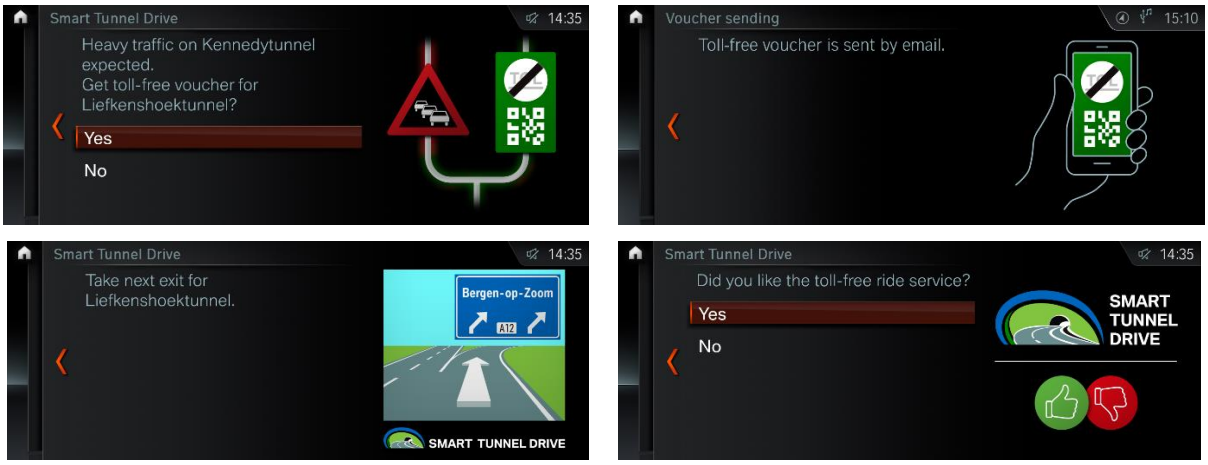

FIGURE 9: CASE B: SERVICE SCREENS SEQUENCE TOWARDS THE LIEFKENSHOEKTUNNEL OF THE IN VEHICLE END USER SERVICE OF THE BMW GROUP

If the user accepts, he get sent a QR-Code by email to his registered email address. And a notification is shown in the main display of the car, that the QR code has been sent to his registered email address.

The in car notification with the QR code included in the pop-up is repeated again when the user is in front of the toll booth. But for scanning the user has to show the QR code on his mobile phone.

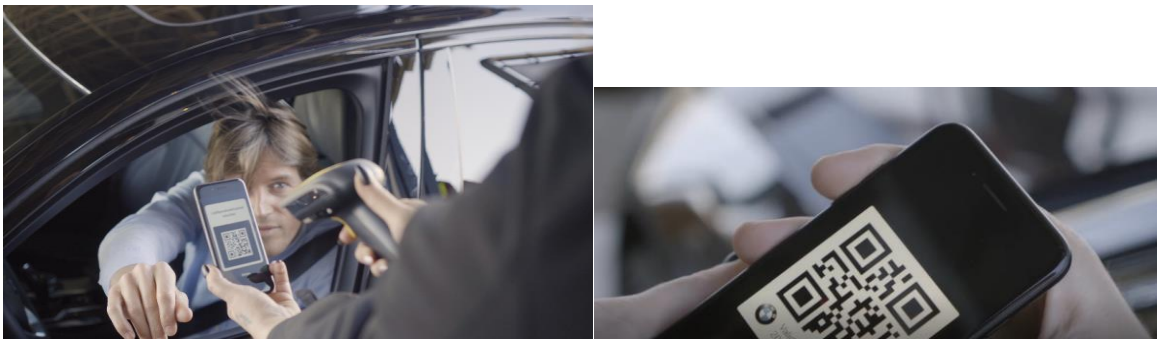

FIGURE 10: QR CODE VOUCHER SCANNING AT THE TOLL BOOTH OF THE LIEFKENSHOEKTUNNEL

After passing the tunnel the user gets an in car pop-up whether he liked the service (yes/no).

When approaching the toll booth an additional notice is shown in car to use one of the Liefkenshoek toll booths with a green arrow sign to get the QR Code scanned.

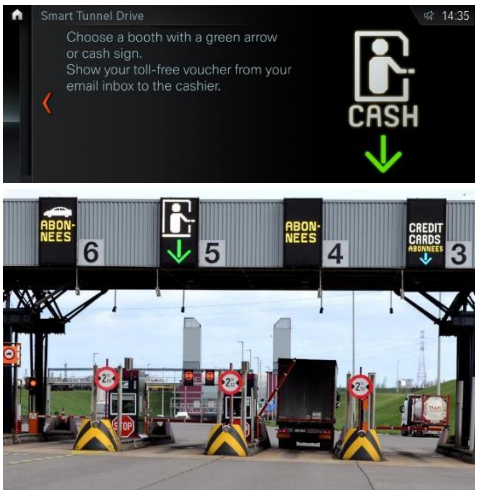

FIGURE 11: IN CAR POP-UP TO REMIND THE USER TO CHOOSE A GREEN ARROW BOOTH

FIGURE 12: EXAMPLE OF THE BMW SERVICE ON THE IN VEHICLE DISPLAY

3. INFORMATION ARCHITECTURE – ONTF TOLL SUSPENSION

3.1. Sequence diagram ONTF toll suspension

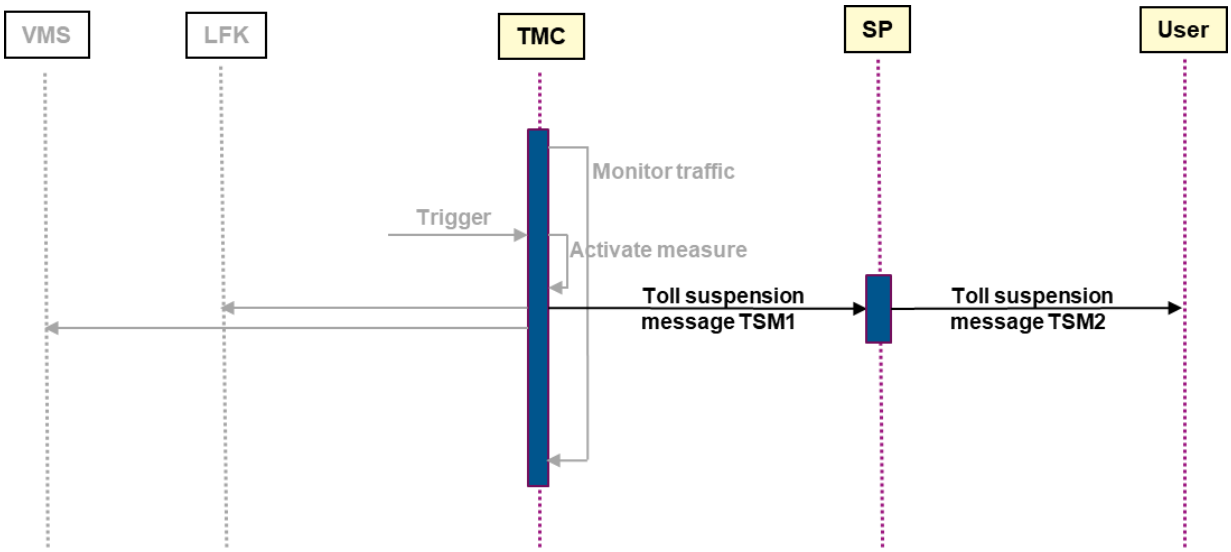

FIGURE 13: SEQUENCE DIAGRAM ONTF TOLL SUSPENSION

3.2. Processes and interactions

Below, the processes and interactions between processes as depicted in the sequence diagram are further described. The processes are generally conducted by one stakeholder as an internal process. A process receives and collects data, enriches the data and produces information as a product. Information is sent via protocols to other processes in the architecture.

Step 1: Information on toll suspension to service providers
The TMC monitors the performance of its road network continuously. It identifies triggers for the activation of the toll suspension measure and it activates this measure when a corresponding trigger occurs. The TMC informs service providers whenever the toll suspension measure is activated. The message includes information about start time and end time of the measure as well as the location of the tollstation, the applicable driving direction and tollbooths and the related situation that caused the activation of the measure.

Step 2: Information on toll suspension to end users

When the service provider is informed about a toll suspension by the TMC, the service provider will inform its travellers accordingly and it will take this information into account when advising its end users.

4. SYSTEM ARCHITECTURE – ONTF TOLL SUSPENSION

4.1. System overview

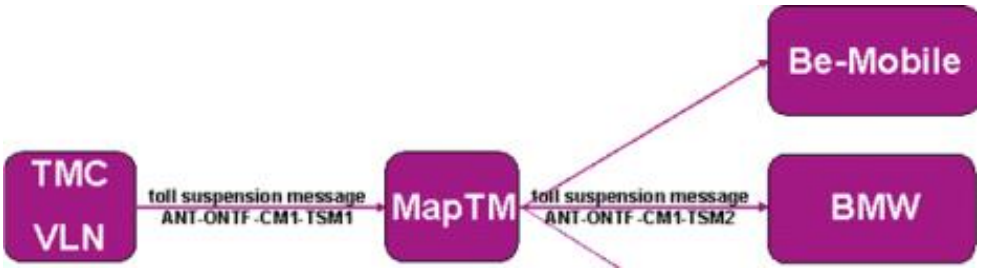

FIGURE 14: SYSTEM OVERVIEW ONTF TOLL SUSPENSION

4.2. Overview interfaces

Interface **ANT-ONTF-CM1-TSM1:**

Push notification

Objects to be included (technical description):

name	Type	definition	comment
Id	number	unique identifier of the message	
version	number	version	
type_of_measure	enum	toll suspension, toll reduction	
starttime	datetime	begin of the toll suspension/reduction	
endtime	datetime	end of the toll suspension/reduction	only applicable for toll suspension
type	enum	activation, prolongation	only applicable for toll suspension (no cancellation message)
location_tollstation	georeferencing - OpenLR	position of the toll station	
driving direction	heading (°)	driving direction for which the message applies (north, south)	1 message per driving direction
applicable_tollbooth	enum	id's of toll booths where toll suspension/reduction is granted	
charge	integer	(new) toll charge	

amount_of_vouchers	number	maximum amount of vouchers that can be issued in the given time period	Only applicable for toll reduction. SP-specific.
relatedSituation	id + version	reference to related situation (accident, public event, …)	
info	Text	short description of the reason for the measure	

TABLE 1: INTERFACE ANT-ONTF-CM 1-TSM1

Interface **ANT-ONTF-CM1-TSM2:**

Push notification

This interface is proprietary and falls under the responsibility of the service providers themselves (should be further developed by service providers).

5. INFORMATION ARCHITECTURE – ONTF TOLL REDUCTION

5.1. Sequence diagram ONTF toll reduction

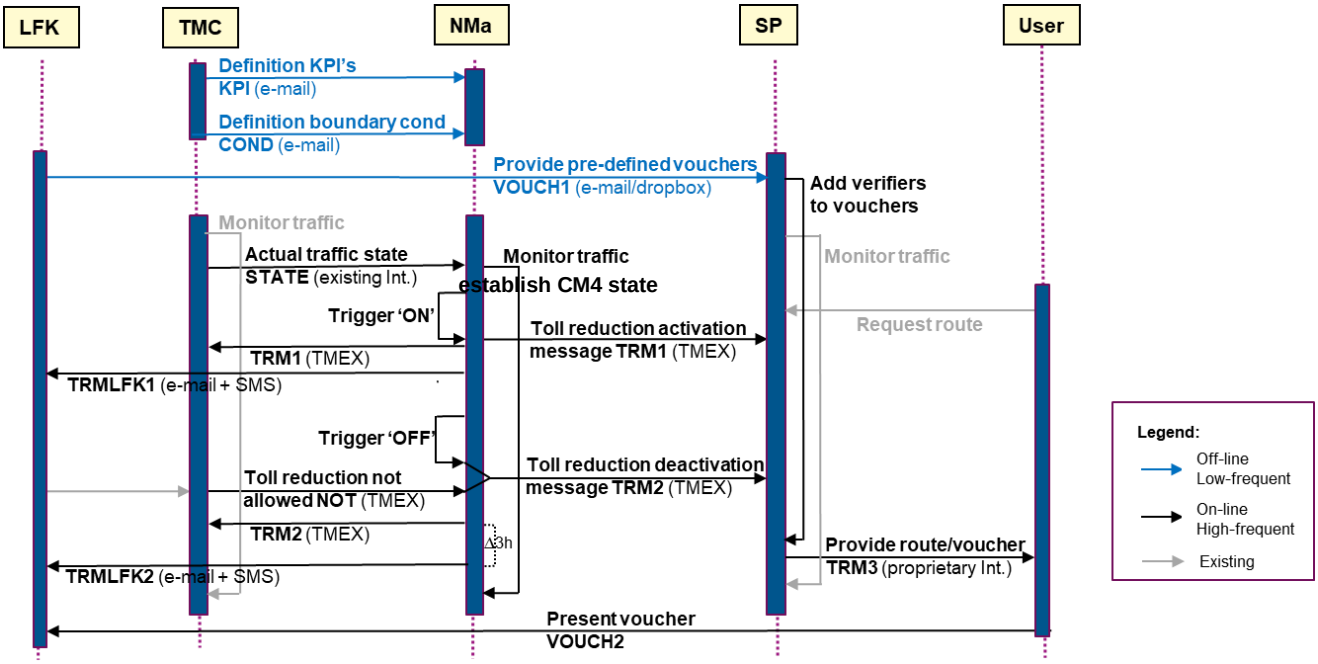

FIGURE 15: SEQUENCE DIAGRAM ONTF TOLL REDUCTION

5.2. Processes and interactions

Below, the processes and interactions between processes as depicted in the sequence diagram are further described. The processes are generally conducted by one stakeholder as an internal process. A process receives and collects data, enriches the data and produces information as a product. Information is sent via protocols to other processes in the architecture.

Step 1: Information on toll reduction to service providers
The Network Monitor monitors the traffic situation in both tunnels continuously. Triggers for the activation of the toll reduction measure are pre-identified and when a corresponding trigger occurs, it activates this measure. The network manager informs service providers whenever the toll reduction measure is activated. The message includes information about start time and end time of the measure as well as the location of the toll station, the applicable driving direction and tollbooths and the amount of vouchers that can be issued.

Step 2: Information on toll reduction to end users

When the service provider is informed about a toll reduction by the Network Manager, the service provider will provide its eligible travellers with an alternative route via Liefkenshoektunnel. If these travellers accept the detour, they will subsequently be send a QR code on their smart phone which they can use as a method of payment at the toll booths.

6. SYSTEM ARCHITECTURE – ONTF TOLL REDUCTION

6.1. System overview

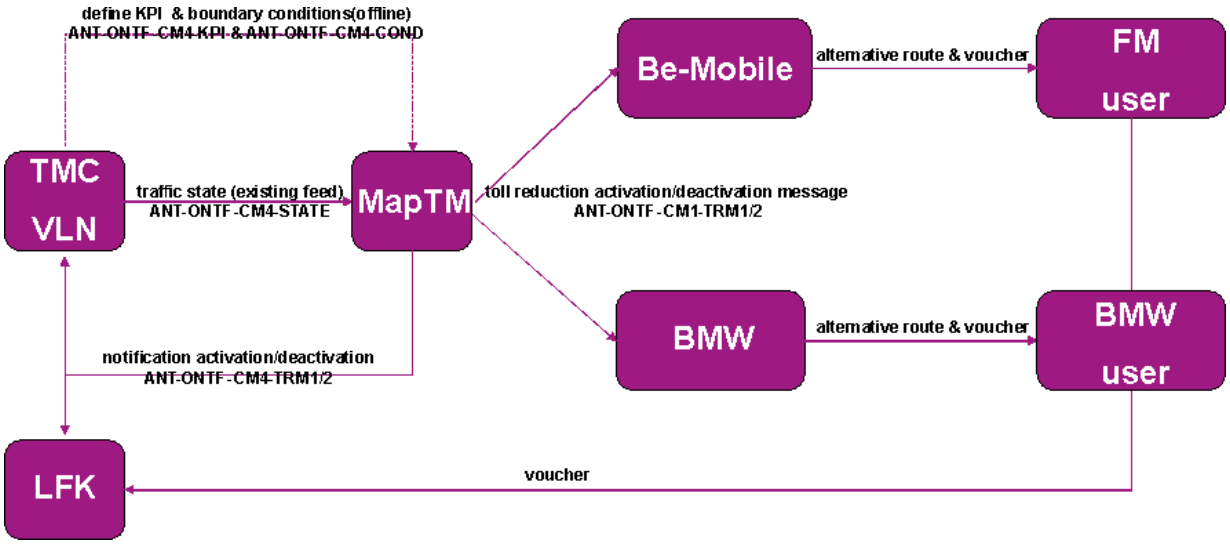

FIGURE 16: SYSTEM ARCHITECTURE ONTF TOLL REDUCTION

The Network manager application collects data provided by Flemish TMC, and calculates and monitors pre-defined KPI's on traffic performance at strategic points (Kennedytunnel and Liefkenshoektunnel) in the network. When a KPI is reached for traffic throughput in the Kennedytunnel a check process is triggered by the Network manager to verify that capacity is sufficient for rerouting through the Liefkenshoektunnel. In case of a positive result to this check, a message is send by the Network manager out towards Service Providers to inform them that rerouting via Liefkenshoektunnel including Voucher issuing is allowed for a specific travel direction, time period and maximum number of vouchers. Apart from this notification, Liefkenshoektunnel is also notified by the Network manager that vouchers are distributed for the specific direction of travel and time period and should be accepted and the tollgates within this set of rules. Service Providers will reroute their users based on their own business rules and issue vouchers to a customer in case the customer accepts the reroute advice. The customer arrives at the tollgate, shows the voucher to the Liefkenshoektunnel attendant at passes the tollgate free of charge and congestion.

Interface ANT-ONTF-CM4-TRM3 will be integrated into Be-Mobile's driver companion app Flitsmeister. At the start of their trip, and when the toll reduction measure is active, users who have chosen a route which (i) goes via the Kennedytunnel, and for which (ii) the additional travel time of the alternative route via the Liefkenshoektunnel is not higher than 20 minutes, receive an offer for a voucher in the Flitsmeister app. If accepted, users then get the voucher (QR code) sent to the email address linked to their Flitsmeister account. (see designs below).

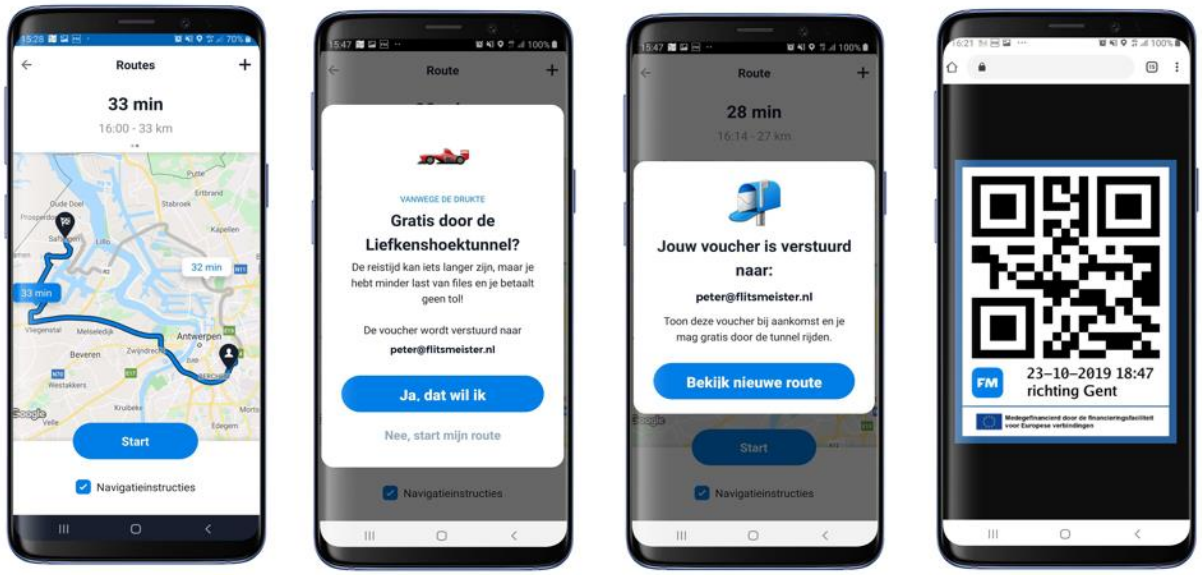

FIGURE 17: REROUTE ADVISE AND VOUCHER IN THE FLITSMEISTER APP

The BMW car of registered users to the BMW Smart Tunnel Drive Service will be set up over the air with the in car App GenIE. Interface ANT-ONTF-CM4-TRM3 will be processed by the BMW Socrates Backend: In case of heavy traffic in the Kennedytunnel and activated service request, the GenIE in car App triggers relevant users based on their actual position in pre-defined geofences when to change their route to the Liefkenshoektunnel to spread traffic best and to reduce congestion. A pop-up in the main display of the car offers the driver a toll-free drive through the Liefkenshoektunnel. He may accept or decline the alternative route suggested in the GenIE in car pop-up (see designs below):
If he accepts, he get sent a QR-Code by email to his registered email address and a notification is shown in the main display of the car, that the QR code has been sent to his registered email address. The in car notification with the QR code included in the pop-up is repeated again when the user is in front of the toll booth. But for scanning the user has to show the QR code on his mobile phone. After passing the tunnel the user gets an in car pop-up whether he liked the service (yes/no).
If he declines the initial GenIE pop-up, he just has to follow his initial route via the Kennedytunnel.

FIGURE 18: REROUTE ADVISE IN THE BMW IN CAR SERVICE AND VOUCHER IN THE APP

6.2. Overview interfaces

Interfaces **ANT-ONTF-CM4-TRM1**, **ANT-ONTF-CM4-TRM2** and **ANT-ONTF-CM4-NOT** are variants on Interface **ANT-ONTF-CM1-TSM1** (see chapter 3.2) and have the same technical interface description. All are push notifications sent over TMEX.

Interface **ANT-ONTF-CM1-TRM1:**

Push notification

Objects to be included (technical description):

name	Type	definition	comment
Id	number	unique identifier of the message	
version	number	version	
type_of_measure	enum	toll suspension, toll reduction	
starttime	datetime	begin of the toll suspension/reduction	
endtime	datetime	end of the toll suspension/reduction	only applicable for toll suspension
type	enum	activation, prolongation	only applicable for toll suspension (no cancellation message)
location_tollstation	georeferencing - OpenLR	position of the toll station	
driving direction	heading (°)	driving direction for which the message applies (north, south)	1 message per driving direction
applicable_tollbooth	enum	id's of toll booths where toll suspension/reduction is granted	
charge	integer	(new) toll charge	
amount_of_vouchers	number	maximum amount of vouchers that can be issued in the given time period	Only applicable for toll reduction. SP-specific.
relatedSituation	id + version	reference to related situation (accident, public event, …)	
info	Text	short description of the reason for the measure	

TABLE 2: INTERFACE ANT-ONTF-CM1-TRM1

Interface **ANT-ONTF-CM1-TRM2:**

Push notification

This interface is proprietary and falls under the responsibility of the service providers themselves (should be further developed by service providers).

6.3. Overview assessor interfaces

The role of Assessor was added during the operational phase and defined as the executor of “off line analysis” of performance of the several services offered by the use case actors with the objective to periodically evaluate the overall performance of the service and support the optimization of the service towards win-win-win.
All partners involved in the service logged their actions and made these actions available to the Assessor. Hereunder a list and functional description of logged data per role received periodically at low-frequency by Assessor:

(1) Network monitor log:
- Current network states at both tunnels:
    - Average traffic speed at selected representative road sections
    - Average traffic flow at selected representative road sections

(2) Network manager log:
- time and duration of (de)activations of service requests per direction and
- time and duration of prolongation of service per direction

FIGURE 19: EXAMPLE OF PRESENTATION OF ASSESSOR DASHBOARD WITH NETWORK MONITOR AND NETWORK MANAGER LOG DATA

(3) LFK log on delivered vouchers per service provider with timestamp, voucherID, driving direction. Log is periodically (low frequency) made available via TMC.

(4) Service providers store a list of data elements related to the service activations and deactivations (SR) as well as trip data elements concerning the delivery and usage of the available vouchers, as well as follow up behavior of users (in aggregated manner). The interface used is based on the “Waterfall report” initially developed for Pilot Amsterdam and adapted to the Antwerp ONTF case. The waterfall report is provided by the service provider to the Assessor every week. The common data elements of the “Waterfall report” are:

Data field	Description
SR	Service request ID
SR_start	Start time of SR
SR_end	End time of SR
SR_direction	Tunnel direction of SR (North or South)
SR_type	Type of SR (Reduction or Free)
noVoucher	User was not offered a voucher due:
noVoucherAvailable	No available vouchers
noVoucherNoRoute	No route found through LFK
noVoucherThreshold	Route found but time difference to large
noVoucherNoUserAction	User did not click start button
voucherOffered	User offered voucher
voucherOfferedAccept	User accepted a voucher
voucherOfferedNonAccept	User did not accept the voucher
tunnel_taken	Tunnel passed by user

TABLE 3: DATA ELEMENTS OF WATERFALL REPORT ANTWERP

7. USE CASE SPEED AND LANE INFO

7.1. Use case description

On a large part of the Antwerp motorway network, there is a lane control system operational, displaying which lanes are open/closed for traffic (green arrows and red crosses) and also imposing speed limits displaying the according road sign. The actual image state of each sign of the lane control system is made in real time available by the Flemish Traffic Centre via an open data feed. Up till now, there was no service provider that used this data feed in their end-user services. The aim of this Use Case is to visualise the actual image state of the lane control system in the navigation app, so that the road user receives the same information on his or her navigation app as they se on the gantries while driving on the Antwerp motorway network. This would be a first step which later on could be extended with speed and lane info on road sections where there are no physical gantries available.

7.2. Active Partners

Partners active in this use case are the Flemish Traffic Centre and Be-Mobile with the Flitsmeister app as end user service

7.3. Description of the end user services

Be-Mobile's Speed & Lane Advice service aims at providing speed advice and lane advice to travellers in the Antwerp region (actually this service is deployed throughout Flanders). The service informs Flitsmeister users in-car about dynamic speed limits and temporary lane openings or closures, in correspondence to the images that are displayed on gantries at the roadside by the road operator.
Temporary lane openings or closures and dynamic speed limits are shown to the end user for each lane of the road he/she is driving on:

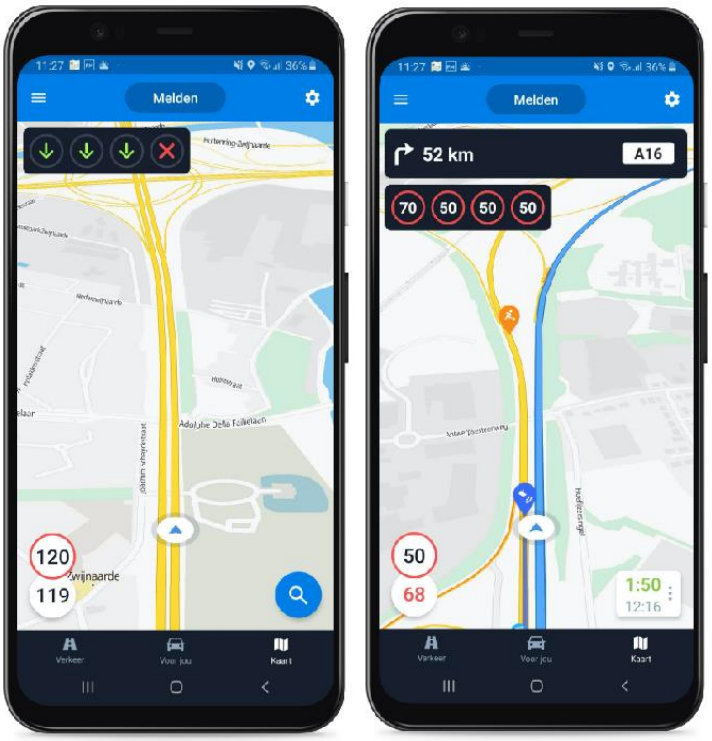

FIGURE 20: DYNAMIC LANE OPENINGS AND SPEED LIMITS PER LANE IN THE FLITSMEISTER SERVICE

8. INFORMATION ARCHITECTURE – SLA

8.1. Sequence diagram SLA

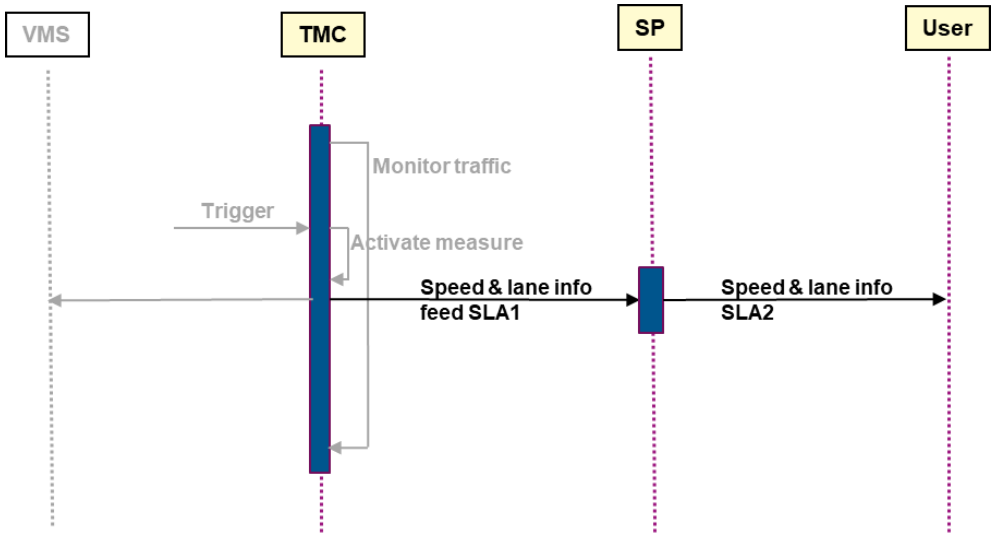

FIGURE 21: SEQUENCE DIAGRAM SLA-ANTWERP

8.2. Processes and interactions

Below, the processes and interactions between processes as depicted in the sequence diagram are further described. The processes are generally conducted by one stakeholder as an internal process. A process receives and collects data, enriches the data and produces information as a product. Information is sent via protocols to other processes in the architecture.

Step 1: Information on speed limits and lane openings to service providers

The TMC monitors the traffic conditions on its road network continuously. It identifies triggers for the activation of the measures 'Dynamic Maximum Speed' and 'Lane closure/opening' and it activates this measure when a corresponding trigger occurs. The TMC informs service providers whenever the measure is activated.

Step 2: Information on speed limits and lane openings to end users

When the service provider receives information on 'Dynamic Maximum Speed' and 'Lane closure/opening' from the TMC, it will inform its travelers accordingly and it will take this information into account when advising its end users.

9. SYSTEM ARCHITECTURE – SLA

9.1. System overview

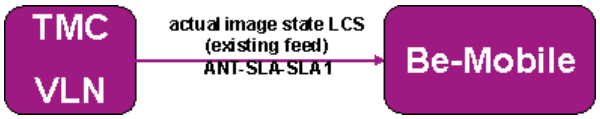

FIGURE 22: SYSTEM OVERVIEW SLA

Interface ANT-SLA-SLA2 will be integrated into Be-Mobile's driver companion app Flitsmeister. The dynamic maximum speeds and dynamic lane closures/openings will be shown as overlay displays in the map feature of the app (see designs below).

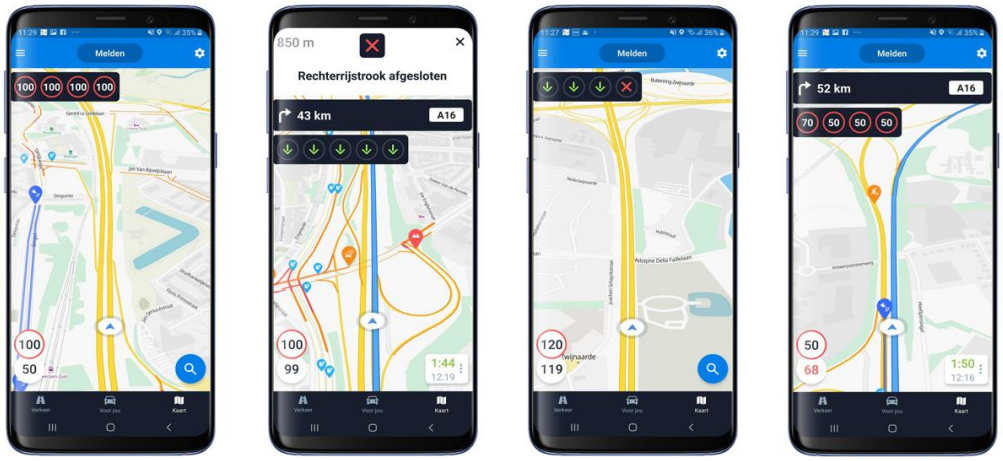

FIGURE 23: DYNAMIC SPEED LIMITS AND LANE CLOSURES IN THE FLITSMEISTER SERVICE

9.2. Overview interfaces

Interface **ANT-SLA-SLA1:**
Pull message
This is an existing interface, nothing new needs to be developed.

Interface **ANT-SLA-SLA2:**
This interface is proprietary and falls under the responsibility of the service providers themselves (should be further developed by service providers).

10. INTRODUCTION RW

10.1. Use case description

The operational DatexII open data feed from the Flemish Traffic Centre contains information about actual road works on the network. This information is derived from road works info from the Flemish road administration AWV. In case of the motorway network, the traffic Centre has several means (induction loops, cameras, notifications by the police, …) to check whether this information is consistent with the actual traffic situation on the road. If there are inconsistencies detected, the road work information in the DatexII-feed is adapted accordingly. On the main non-motorway roads, these means are almost entirely absent, resulting in road work info that is not checked. It is thought that therefor road works info on the non-motorway network is less reliable, but even on the motorways some road works info could be less accurate. In this Use Case, the aim is to combine the road works info in the existing DatexII feed with road works info that Service Providers derive from their own sources in order to get a better view on the actual state of road works and ameliorate the DatexII feed accordingly.

Goals

The use case Road Works focusses on data quality improvement in real-time as described and finalized in activity 3 for Road Works use cases. The use case is deployed in the following pilot sites:

- Antwerp
- Amsterdam
- Munich

The basis for all pilot sites is the same and resembles the use case description as for Antwerp. The pilot sites Munich and Amsterdam build upon this basis to both incorporate a pilot site specific detail/extension.

Goal of the Road Works use case is to create a systematic feedback loop regarding:

- Use service provider data to provide supplemental data on top of available public data on what is actually happening with road works, including both location and time;
- Provide improved roadworks information to the public via service providers;
- Incorporate data from Road user Feedback loop.

Research Questions for the use case are:

1. How much will the quality of road work information improve when we share our data?
2. What kind of exchange model is suitable?
   - CM1: exchanging data, but everyone creates its own CSP or
   - CM3: exchanging data + creating a common CSP where everyone has access to

CM3 is the most suitable from a business model perspective / win-win-win perspective.

Approach

Within Socrates 2.0 the use case 'Road Works' as deployed within the pilot sites Antwerp, Munich and Amsterdam focusses on creating a common ground truth. This common is generated on data from all partners and shared with all partners providing data. Data is retrieved from the various partners and data providers within the project. These partners are TomTom, HERE, Be-Mobile and the government bodies Bäyerisch Verkeersambt (Germany), Vlaamse Overheid (Belgium) and NDW (The Netherlands). The data is retrieved from these parties in their current form. On the providing side, all systems have been left unchanged. For the use case implementation, and the stated research questions, it was explicitly chosen to not alter current data provisions from the partners. Partially to save time but mostly to establish to what the added value could be in the current environment.

First goal was to combine the retrieved data from the partners and provide a new message set with actual roadworks and provide a quality indication to the road work messages based on combining the same messages of a Road Works from the different partners. The content of the combined message set was aligned with the partners within Socrates. The message set was built upon the TMex principals, for data exchange, developed within the project.
If successful a next step would be a fusion of Road works based on multiple notifications of the same roadwork by the partners. This fusion would not only combine on time and location information but would also combine all available detail information and meta data for the provided Road Works into a 'most complete data set'. It must be stated that 100% completeness is only achievable in theory.

10.2. Processing the data

Every data feed of the partners was aligned with dataset (TMex) for the Road Works that was agreed upon and where useful information was added if one of the partners data feed had specific useful information. **Error! Reference source not found.** Table 6 shows the contents of the RW-TMex message. As the table shows the list of fields is rather straight forward without nesting information in (sub)containers. Many data fields are already available in varying degrees within the data feeds provided as sources for this use case.

Response field	Name	Type	definition	Comment
s20_tmexid		VARCHAR	Socrates 20 uuid	
s20_creationtime		Integer	First creation time	Within framework
s20_updatetime		timestamp	Last update time	Within framework
s20_endtime		timestamp	Detected end time	Within framework
s20_version		timestamp	Version of message	Within framework
s20_isactual		boolean	Message is current	

roadname		VARCHAR	Streetname	
locationdescription		VARCHAR	descriptive text for location information	
directiondiscription		VARCHAR	orientation of RW	
impactdelay		Integer	Time lost due to RW	best guess value
-	*location OpenLR*	*openLR*		
location_wgs84	location WGS84	Linestring		
location_fordisplay	location for display (WGS84)	POINT		
alertccountrycode	from alertC when available	VARCHAR		
alertctableid	from alertC when available	Integer		
alertcttrafficcode0	from alertC when available	Integer		
alertcdescription0	from alertC when available	VARCHAR		
alertcduration0	from alertC when available	VARCHAR		
alertcdirection0	from alertC when available	VARCHAR		
alertcttrafficcode1	from alertC when available	Integer		
alertcdescription1	from alertC when available	VARCHAR		
alertcduration1	from alertC when available	VARCHAR		
alertcdirection1	from alertC when available	VARCHAR		
planned_startdatetime_rw	Planned Start datetime RW	timestamp	Start time of Road works	
actual_startdatetime_rw	Actual start datetime RW	timestamp	Reported Start time	
detected_datetime_rw	Detected datetime RW	timestamp	This is NOT a start time	
situationalrecordversion	Situational record version	Integer		
generalnetworkmanagementtype	Network Management type	VARCHAR		
situationalrecordfirstsupplitime	Situational record first supplier version time	VARCHAR		
number_ofoccurences	Number of data suppliers reporting the same RW	Integer	Number of sources reporting some RW	
probability_ofoccurences	Probability of occurrence	VARCHAR	rate for RW are to be seen on the road	
probability_rate	Probability rate	REAL	rate for trueness of RW info	
type_ofroadworks	Type of Roadworks	VARCHAR	moving, stationary, long-term	
numberoflanesrestricted	lanes closed/available	Integer	status of lane availability	When available
numberofoperationallanes	Number lanes opened for traffic during RW	Integer	Number of lanes available	When available
originalnumberoflanes	Number of lanes opened for traffic during normal operation	Integer	Number of lanes available in normal situation	
not available currently, planned for future incorporation	Narrow Lanes	TEXT or INT	lanes wit reduced width	
roadclosed		boolean	Road closed due to road works	
temporaryspeedlimit	Reduced speed	Integer		
onelanetrafficcontrol	one lane traffic control	boolean	Temporary Traffic Light Signals in use or Traffic Warden	

counterflowtraffic	Counterflow traffic	boolean	Traffic is divert to the other side of the road
detourinformation	Detour information	VARCHAR	
passableforemercencyservices	Passable for emercency services	boolean	
changedtrafficsituation	Changed Traffic Situation	VARCHAR	Road Layout has changed
author	Author	VARCHAR	Alert created by

TABLE 4: TMEX MESSAGE SET

Data Harmonisation

During the matching stage of de data feeds of the partners towards the TMex message set, it was striking how much the shape and the contents differed per feed, provider and even between sites(e.g DATEXII). So, for every feed for every site the code to retrieve and convert to the Socrates dataset (TMex) was rewritten and adapted. Feeds differ in complexity, from a compact and straightforward dataset with actual road works to complex DATEXII data sets including not only actual roadworks but also planned or even past events. Moreover, the naming and coding (e.g. containers or not) of the fields differs per feed. This is also regarding TMC and DATEXII standardized fields as well.

Differences in georeferencing:

- TMC is not harmonic over all sites. The implementation of the TMC principle divers per site/country and thus has had its particularities per site.
- Documentation for TMC is only available for paying members of TISA. Beyond that a current TMC table must be retrieved from the relevant governing bodies and isn't available as open data everywhere. Though, payment is never required for obtaining the TMC tables.
- Service Providers use different geospatial projections. But in most cases provided alternative projections within the feed.
- The Flemish Traffic Centre data feed is provided with only TMC as geospatial reference.
- Relying solely on TMC geospatial referencing limits the area where RW can be reported as TMC is not covering all roads (e.g. local and residential roads). This difference is especially visible between Public and Private sources.

Differences in data provision:

- DATEXII has proven not harmonic over all sites
- Detail information is not consistent added
- Update intervals are not always clear and never in sync.
- DATEXII feed from NDW was too large for a stable feed. To get a good performance Extra RAM memory was allocated on the NDW side and we used a cut out from the region of Amsterdam.

10.3. Common roadworks picture

Timing information

The timing information differs between the data feeds. Some providers broadcast roadworks which are actual. But NDW for instance broadcasts, running and planned. One source gives status actual and end time.
MDM broadcasts multiple datetime fields. To see if a roadwork is actual the fields startofperiod and endofperiod were used.

Geospatial information

All the feeds define a start point/location for display. Some combine this with a line string (for instance MDM) and/or an endpoint. Flemish Traffic Centre gives start- and endpoint, no line string but offset distances to be calculated based on a map matching procedure and requires knowledge of the used Flemish Traffic Centre implementation and possession of the relevant Flemish Traffic Centre tables. Same goes for NDW and one of the private providers.
When looking at the Flemish Traffic Centre point information, some points where not available in the basic information of the Flemish Traffic Centre points table. This is probably due to having possession of TMC3.1 while the broadcasted information is version 3.3.
Having said that, a known issue when plotting data to any map is the differences between maps, differences between how geo information is written down (X/Y, TMC, Alert-C, VILD) and differences in how geo information is projected on a map altogether. Differences in projection occur due to the fact that the earth is a sphere and it is near impossible to correctly plot any point on that sphere on a flat representation of the sphere. The most common projection is the Mercator projection, invented by Flemish cartographer and geographer, Gerardus Mercator. As an example Flemish Traffic Centre point data has been provided in a different project within this project. Just indicating how divers this data spectrum can be. Figure 25 illustrates this.

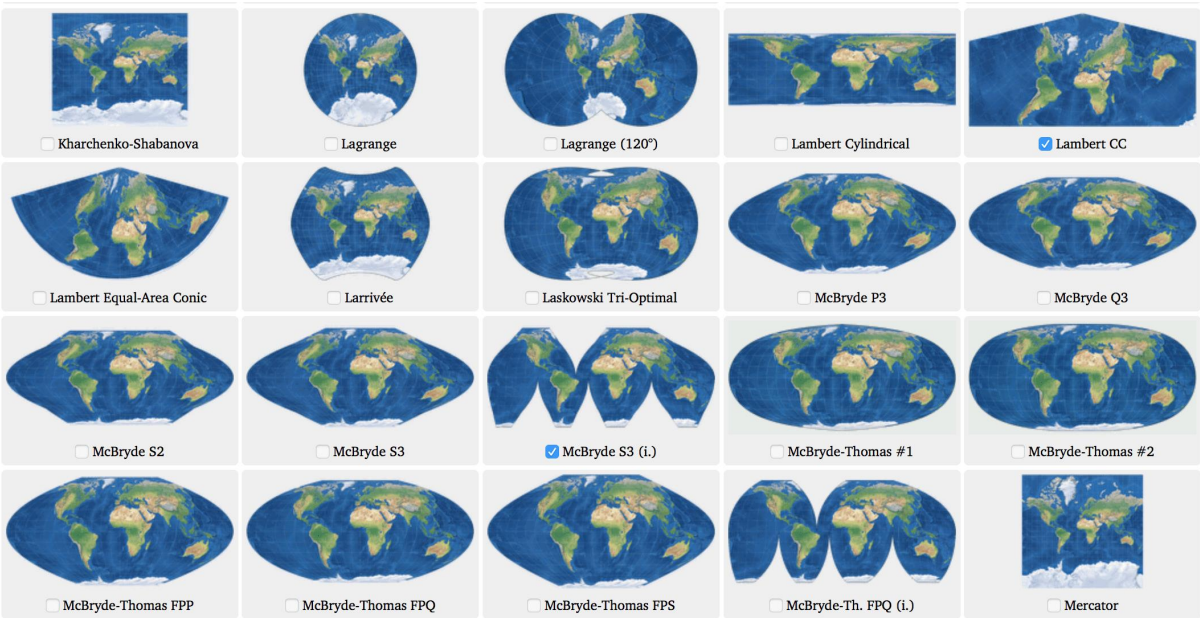

FIGURE 24: AN INCOMPLETE LIST OF TYPES OF MAP PROJECTIONS

For this purpose, all provided geo data had to be translated to a common projection in order to be able to find matches l.

For a first analyses the start point/location for display was used for geographical referencing.

11. OPERATIONAL PILOT

The pilots site has started being operational on 24 October 2019 whit the launch of the Be-Mobile Flitsmeister services (UC ONTF toll suspension, UC ONTF toll reduction and UC SLA). The BMW services (UC ONTF toll suspension and UC ONTF toll reduction) were operational starting on 18 February 2020. The first stage of the UC Roadworks was operational from 27 January 2020. All services were ended 31 December 2020 within the Socrates$^{2.0}$ project, though Be-Mobile continues the services SLA and ONTF toll suspension beyond this project.

11.1. User Recruitment

A registration page https://register.socrates2.org/ on the general project homepage has been set to recruit test users. A short overview of the different services in the four pilot sites has been given here as well. The different involved service providers had been listed and by clicking a redirection towards the specific registration pages of the service providers was linked.

FIGURE 25. LINKED RECRUITMENT WEBPAGES BY CLICKING ON THE SERVICE PROVIDERS' LOGOS ON THE GENERAL SOCRATES2.0 HOMEPAGE

A video, explaining the use case in general and the services by the involved providers BMW and Be-Mobile, had been produced jointly by the Socrates2.0 partners and included in the webpages.
To kick off the pilot phase, a joint press conference of the Flemish Traffic Centre, BMW, Be-Mobile and MAPtm was held on 22nd of October 2019. Representatives of the parties

gave the invited journalists an overview of the ONTF Service, but also a live demonstration of both services. In addition the Service was advertised on the social media channels.

FIGURE 26. PRESS CONFERENCE AND IN CAR DEMONSTRATION TO KICK-OFF THE PILOT

11.1.1. User Recruitment Be-Mobile

Be-Mobile recruited most of its Socrates users by location-based advertisement. Flitsmeister users that were observed in the study area (crossing the river Scheldt) got a message inviting them to be part of a field trial to test the new Socrates services. The message was sent post-trip to avoid issues with traffic safety.

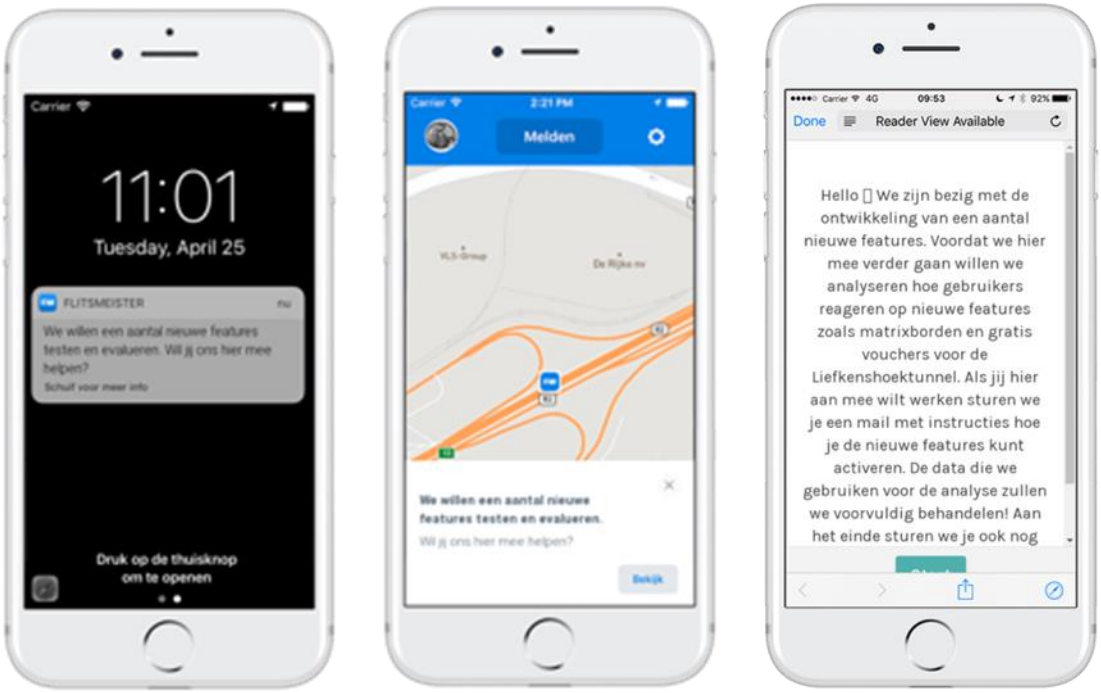

FIGURE 27: LOCATION BASED ADVERTISEMENT (POST-TRIP) FOR RECRUITMENT OF SOCRATES USERS

When users accepted to be part of the field trial, they got a link to the Flitsmeister landing page. On this landing page, Flitsmeister users could register to be a Socrates user or a Socrates evaluation user. When they did so, they were e-mailed with instructions on how to enable the use-case service in the Flitsmeister app. Evaluation users needed to enable a second switch to opt-in to be logged.
On 31/12/2020, Be-mobile counted **7878** unique Socrates users and **275** unique evaluation users for its Optimizing Network Traffic Flow services. The same users also used the Speed and Lane Information service.

11.1.2. User Recruitment BMW Group

To recruit pilot users, BMW set up a web page on BMW LABS (https://labs.bmw.com/). BMW LABS is a program where you can be among the first users to test BMW's latest mobility services. As a test user you get an access to the BMW services that are not yet on the market available. Based on the users' feedback the services are developed.
The BMW services for the different Socrates2.0 pilot sites had been listed on BMW LABS since May 2019 as "BMW Managed City Drive Service" in general and the Antwerp ONTF use case in detail as "BMW Smart Tunnel Drive Service" (https://labs.bmw.com/services-overview/13). The BMW LABS pages gave a short description of the service itself, the vehicle requirements, the terms and conditions, and the Socrates2.0 context. Interested users could leave their email address on the page to stay informed about the services in general and to get noticed when the specific pilot phases will start.

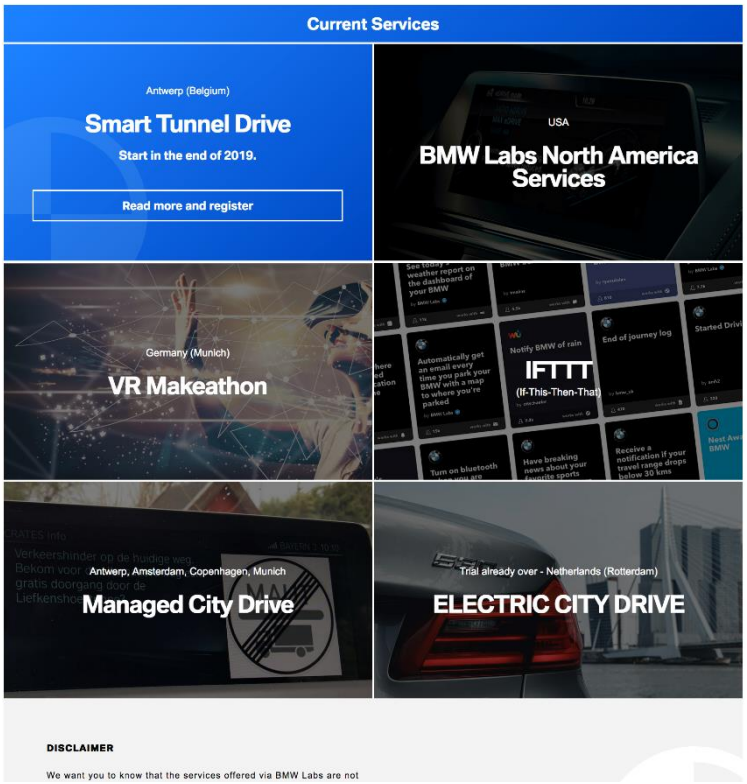

FIGURE 28: SERVICES AT THE BMW LABS WEB PAGE

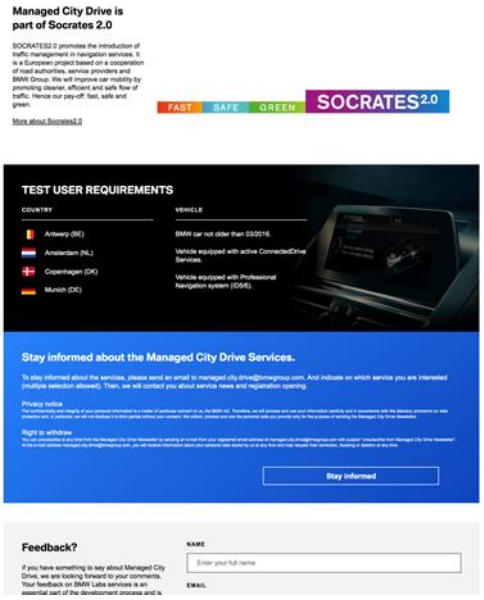

FIGURE 29. SERVICES AT THE BMW LABS WEB PAGE

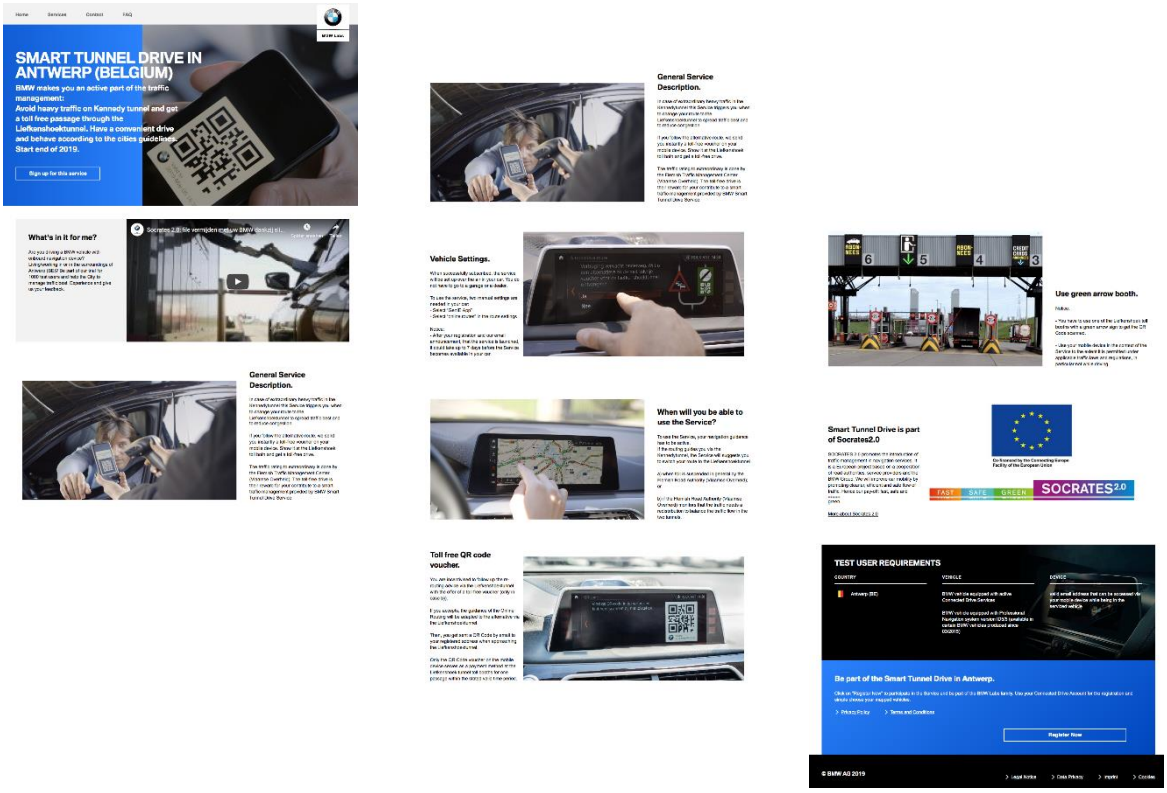

FIGURE 30. BMW'S RECRUITMENT WEB PAGE ON BMW LABS FOR THE BMW SMART TUNNEL DRIVE SERVICE

From the day of the press conference (see chapter 11.1.1) on, the subscription to the BMW Smart Tunnel Drive Service via the BMW LABS page had been open. Interested users had to sign-up with their specific BMW car and BMWConnectedDrive Account. In background a validity check was done, whether the matched vehicle fulfilled the requirements. If not, the registration process was interrupted and a notification for insufficient requirements was sent to the user. Thus, only valid BMW drivers with the specific vehicle conditions could sign up successfully.

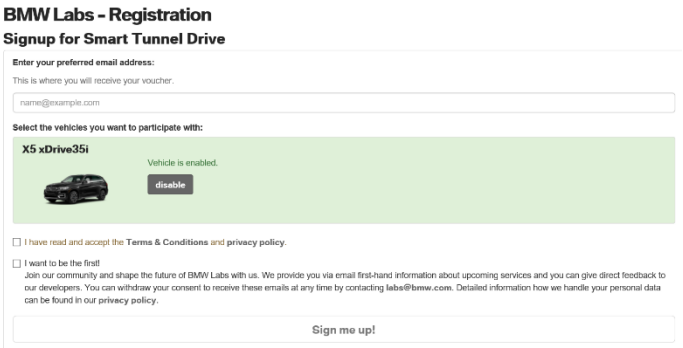

FIGURE 31. SIGNUP FOR BMW SMART TUNNEL DRIVE

Before the BMW Smart Tunnel Drive Service went active for the registered pilot users in February 2020 (phase I) and for the additional registered users in July 2020 (phase II), an email was sent to the registered persons. It was noted that the car will be set up over the air within the next days and that the service could then directly be used in car. A more detailed How-to-guide was attached in addition.

12. CONSCLUSIONS

To summarize the usage behavior analysis in a few statements:

(1) Most users, for whom driving through Liefkenshoektunnel was not a detour, accepted the service and took the route via the tunnel.
(2) Even though it did not make sense for them, many users accepted the service
(3) All users who gave feedback via the in-car questionnaire, returned a “like”.
(4) With an extension of the service activation times, more users can be reached by the service
(5) If the user’s destination is considered when asking him/her for a reroute possibility, the number of “rejects” can be reduced significantly, which probably improves the service satisfaction and less ignored messages.
(6) The trust in the quality of a route advice by BMW is very high and stated as main reason to follow the alternative.
(7) Dominating aspects to choose the route via the Liefkenshoektunnel are congestion avoidance and travel time savings. On a distinct lower level but equally stated, the toll-voucher as well as the traffic balancing aspect had been answered by the users.
(8) The service usage was clear to understand and worked fine.