MAVEN

Managing Automated Vehicles Enhances Network

WP8 Generic concept, use cases, requirements and specifications
Deliverable nº: D8.7

Communication materials (final version)

Dissemination Level: PU

Version	Date	Release	Approval
1.5	29/08/2019	Robbin Blokpoel (DYN)	Florinda Boschetti (POL) Meng Lu (Dynniq)

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Document Log

Version	Date	Comments	Name and Organisation
1.0	28-02-2018	Initial version with project flyer	Robbin Blokpoel (DYN)
1.1	27-09-2018	Collection of communication materials	Robbin Blokpoel (DYN)
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Executive Summary

MAVEN project has developed its own brand identity and a set of communication materials for online and paper-based communication (project leaflet, newsletters, posters, project fact sheet).

This deliverable offers an overview of key communication materials which were produced over the full 36 months of the project's lifetime.

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Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690727. The content of this document reflects only the authors' view and the European Commission is not responsible for any use that may be made of the information it contains.

List of Figures

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690727. The content of this document reflects only the authors' view and the European Commission is not responsible for any use that may be made of the information it contains.

1 Introduction

This deliverable provides an overview of MAVEN dissemination materials produced over the full 36 months of the project's lifetime.

The communication and dissemination tasks primarily address the main target audience of MAVEN project. These encompass:

- City authorities;
- Policy makers;
- Transport service providers;
- Sector representing organisations;
- Academics;
- External Advisory Board members;
- Organizations which have submitted Letters of support.

A wide variety of communication and dissemination actions was therefore planned within work package 8. Communication materials are supporting the consortium's dissemination efforts.

This deliverable is of the category "Websites, patents filling, etc." and not a "report". Therefore, a document was not originally intended, but the consortium wanted to provide some additional context. The document aims to describe the MAVEN corporate identity, project website and online social media, and communication materials comprising: flyer, posters, newsletters, project factsheet and presentations.

2 MAVEN corporate identity

At the outset of the project a suitable Visual Identity and Branding guidance including an overall corporate identity (Word template for reports, PowerPoint template) were designed and agreed with the partners. The logo is shown below in the figure.

Figure 1: MAVEN project logo

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3 Project website

The project website is a key element of the communication and dissemination channels. This includes all relevant information about MAVEN and its progress. The website is in English and is available at http://maven-its.eu/.

The website structure includes the following menu and sub-menus:

- Home page
- About MAVEN
- Partners
- News
  - Recent news
  - Newsletter
- Events
- Documents
  - Meetings
  - Deliverables
  - Publications
  - Related links
- Contact

With over 30 news articles published during the project lifetime, the website was kept up-to-date regularly.

The landing page of the MAVEN website is shown in the figure below:

Figure 2: Project website: Homepage

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4 Social media

Nowadays social media platforms are a common tool used also in European projects to further disseminate projects results and findings among a larger audience who is virtually connected without been directly involved in the project activities.

MAVEN has developed a Twitter account and a new LinkedIn professional discussion group. To increase the number of followers, MAVEN social media icons are placed on all project material (leaflets, newsletter, presentations, posters) and on the website homepage.

The Twitter account @MAVEN_its uses short messages in English to disseminate, into the public domain various milestones and results of the project: upcoming events and workshops, published papers and articles, etc.

The LinkedIn account www.linkedin.com/groups/8571587 is targeting the professional community of practitioners and researchers working in the field of automation.

5 Communications materials

5.1 Project flyers

The project flyer is printed in A5 format recto verso. In total 3 flyers were designed and printed. They are distributed at meetings, workshops and seminars with local stakeholders, practitioners, experts and at other events at the European level which are attended by partners for dissemination purposes. Each flyer was printed 500 times, with the first flyer printed twice in batches of 250.

Flyer 1, printed March 2017, reprint May 2017:
This flyer aimed to introduce the project and its test sites to a broad audience. A short text gives an overview of MAVEN at a glance and illustrates the threefold benefits for infrastructure service providers, cities and the automotive industry. The MAVEN test sites and simulations are described for Helmond (BE), Braunschweig (DE) and Prague (CZ).

Flyer 2, printed October 2018:
A bit over half-way the project a series of events were on the agenda where the project would have a presence on an exhibition stand. Therefore, the selected use cases and a summary of the results so far were presented on this second flyer.

Flyer 3, printed May 2019:
To support all activities of the project at the final event and for partners to have a last set of flyers to present to visitors of their office beyond the end of the project, a final flyer was designed. The front presented the final event demo scenario, while the rear presented the key high level results of the project.

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5.2 Newsletters

During the course of the project, newsletters produced in PDF format are disseminated thorough the project website and mass mailing shot. The newsletter in English is aimed at disseminating on the European level about the project's progress.

Two newsletters were produced within the initial 18 months:

- Newsletter No. 1 (September 2016)
- Newsletter No. 2 (July 2017)
- Newsletter No. 3 (April 2018)
- Newsletter No. 4 (October 2018)

Newsletters are disseminated in PDF format through partners' communications channels, through the project website and can be found in the sub-menu News > Newsletters.

The main purpose of the newsletters is to inform about the latest results and upcoming activities. Some results were not otherwise accessible at that time because they would be part of a deliverable that is due in a later phase of the project. Therefore, in the final months of the project, another newsletter wasn't necessary anymore as all results would be directly published in the released deliverables.

5.3 Project fact sheet

A MAVEN project fact sheet is produced following recommendations from the European Commission and is intended for dissemination at European Level.

5.4 Project posters

MAVEN has produced two posters for disseminating at the following events:

- Collaborative Innovation Days in 2017
- Automated Vehicle Symposium 2017 11-13 July 2017 San Francisco, U.S.A.
- The last poster was also used at the CARTRE event attached to the TRA conference in Vienna in April 2018.

5.5 Videos

During the course of the project, MAVEN has produced several videos. Experience learned that this was not only a good method for "demonstrator" deliverables, but also very effective to show concepts to a wider audience. All videos are also published with a news article on the website. The following videos were made:

- Project promotional video explaining the negotiation use case with animations.
- Negotiation demonstration video in simulation environment.
- VLOG of the negotiation integration tests in Helmond.
- Green wave video showing simulations of the baseline and green wave integrated with GLOSA and lane advice.
- Braunschweig integration video with Hyundai and DLR vehicles platooning while following AGLOSA advice.
- Demo video of the ITS Europe demonstration scenario in a cooperative vehicle and with a live presentation at the infrastructure control room.

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5.6 Final event materials

For the final event a flag was ordered to attract visitors to the demo area booth by increasing visibility. This flag and a magnetic sticker are shown in the figure below:

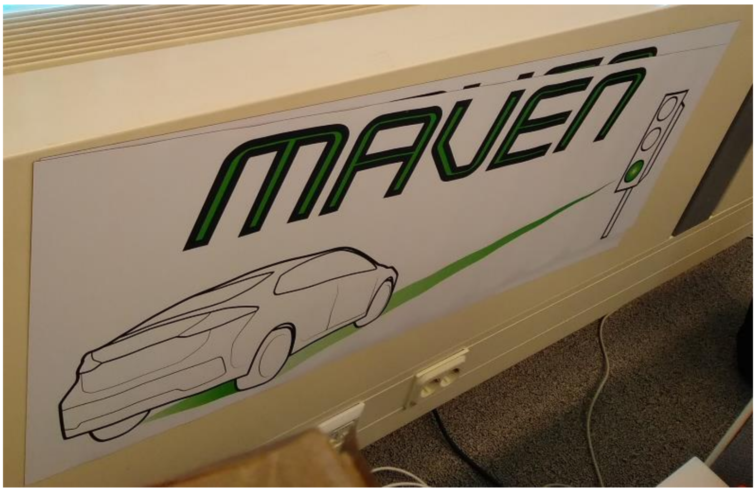

Figure 3: MAVEN flag and magnetic sticker

Both photos were taken at the Dynniq office. The magnetic stickers were glued on the demo van doing to open road demonstrations at the ITS Europe congress. At the main exhibition of the ITS congress in Eindhoven, MAVEN hired a corner of a stand next to the Dynniq stand. This was decorated with the green colour of the project, although the wall should have been white to let the logo stand out more.

Figure 4: MAVEN stand at ITS Europe congress

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The demo area was also facilitated by a large screen that could be used for presentation during the closed road days, which can be seen in the picture below:

Figure 5: MAVEN final event presentation environment

Lastly, 20 hard copies of the transition roadmap were printed for interested visitors to the workshop presentations. These were produced as a small booklet with transparent cover and rear page to increase durability.

6 Presentations

The project has prepared two Power Point presentations for partners to use at dissemination events.

- Project Introduction. This is a general presentation of MAVEN and its objectives.
- Automated driving in an urban environment. This presentation illustrates the technical requirements and conditions to run the MAVEN technology for automated vehicles. It illustrates in greater details the setting in the pilot sites and introduces the test planning schedule.

It should be noted that many more presentations were made for various events. They generally use content of the two provided presentations, with a few slides extra to tailor to the specific audience of the event.

The presentations of the workshops can be directly downloaded from the website, as well as the presentations of the final event (under documents – meetings). Only the initially created presentation templates can be found as appendix to this deliverable. The 26 workshop presentations and 8 other presentations from congresses and other events can be downloaded directly from the website.

7 List of materials in the appendix

The next pages are an appendix with the following materials presented back-to-back:

- A case study on unmanned logistics.
- Flyer 1, 2 and 3.
- Newsletter 1, 2, 3 and 4.
- Poster 1 (Collaborative Innovation days), Poster 2 (Automated Vehicle Symposium).
- Presentation template.

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Case study of unmanned logistics in Helmond

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Introduction

Road transport Logistic is a becoming more and more complicated because of the multiple dimensions involved. To name a few: its range of physical activities spreads and connects across the whole network, forming logistic chains and logistic networks to transport and deliver people, goods and materials from specific origins to destinations; its sheer increasing demand and requirements from customers and in return, the increased demand for complex information and communication control systems of today's global business environment; its unpredictable interactions with existing traffic flows on road, worsening traffic congestions with significant effects on the number of road accidents.

These complications of dimensions require synergistic optimization of infrastructure and application of innovative technologies, such as unmanned vehicles. Thanks to advanced sensors, vision and geo guidance technology, unmanned vehicles have already taken on a significant part of the logistics work process, mostly within restricted areas, such as closed roads in modern warehouses in airports, harbours, and yards. The current developments of unmanned logistics are reviewed in Section 9.4 of MAVEN D4.4, which presented the thriving field tests of unmanned logistic prototypes on open roads. Although it is far from full spectrum of unmanned logistics on the open road, the future of logistics is undoubtedly heading towards the direction of full autonomous with drastic developments.

The MAVEN project foresees that the first deployment of a significant fleet of automated vehicles will be related to public transport and logistics applications.

The current urban mobility system has one clear problem: there is a vast range of transport vehicles that are set out to bring goods and people between specific locations, which are rarely the same as their origin or destination. This misalignment between actual service locations and precise origin-destination is commonly recognized as the "first mile, last mile" problem of the transport network. Autonomous vehicles can solve these problems in the following ways:

1. Smaller pods can offer efficient last-mile transport because they only need to serve a few destinations, keeping detours at a minimum;
2. More on-demand, comfortable and seamless connections when a trip involves transfers among various forms of transport means;

When looking at traditional public transport, prioritization through dedicated lanes and high priority signal groups at intersections, reduce traffic capacity and intersection throughput if not optimally designed. This is potentially a problem with adding a larger number of smaller transport vehicles. On the other hand, the total demand of vehicles on the network will reduce due to a modal shift. The effects of these factors in the urban traffic network is mostly unknown and needs to be investigated. Therefore, the MAVEN project initiates an unmanned logistic use case targeting the following objectives to tackle these problems:

1. To study the performance of Helmond N270 corridor in two decades, when unmanned shuttles and pods are integrated in the evening peak traffic flow.
2. To investigate the impact of existing road infrastructure and intersection signalization strategies when unmanned logistics is incorporated.
3. To analyse platooning effect of unmanned shuttles and pods, and to balance the priority management strategy of unmanned logistics and other traffic flows.

MAVEN approach

In the MAVEN project, an overview on current developments of unmanned logistics is presented in Section 9.4 of D4.4. The study of current developments shows that the logistic process is becoming more and more complicated due to increasing demand and highly specific requirements of customers: In urban transport and distribution networks, goods, materials and people are handled using a vast range of equipment and transport vehicles from origins to destinations. The study also shows that autonomous vehicles in logistics have been playing a significant supporting role in the automated logistics process.

These findings not only give us specific trends that are applicable for the urban environment, but also inspire a new use case: unmanned logistics in urban area. This futuristic design encompasses autonomous shuttles and pods that coexist and replace buses. With the pods traveling below 25km/hr, using the bicycle lanes on the main roads and parking on pedestrian lanes/sidewalks. This use case focuses on autonomous transport, which uses the same infrastructure as cars, bicycles, pedestrians and Public Transport in urban areas. More general design details are listed below:

- Shuttles and pods are simulated as level 4/5 autonomous driving, unmanned vehicles, practically a new modality utilizing existing road design and infrastructure, such as road surface, signalized intersections etc.
- Shuttles are running as “intercity bus (mid/long-distance)” using the vehicle lanes while not requiring guided/dedicated bus lanes; pods are running on the vehicle lanes and on the bicycle lanes as “stop bus (short-distance)” - an alternative to bicycles, scooters etc., to battle the “first mile”/ “last mile” conundrum and bring persons and goods from door to door.
- Pods can commute persons or distribute goods through the network. A pod can pass from bicycle lane to pedestrian lane/sidewalks and deliver goods from door to door.
- Modal shifts from passenger car and bicycle to shuttle and pod can be expected. Willingness of acceptance (compliance rate) for the modal shift are presumed to be 68.9% of the available shuttle and pod capacity. The regular line buses are fully replaced by shuttles and pods with 100% modal shift.
- In the MAVEN simulation, the capacity of a shuttle is 20 persons and the capacity of a pod is 5 persons. The goods capacity highly depends on the form factor and weight of the transported objects.
- Shuttles and pods travel in a mixed traffic environment with other existing traffic flows, such as non-autonomous passenger cars, bicycles and pedestrians.

- Shuttles runs on schedule and uses dedicated stops (long-distance between stops, e.g. 5-10km apart approximately). Pods runs on-demand and can theoretically stop anywhere, such as shuttle stops, container stops (to deliver goods), charging stations (to self-charge and maintenance) and even ad-hoc locations if deemed necessary.
  In the simulation, the transfers between shuttles and pods occur at Helmond train station square. Thus, the pods are in practice often synchronized to the shuttles, demonstrating seamless transfers between shuttles and pods.

Correlation to MAVEN use cases

The use case of this case study combines platoon management, queue estimation, signal optimization, signal priority and negotiation. These are implemented as follows:

[1] Platoon management:
Multiple shuttles with 5 seconds departure interval are forming platoons at the first intersection they encounter.
Pods of the same route are released in a platoon ranging from 2 to 4 except when a breakup is initiated due to safety for other surrounding traffic.

[2] Priority management:
In the baseline scenario, autonomous shuttles and pods have been given "zero priority". They travel on the network as other traffic flows, such as passenger cars, bicycles, pedestrians.
In the priority scenario, they have been given a higher priority as the previous scheduled public transport such as regular line buses. This is to stimulate the modal shift with competitive travel time.

[3] Queue modelling:
The detailed information of the shuttles and pods was taken into account in the queue model of the intersection. Especially for the pods this is important, as their speed is significantly lower and the control algorithm would plan phases in advance of their arrival.

[4] Signal optimisation:
The scenario utilizes the existing intersections and as many as possible of the existing signal groups to minimize new conflicts that could increase intersection cycle time or reduce controller efficiency. This was a special point of attention when designing the transitions of the pods from a minor road to the cycle path of a major road.

[5] Negotiation
This is the cooperation between the priority, queue modelling and signal optimization use cases. Thanks to the extra information the vehicles provide, a specific control plan can be provided to them with minimal hindrance for other traffic.

Simulation setup

The simulation adopts the N270 corridor network with multiple intersections in Helmond city centre. Namely, intersections HEL701, HEL702, HEL704, HEL101, HEL102, HEL103 and HEL104 are distributed on this stretch of corridor. These intersections have similar intersection layout and road branches. The main east-west and west-east directions are dominant in terms of traffic demand due to the connection to the A270 to the west and the A73 and A67 motorways to the east. All intersections have pedestrian and bicycle traffic as well.

Besides similar intersection layout, this network cut-out covers the busiest trips (origin-destination pairs) and most POIs, such as central train station (connections to other cities), departure-terminal centre (e.g. public transport distribution plaza) on the south arm of HEL103. Ergo, current public transport routes are also heavily concentrated on this network.

Based on the aforementioned characteristics, this network is the most compatible for introducing new modalities, or eventually replacing current public transport system with upcoming public transport mode featuring unmanned shuttles and pods.

Figure 1 presents the layout of the simulation network. The 700-series and 100-series intersections indicated in this figure are controlled with adaptive controller ImFlow. However, only the four 100-series intersections: HEL101, HEL102, HEL103 and HEL104 are configured for the use case simulation experiment, replicating the current traffic controllers in real-time.

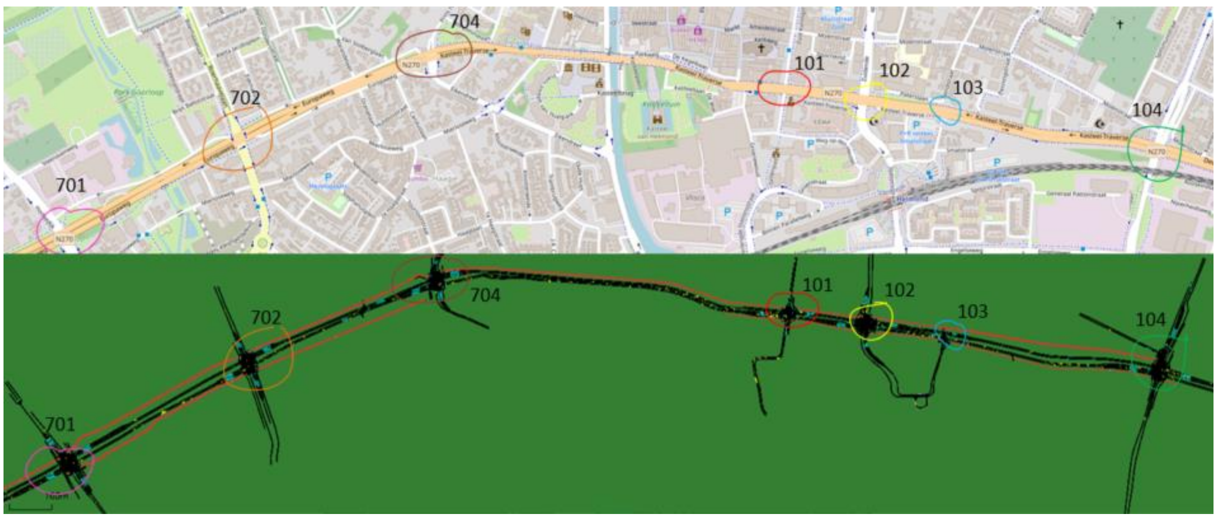


Figure 1: network of Helmond (top) and the simulation network in SUMO (bottom)

- Intersection 701, Hortsedijk/ Europaweg
- Intersection 702, Boerhaavelaan/ Europaweg
- Intersection 704, Prins Hendriklaan/ Kasteel-Traverse
- Intersection 101, Zuid Koninginnewal/ Kasteel-Traverse
- Intersection 102, Zuidende/ Kasteel-Traverse
- Intersection 103, Penningstraat/Smalstraat/ Kasteel-Traverse
- Intersection 104, Burgemeester van Houtlaan/ Kasteel-Traverse

The current public transport routes and flows are replaced with shuttles and pods, which have a total capacity to carry 320 persons and 64 pods full of goods (only dispatch at a pre-defined container stop in the experiment) across the network (from west of HEL701 to east of HEL104 and vice versa. Since the amount of passengers is significant, the related traffic flows are recalibrated according to the modal shift mentioned previously according to the OD pairs replaced by the shuttles and pods. The other “normal” traffic, such as passenger car flows (except for the two OD pairs due to modal shift), bicycle flows and pedestrian flows have been kept the same as current situation.

Actors and relations

As unmanned logistics use case paints the picture of traffic situation of Helmond city centre in two decades, a few new actors and the associated relations among all actors need to be examined and addressed.

- Unmanned shuttles: As this category of actor requires no manual action, unmanned shuttles act as fully automated and autonomous bus (level 4 or 5). In this use case, they are designated to drive on vehicle lanes; follow two pre-defined routes and load/unload passengers at pre-defined shuttle stops; they use the traffic signals of existing vehicles and the PT traffic signals in the PT distribution centre.
- Unmanned pods: Pods are automated driverless vehicles that can provide rapid transit to persons and goods and they can self-charge (at electric vehicle charging points) during out-of-service time. They use existing road network and infrastructure instead of building new and extensive infrastructure. With a maximum speed of 25km/hr, they are able to drive on bicycle lanes, vehicle lanes within an exclusive area (such as a PT distribution plaza), and they can ride-on/park on pedestrian lanes or perform curbside stopping. They use mostly the traffic signals of bicycles and the PT traffic signals in the PT distribution centre.

  One of the future features of pods is that they can operate on-demand to provide swift travel service in congested areas. In the simulation experiment, the full scale on-demand feature has not been fully simulated. In the short term, the simulation experiment features transfers between shuttles and pods at pre-set locations that are concentrated on the PT distribution centre behind Helmond train station.
- Shuttle stops: similar to current bus stops (but longer distances, ca. 5~10 km, between stops), there are in total four shuttle stop locations configured on the simulation network of Helmond. One on the furthest location on the westernmost link, one on the furthest location on the easternmost link, and two stopping bays at the PT distribution centre where passengers and goods can change modalities with the most possibilities in a centralized manner. In reality these would be further away (e.g. the motorway exit of Nuenen to the west and the intersection with the N279 to the east), but due to the size of the network they were placed at the edge instead.
- Pod stops, container stops, charging stations: These three types of stops are designed for pods to achieve the following functions.
  - Pod stops: embark, disembark of persons and goods. Two pod stops are currently set-up in the PT distribution centre, targeting the transfers among modalities mostly.
  - Container stops: deliver, gather goods. One container stop is configured on the pedestrian lane (next to the bicycle lane) between intersection 103 and 104, which is intended to deliver goods to door.

- Charging stations: Pods can perform self-charging autonomously in the charging station when the electrical power is below a threshold. These pods are in the "on-call" mode, which means they are off to service if needed. One charging station is configured in the PT distribution centre in the simulation network. All pods in this simulation experiment perform a full charge at this station before picking up passengers.

The current traffic flows and infrastructure of Helmond city centre are composed of the followings:

- Existing vehicles: passenger cars and trucks travels on the road surface and use the traffic signal for vehicles.
- Existing bicycles: bicycles of generalized bicycle category that travel on the bicycle lanes with a maximum speed of 25km/hr.
- Existing pedestrians: pedestrians walking on pedestrian lanes/curbside. Shuttles and pods can perform collision avoidance actions autonomously when they are interacting with pedestrians.
- ImFlow traffic controllers: Intersections 700-series and 100 series on N270 of Helmond are controlled with ImFlow traffic controllers. Customized changes can be made to configure different scenarios.

Routes and schedules of unmanned shuttles and pods

To see the impact of different types of automated public transport units – namely shuttles and pods, 35 shuttles, 64 pods and 320 persons /goods following designated PT routes are simulated. The shuttles and pods are following a pre-configured schedule, in specific a time table with flexile time windows.

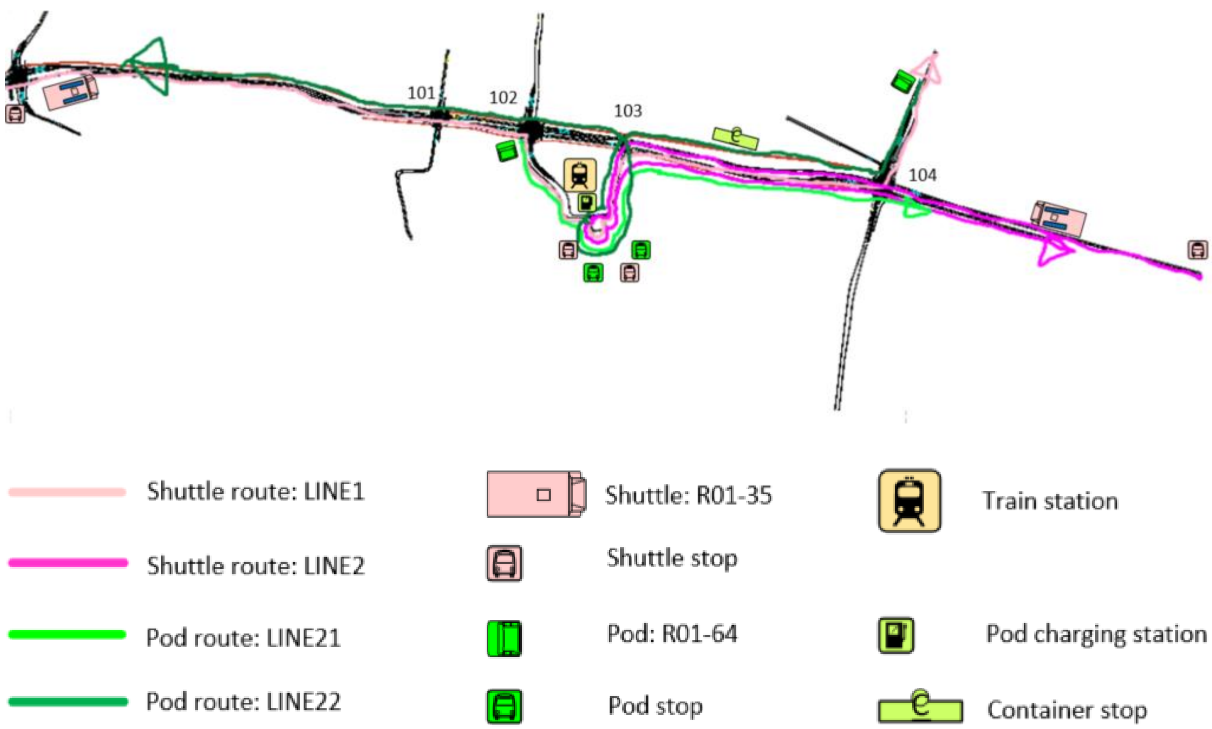


Figure 2: Overview of shuttle routes, pod routes and important POIs.

The top half of Figure 2 intends to show the general ideas of shuttle/pod route map, while the bottom half listed the legends. As presented, the strategic objective of unmanned shuttles and pods is to orchestrate a barrier-free door-to-door trip. Shuttles serve as intercity travels and pods serve the "first and last mile" of a trip. Note that the shuttles ride only long distance with scheduled stops approximately 5-10 km apart.

In the simulation experiment, we expect there should be a high amount of transfers, for example: persons and goods transfer from train to pods/shuttles, from shuttles to pods, and vice versa. Therefore, shuttle and pod stops are clustered on the PT distribution centre behind the train station, as shown in Figure 3 (A zoomed-in snapshot from SUMO simulation).

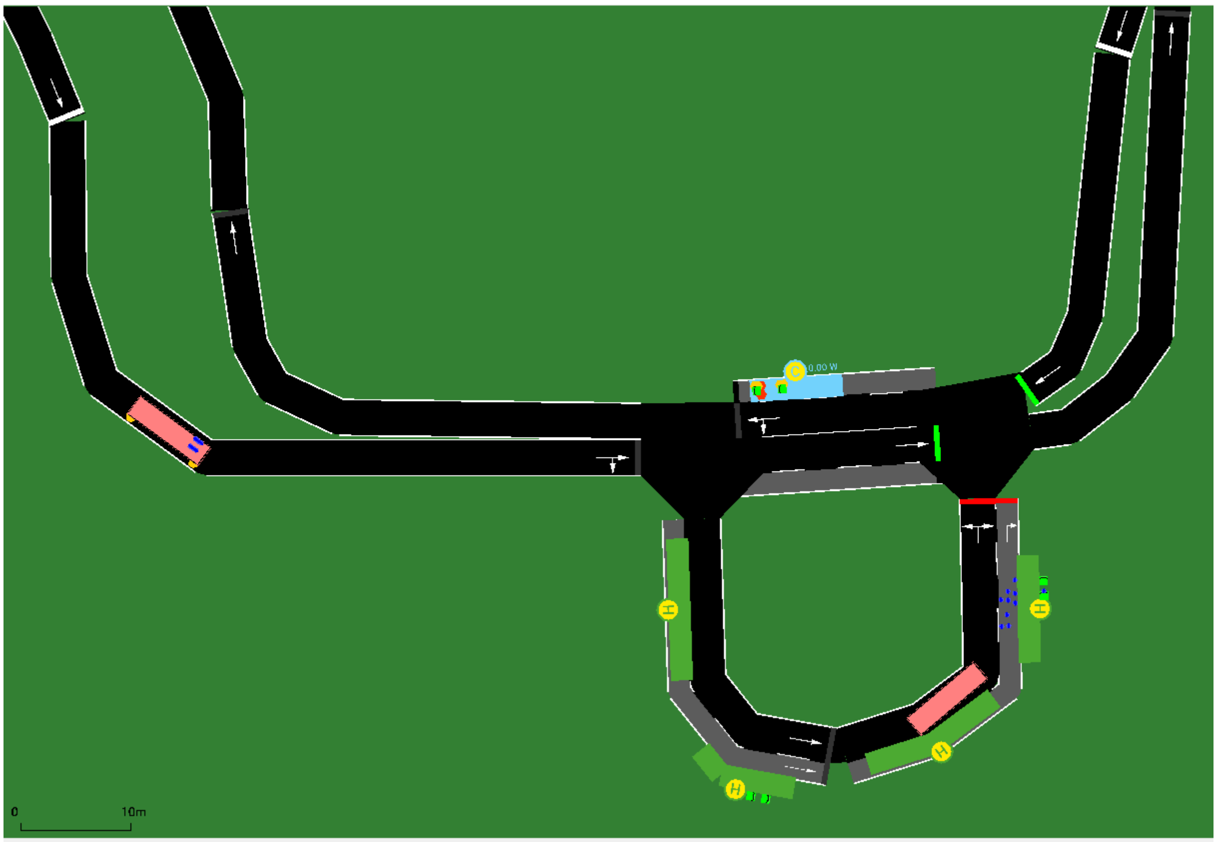


Figure 3: The trip transfers (blue dots represent persons or goods) at the distribution centre

This figure shows passengers and goods from potentially long shuttle ride disembark and move to the pods (parked at the pod station east one minutes ago) to finish the last short trip piece to reach their final destinations.

Although public transport routing using multi-modal travel means has been studied for years, its models and solutions are still limited and case-specific for most of the situations. Therefore, the shuttle routes are set to fixed routes, so are the simulated pod routes, in order to deflect from dynamic routing uncertainty.

The shuttle schedule has 35 shuttle trips of LINE 1 and LINE 2, departing every 5-10 minutes. The 64 pods of LINE21 and LINE 22, run on-demand. This is implemented by programming every pod to be on time on the pod stop and wait for the arrival of their designated persons or goods to arrive at the pod stop. After embarking the pod will do the last mile delivery.

Simulations of the other use cases in MAVEN (reported in D7.2) were performed mainly on three simulation locations. These are the current real-life networks of the cities: Helmond, Prague and Braunschweig. Keeping on using SUMO and ImFlow, this use case adopts the simulation approach of the previous single/combined use cases built up on Helmond. In order to ensure the validity of the results, each simulation experiment follows the following approaches:

1) Using real-world data collected in Helmond network, each simulation scenario was thoughtfully planned, monitored, analyzed and calibrated in order to minimize the discrepancies between real-world and the corresponding simulation experiment.
2) Each simulation scenario (with a configured parameter setting) was performed 10 times with a different random seed (two hour evening peak simulation each). The results were averaged over these 10 runs to ensure a statistically significant outcome.
3) It should be noted that while the network includes seven intersections, only four intersections (HEL101, HEL102, HEL103 and HEL104) are evaluated and have the use case configured. This is because the signal groups of these four intersections are heavily used by the unmanned shuttles and pods. Signal groups that are frequently used by shuttle and pods are shown in Figure 4 below.
4) Special detectors are added on SUMO and ImFlow. First, the simulated traffic is detected in SUMO, then the information of these detected shuttles and pods are sent back to ImFlow to calculate and optimize the signal timing plan. After making the decision of which plan to choose, ImFlow sends back the chosen plan to SUMO to continue the simulation.

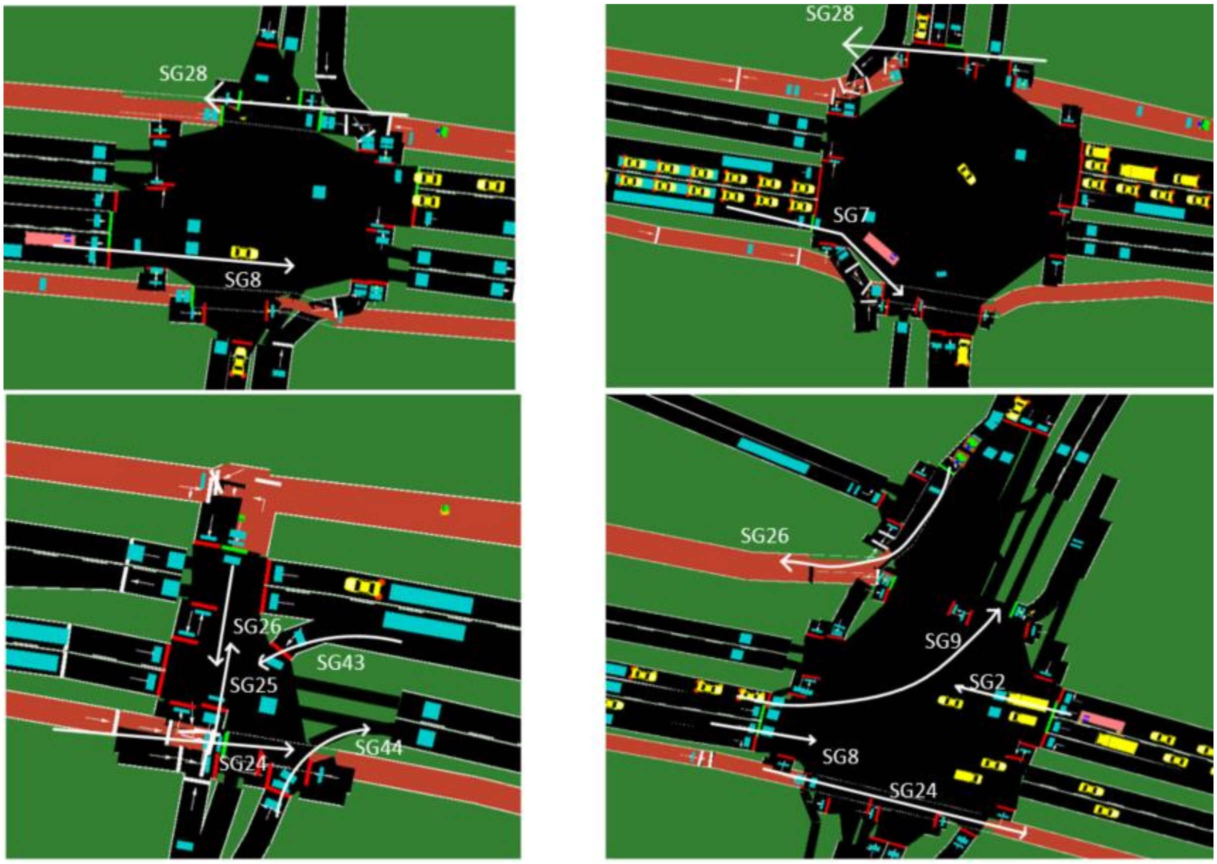


Figure 4: Snapshots of HEL101 (top-left), 102 (top-right), 103 (bottom-left) and 104 (bottom-right) during simulation; white arrows and text indicate SGs that are used by shuttles and pods

Simulation scenarios and KPIs

Three scenarios are set up to perform the simulation experiments:

1 *Scenario baseline*: scenario baseline simulates the current traffic conditions in Helmond. The original ImFlow configuration is used at the traffic lights. The demand is set to the normal workday evening peak hour levels.

2 *Scenario future*: Scenario future paints the same network as baseline, but with unmanned shuttles and pods fully operated as unmanned transport as it could be in two decades. Intersections are handled as scenario baseline with the same ImFlow configuration on current road. Due to the high amount of persons transferred with unmanned shuttles and pods, the demand and eventual traffic flows of the related OD-pairs are recalibrated. The goods are generally already transported by vans and trucks stopping at multiple addresses. Some shopping trips by car may be saved, but this is not taken into account for the simulation.

3 *Scenario futurePriority*: Scenario future priority is based on scenario future and adds the traffic management strategies of MAVEN, which is most notably the priority for the shuttles

and pods. The corresponding policy plans and routes are configured on top of the current ImFlow configuration.

Through SUMO and ImFlow, simulation experiments are performed according to above mentioned sections. Raw results are generated and written in output files. Based on the objectives and expectations summarized above, a list of KPIs is provided here, which have also been used in the MAVEN project in previous use cases to evaluate the impact (see D7.2).

1) KPI 1 Average impact

A measure of effect introduced in MAVEN D4.4 indicating the performance of the traffic network is an impact. It can be defined using the following formula:

$$impact = \frac{\sum_{i=0}^{i=I} delay_i + 8\ stops_i}{I} \tag{1}$$

The formula sums over all traffic participants (I) to calculate the average overall impact. The average impact can also sums over participants of a special interest vehicle category or a specific signal group of an intersection. The value 8 in the formula is often used as a rule-of-thumb factor by traffic engineers. It is based on CO_2 emissions and road user comfort of not stopping.

2) KPI 2 CO_2 per run (kg)

The CO_2 emission of all vehicles/special group vehicles of one run. Ten simulation runs were performed in the simulation experiment and KPI 2 is an average over the 10 runs.

3) KPI 3 Throughput (veh)

Throughput is defined by the number of vehicles passing the intersection for a specific (set of) turn direction(s). It can be acquired from the simulation output on the network level and per signal group level.

The above mentioned KPIs will be compared in two levels for results analysis and impact assessment purposes:

Network average level: including whole network and all vehicle categories in order to verify the effect on all users, including the ones not directly involved in the use case;

Per signal group per vehicle class level: only consider shuttles/pods and the specific SG they have passed (labeled special interest group). In specific, it means that all impact, delay, stops and throughput that incurred to a vehicle upon entry of the network up to the passage of the first traffic light, will be attributed to the signal group it just passed, so on so forth for the next signal group when the vehicle goes through the next passage.

Collecting the data per signal group is to perform deeper analysis between scenario future and scenario futurePriority. Since these results of per signal group should exhibit a similar trend but can also be considered stand-alone, only interesting findings of special interest groups (e.g. the average results of the special interest category is defined to the average results of shuttles and pods when they pass the SGs) will be reported to keep the discussion concise yet comprehensible.

Results

The results of all simulations for the three scenarios are exported and results analysis is performed using evaluation scrips, both on the network level and on a per signal group level as aforementioned.

Network level

On the network level, the average impact, CO2 emissions and total throughput of all vehicles are extracted and plotted in this section. Figure 5 shows the average impact of all vehicles for the three scenarios: baseline, future, futurePirority.

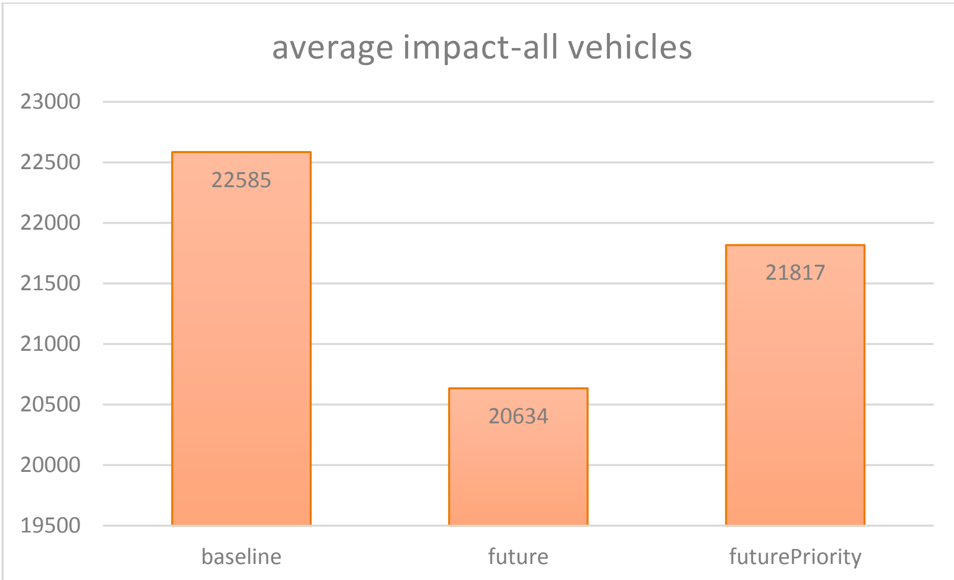


Figure 5: average impact of all vehicles on the network

From scenario baseline to scenario future, the average impact decreases by 8.6%; from scenario future to scenario futurePriority, the average impact increases by 5.7%.

The decrease from scenario baseline to scenario future is as expected and it confirms the positive effect of unmanned shuttles and pods on the network performance, when the compliance rate of modal shift from passenger car to shuttle/pod is 68.9%.

The increase (5.7%) of average impact from scenario future to futurePriority is also as expected based on experience. Since scenario futurePriority gives a high priority to all shuttles and pods when they approach existing traffic signals. However, the performance is still better than in the baseline.

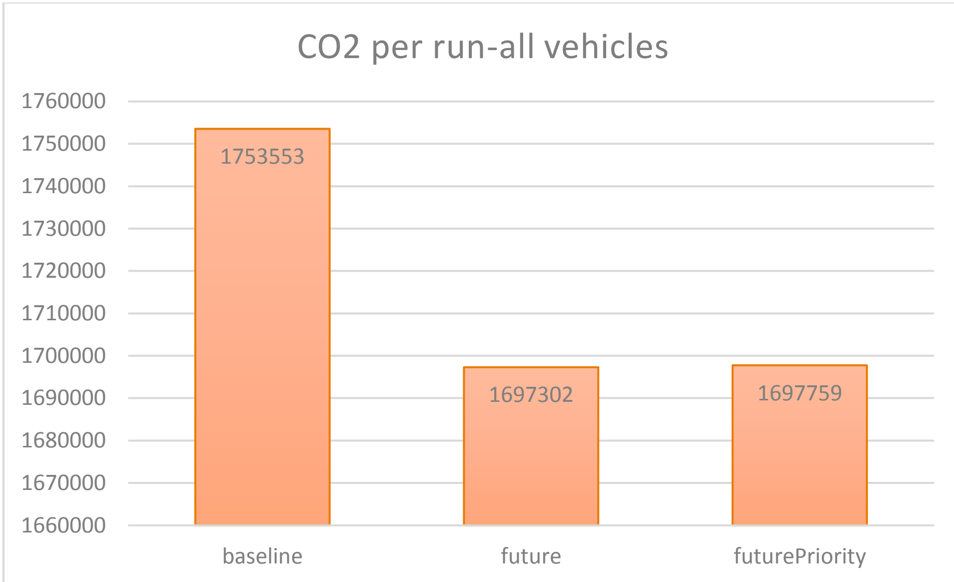


Figure 6: average impact of all vehicles on the network

Figure 6 shows the CO_2 emission of all vehicles during ten runs for the three scenarios: baseline, future, futurePirority. From scenario baseline to scenario future, the CO_2 emission decreases by 3.21%; from scenario future to scenario futurePriority, the CO_2 emission insignificantly increases by 0.027%.

These results are corresponding to the positive average impact exhibited in the previous figure. On the one hand, the decrease of CO_2 emission is quite promising on the network level even with the fact that only Pods are considered fully electrical with zero emissions while shuttles are following the PHEMlight model for bus in SUMO. In the future, the shuttles should actually produce less CO_2 emissions comparing to bus. On the other hand, the slight increase from scenario future to futurePriority is quite insignificant, which verify our assumption that the network performance is not deteriorated by giving a higher priority to shuttles and pods.

The total throughput is 180 vehicles lower in the future scenario's compared to the baseline. Between the future scenarios there is no significant change, which ensures that there is no congestion forming.

As mentioned in the section about simulation scenarios and KPIs, the latter are analysed for both the total network and for specific vehicle classes per signal group. This resulted in a total of 13 special interest vehicle class/ signal group combinations that were part of any shuttle or pod route. The results of these 13 special interest groups are examined one by one. The results are shown in Figure 7:

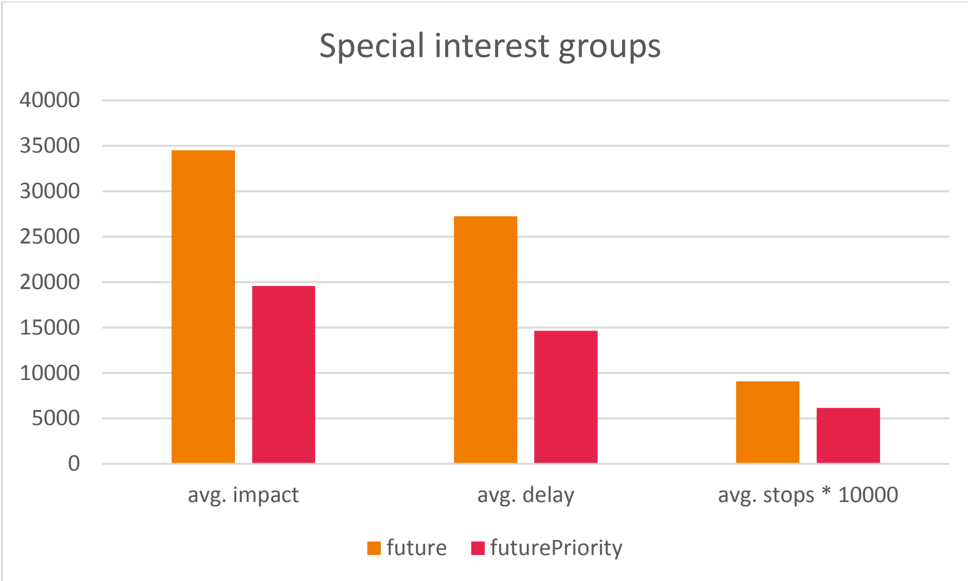


Figure 7: average impact, delay and stops of all prioritized traffic

A decrease of 43.3% on average impact is observed from scenario future to scenario futurePriority, which shows the significant positive effects of priority targeting special interest groups with pods and shuttles, which should stimulate the envisioned modal shift. The average amount of stops were multiplied by 10,000 to make them visible in the graph (decrease from 0.9 to 0.6).

Conclusion and further research

The average impact and the CO_2 emissions on the network level (all vehicles) are significantly decreased with 8.6% and 3.21% respectively, from scenario baseline to scenario future. When adding the priority the average impact increases with 5.7% while the CO_2 emissions don't change significantly.

The decrease of 43% for the impact on prioritized vehicles demonstrates it is possible to give a large advantage to these vehicles with traffic management policies. This shows that a 68% compliance rate for the modal shift from private vehicles to unmanned shuttles and pods would be realistic. At the same time, the overall performance is still better than in the baseline without shuttles and pods, making this solution beneficial for all traffic participants.

The case study showed a clear beneficial application of the MAVEN use cases to a realistic future situation. Thanks to the combination of the use cases, an effective priority could be given with minimal impact on other traffic participants.

The future of logistics on the public roads will undoubtedly head towards the direction of full automation. In this paper a first glance is given on the foreseen impact of unmanned logistics on road transport in an urban area. Whereas unmanned logistics is a new kind of transportation, further research regarding the logistical organization, forms of distribution and also steering from the government is desirable. For instance, in this case study commuting persons and delivery of goods are combined in one transportation system, which has a positive impact on the performance of the traffic system. On the other hand, the requirements of a traveller or a package to be delivered are different, such as punctuality, travelling time of day, costs etc. So different approaches and strategies can be developed and weighed on their impact on our resources. This can give us more insight expected benefits and possible side effects and will be able to act on beforehand.

Acknowledgement

The paper presents some preliminary results of the EU-funded project MAVEN (Managing Automated Vehicles Enhances Network), which is funded by the European Commission Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727. The content of this document reflects only the authors' view and the European Commission is not responsible for any use that may be made of the information it contains.

MAVEN

A roadmap to the traffic management systems of the future

Managing Automated Vehicles Enhances Network

www.maven-its.eu

At a glance…

In the future, automated road transport in urban areas will be dependent on connectivity and information exchange between automated vehicles and the road infrastructure. Maven is preparing for this future by researching solutions that will provide:

- Management regimes for automated driving in urban areas
- Monitoring, support and orchestration of movements of road users to guide vehicles at signalized intersections
- Further enhancement for ADAS and C-ITS applications

Benefits for…

Infrastructure service providers

MAVEN is testing cost-effective technical solutions for the deployment of autonomous vehicles using real-world prototype vehicles and traffic simulation studies

Cities

MAVEN is helping road authorities and cities reach the understanding of the requirements for a smooth transition towards integrated, safe and sustainable automated vehicles and their impact

Automotive industry

MAVEN is developing C-ITS communication standard interactions between vehicles (V2V) and the infrastructure (V2I) to support platooning, negotiation and scheduling algorithms

Demonstration sites and simulations…

Helmond pilot

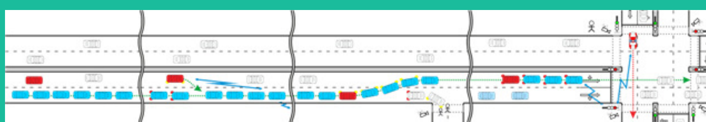
The pilot site in Helmond offers a state of the art infrastructure with all major intersections equipped with cooperative roadside units. Furthermore, the adaptive control algorithm ImFlow traffic control provides the opportunity to implement many different policies.

Braunschweig pilot

This pilot site offers the latest with respect to infrastructure detection as part of the Application Platform for Intelligent Mobility (AIM) test site. Stereo video detection combined with radar and hemispherical dome camera's enable the infrastructure to enhance the safety of automated driving.

Prague and Greenwich simulations

Simulations are essential for impact assessment of scaling up the MAVEN solutions. Therefore, in addition to simulations of the pilot sites, there are dedicated simulation networks of Prague and Greenwich, a borough in London. Each network has their own specific challenge and thus provides a good environment to evaluate MAVEN use cases such as platoon orchestration (e.g. initialisation, lane change, termination), Green Light optimal Speed Advice, enhanced queue modelling and green wave with platoon priority



MAVEN Partners

dynniq, DLR, HYUNDAI MOTOR GROUP, POLIS, TOMTOM, CTU CZECH TECHNICAL UNIVERSITY IN PRAGUE, ROYAL borough of GREENWICH, Gemeente Helmond, MAP TRAFFIC MANAGEMENT

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European Commission

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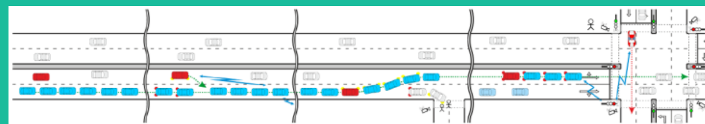


Managing Automated Vehicles Enhances Network

Introduction

In the future, automated road transport in urban areas will be dependent on connectivity and information exchange between automated vehicles and the road infrastructure. Maven is preparing for this future by researching solutions that will provide:

- Management regimes for automated driving in urban areas.
- Monitoring, support and orchestration of movements of road users to guide vehicles at signalized intersections.
- Further enhancement for ADAS and C-ITS applications.

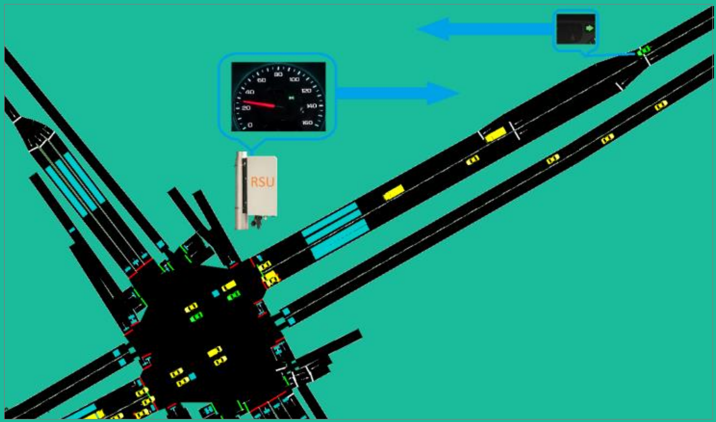
Use cases

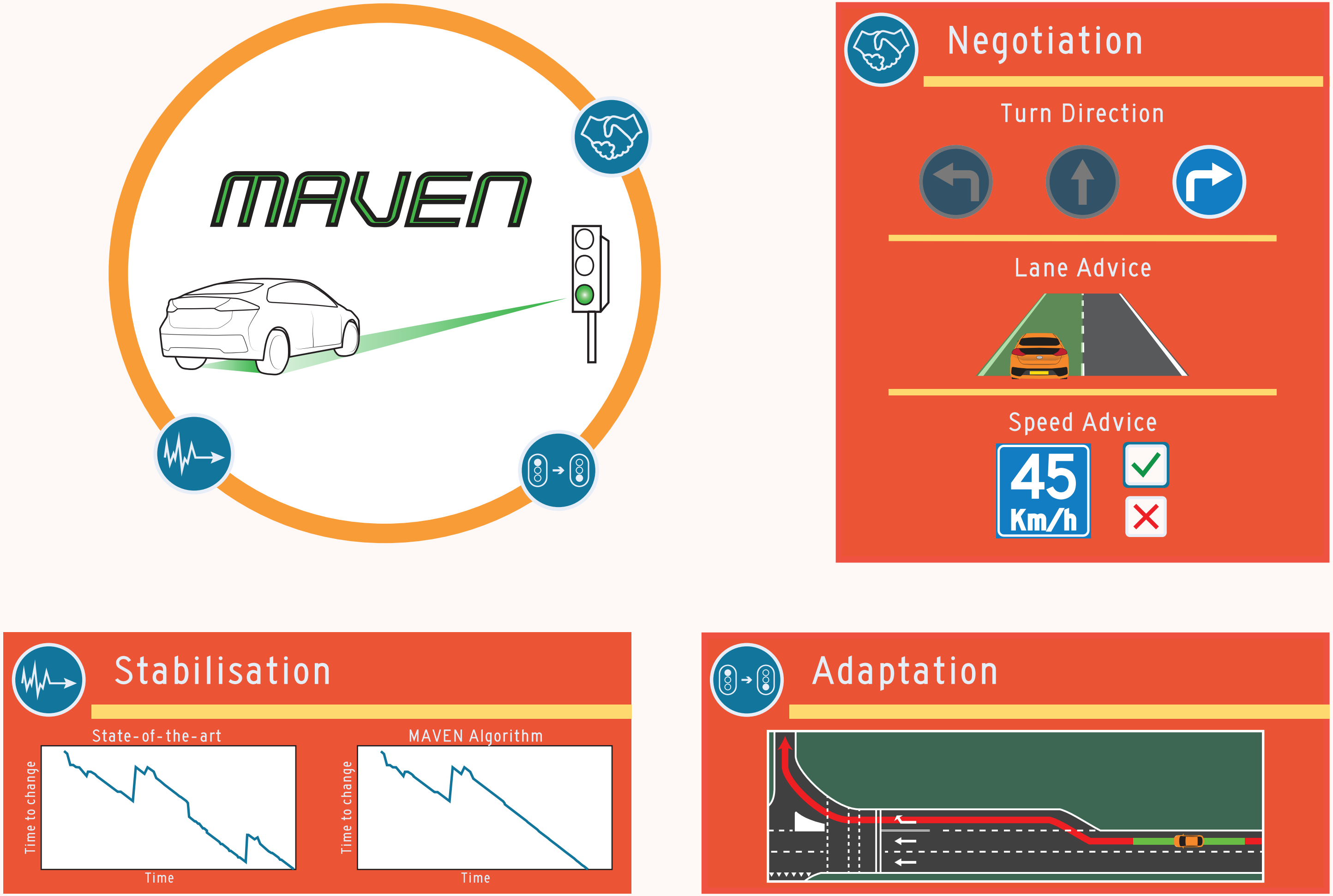
Platoon management UC1: Platoon initialisation UC2: Joining a platoon UC3: Travelling in a platoon UC4: Leaving a platoon UC5: Platoon break-up UC6: Platoon termination	Longitudinal and lateral management UC7: Speed change advisory (GLOSA) UC8: Lane change advisory UC9: Emergency situations
Signal optimisation UC10: Priority management UC11: Queue length estimation UC12: Local level routing UC13: Network coordination – green wave UC14: Signal optimisation	Intersection and other road user management UC15: Intersection negotiation UC16: Detect non-cooperative road users

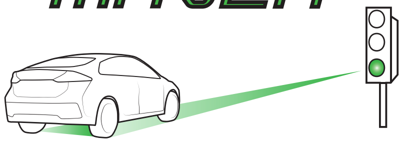
Key results

More information and full reports of these results are open and available on the website:

- Extended message sets to enable platooning and enhanced V2I interactions.
- The MAVEN *transition roadmap* considers political, institutional and organisational aspects. Moreover it identifies steps to be taken by policy makers and road authorities to prepare the infrastructure for increasing penetration of automated vehicles.
- Increased traffic efficiency with the enhanced control algorithms AGLOSA and extended adaptive control. They exploit new opportunities of automated vehicle presence.
- Distributed platoon forming and progression algorithms.
- GLOSA negotiation scheme optimising the approach towards the intersection as demonstrated below:




MAVEN
Negotiation
Turn Direction
Lane Advice
Speed Advice
45
Km/h
Stabilisation
State-of-the-art
MAVEN Algorithm
Time to change
Time
Time to change
Time
Adaptation



Extended message sets allow MAVEN to exchange more information which results in increased traffic efficiency and improved safety.

The intended turn direction, number of occupants and other vehicle characteristics enable the traffic light controller to adapt more effectively to the needs of the approaching traffic, which reduces delay time and emissions.

High confidence predictions are essential for vehicles which adjust their speed based on control plans. MAVEN has developed new methods to deliver those reliable predictions for actuated and adaptive control.

MAVEN developed future concepts for vehicle automation, combining flexible and dynamic urban platooning with automated lane changes and optimal speed and trajectory planning. The new concepts have been tested in simulation, on test tracks and in public traffic.

For more information, visit us at: **maven-its.eu**

Managing Automated Vehicles Enhances Network

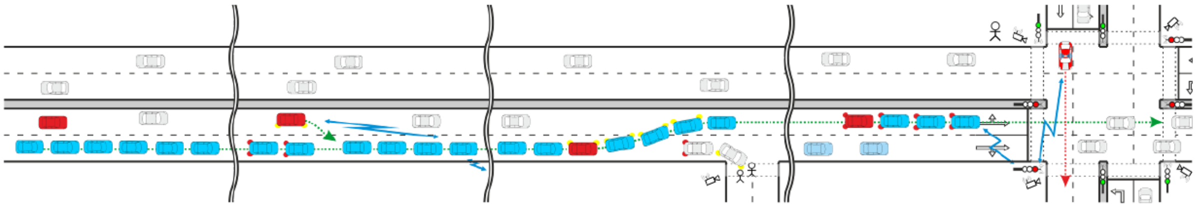
This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 690727

Enhancing intelligent urban road transport network and cooperative systems for highly automated vehicles

Newsletter No. 1 (September 2016)

MAVEN (Managing Automated Vehicles Enhances Network) was launched on 01-09-2016. This 3-year project, under the Horizon 2020 Research and Innovation Framework Programme of the European Commission (Grant Agreement No. 690727), has nine partners with a total budget of EUR 3,149,661.25.

The project aims to provide solutions for managing automated vehicles in an urban environment (with signalized intersections and mixed traffic). It will develop algorithms for organising the flow of infrastructure-assisted automated vehicles, and structuring the negotiation processes between vehicles and the infrastructure. Platooning is an evident example of a technology in this domain. The MAVEN approach will substantially contribute to increasing traffic efficiency, improving utilisation of infrastructure capacity, and reducing emission. The MAVEN project will build a prototype system that will be used both for field tests and for extensive modelling for impact assessment. Furthermore, the project will contribute to the development of enabling technologies, such as telecommunication standards and high-precision maps.



The project will include a user assessment effort. A roadmap for the introduction of road transport automation will be developed, to support road authorities in understanding potential future changes in their role and in the tasks of traffic management. A white paper on "management of automated vehicles in a smart city environment" will position the MAVEN results in the broader perspective of transport in smart cities, and embed these with the principles and technologies for smart cities, as well as service delivery. The project held its kick-off meeting on 20-21 September 2016 at Polis in Brussels and hosts a stakeholder consultation workshop at the 15th of November in Barcelona. More information about the workshop and the registration form can be found here.

For more information about the project, please contact:

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MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

Newsletter No. 2 (July 2017)

Introduction

MAVEN (Managing Automated Vehicles Enhances Network) was launched on 1 September 2016. The project investigates future traffic management of connected, cooperative and automated transport. It will provide:

- management regimes for automated driving in urban areas;
- monitoring, support and orchestration of movements of road users to guide vehicles at signalised intersections; and
- further enhancement for ADAS (Advanced Driver Assistance Systems) and C-ITS (Co-Operative Intelligent Transport Systems) applications.

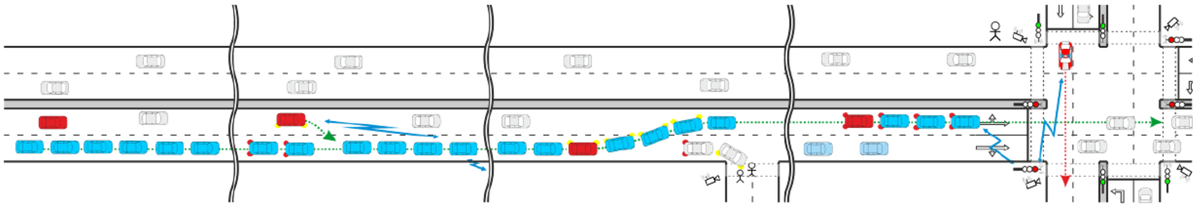


Illustration of MAVEN use cases

Preliminary results and related activities

Generic concept, use cases, requirements and specifications

MAVEN has provided a detailed system design, including use case descriptions, requirements and specifications and engaged road authorities in this process. A stakeholder consultation workshop was organised in Barcelona in November 2016, for discussion and review of preliminary MAVEN results. The workshop audience of 34 persons was made up primarily of local authority representatives – mainly working on traffic management - and project partners. For many participants, this workshop was a first occasion to learn about and to share views on automation and urban transport. Hence, the discussion largely remained at a rather general level, covering the potential advantages and dis-benefits of automated vehicles in the urban environment. Nonetheless, some requirements and recommendations emerged from the discussion that have bearing on the use cases, the demonstrations and impact assessment. These requirements, have been used as an input for the requirements collection step.

Findings from the workshop together with the resulting use case descriptions and system requirements can be found in the report "User needs, conceptual design and requirements" which is publicly available on the project website. In total 16 use cases are described which can be categorised into roughly 3 clusters: platoon management, signal optimisation and vehicle-infrastructure communications at interaction. When combined these provide infrastructure-initiated guidance of highly automated vehicles (HAVs) using negotiation proto-

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

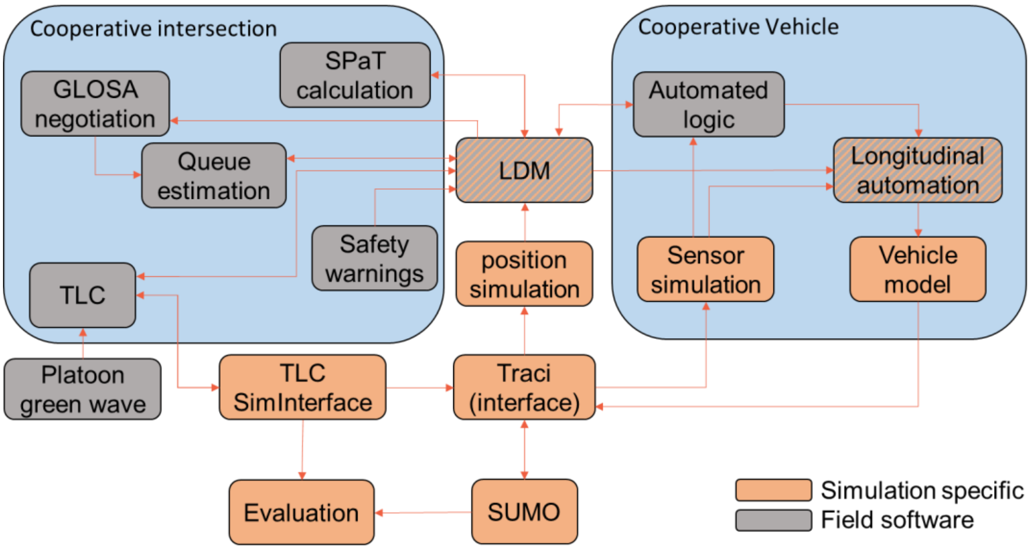
cols between vehicles and the infrastructure through which, iteratively, HAVs receive advice and/or commands from the road infrastructure to adjust their trajectory and manoeuvring policies, while the infrastructure dynamically adapts the traffic light timing of single or multiple signalised intersections based on the anticipated vehicle arrival pattern.

Following this definition work, a state-of-the-art review of previous projects and scientific literature was conducted, system architectures for real-world and simulation implementations were developed and verification criteria were defined. The literature review is available in the report "System architecture, specifications and verification criteria".

The first MAVEN stakeholder consultation meeting with local authorities and urban road stakeholders on 15 November 2016 in Barcelona, Spain

MAVEN Architecture

Within the project, a high-level system decomposition and hardware architecture, as well as a software architecture for simulations have been developed.



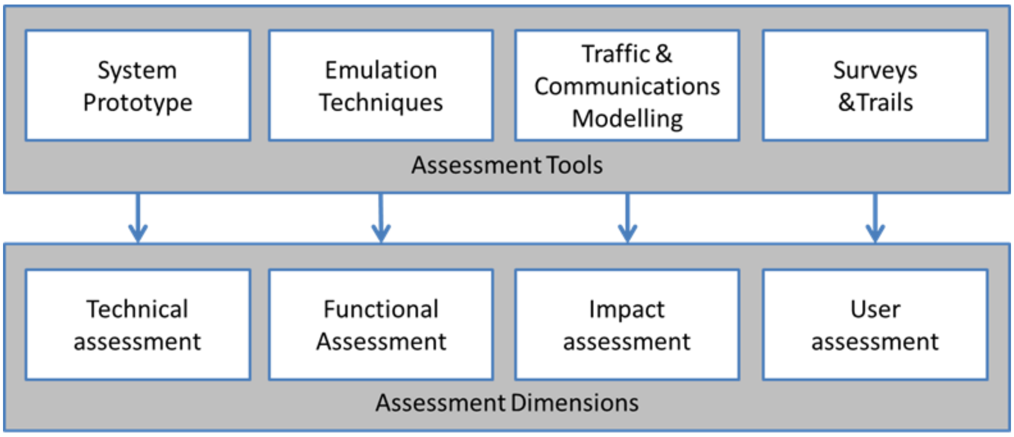
High level simulation architecture

The main actors involved are the cooperative vehicle and cooperative intersection. The figure above-left also shows the actors outside the boundaries of the architecture that interact with the system. These are non-cooperative vehicles and Vulnerable Road Users (VRU) that only interact in traditional ways with the system. Cooperative priority vehicles are vehicles who request priority in a traditional way from a functional perspective (using check-in and check-out points), but use new cooperative technology as communication channel for this. The Traffic Management Centre (TMC) is an external actor that may change policy parameters in the intersections and coordinates green waves over multiple intersections. The road authority or traffic management software can trigger this. For details about vehicle architecture and infrastructure architecture see: [Blokpoel, et al., 2017], which will be published on the website.

A simulation architecture (see the figure above-right) is developed by keeping maximal compatibility and re-use of real-world systems, while enabling retrieving sensor information from the simulation environment and changing states of traffic lights and vehicles according to the actuator outputs. Components that are identical to the real-world implementation are marked in grey, simulation specific components are marked in orange and adapted elements are marked in grey/orange striped. The interfaces to the grey elements should stay the same. Both the vehicle and the intersection have a shared Logical Data Model (LDM), as the communication units have been removed, saving a lot of computational time for encoding and decoding messages. Systems connected to this LDM will not notice a difference, the same data is still present in the same format.

Impact assessment plan

The MAVEN consortium experts have made an impact assessment plan to define particular steps, tools, roles, deadlines, requirement or prerequisites. It covers technical impacts (e.g. meeting of the technical requirements), functional impacts (e.g. covering the needed functionality), impact analysis (e.g. evaluating the impact of platoon organisation, negotiation algorithms, penetration rate of automated vehicles and others) and user impacts (e.g. addressing the acceptance and compliance of drivers and citizens of the MAVEN related use cases). A detailed description can be found in the report "Impact assessment plan", which is a living document.



MAVEN assessment method

MAVEN Special Session at IEEE SCSP 2017 in Prague, Czech Republic

A MAVEN Special Session on "Autonomous vehicles for smart cities" was held on 26 May 2017 at the third IEEE (the Institute of Electrical and Electronics Engineers) Smart Cities

Symposium Prague (SCSP 2017), organised by the Czech Technical University (CTU). SCSP 2017 is an international scientific conference with over 150 participants from 13 countries. The symposium received auspices from the President of the Czech Republic, Mr. Miloš Zeman and the City of Prague. The director of the City of Prague JUDr. Martina Děvěrová along with the CTU rector Prof. Petr Konvalinka opened the symposium.

The main objectives of the MAVEN Special Session are:

- Introduction of the EU-funded project MAVEN
- Addressing some technical issues in the field of connected, cooperative and automated transport, as well as non-technical aspect of automated driving
- Discussions of expected impacts of connected, cooperative and automated transport, e.g. potential impacts, evaluation and assessment approaches, next steps, main trends

Dr. Meng Lu (Dynniq) moderated the session. Dr. Reza Dariani (The German Aerospace Center DLR) presented the state of the art of automated driving. He provided some facts about why autonomous vehicles are needed, and introduced different level of automation levels (0 to 5) and some experiments at DLR test track and simulation, e.g. cooperative lane change assistant system and automated cooperative valet parking.

Dr. Ondřej Přibyl (CTU), who also serve as the Chair of the SCSP 2017 Scientific Committee, gave an introduction of MAVEN. He also addressed the motivation for research related to automated driving, briefly reviewed main projects in this domain, and highlighted the automation levels, core technologies and impacts.

Prof. Tomáš Zelinka (CTU) presented telecommunication technologies for automated driving. He provided a very comprehensive overview of connected and cooperative solutions, trends in automated driving, discussed hybrid communication (architecture), and addressed communication system performance requirements.

Tomáš Peťovský (CEO, UBER CZ) provided his view from economic perspective. He analysed various mobility challenges, with which cities are confronting, and especially addressed shared automated vehicles for the future of urban mobility and the impacts.

At the end of the session, a survey was used to collect the views of the participants on automated driving and future traffic management. The session was attended by nearly 40 delegates. According to the opinion of the majority of the participants, safety is the most crucial aspect or concern for implementing and using autonomous vehicles. The MAVEN Special Session was highly appreciated by the participants of SCSP 2017, and received very positive feedback.

SCSP 2017 key organisers: Miroslav Svítek and Ondřej Přibyl (CTU)

MAVEN Special Session: Meng Lu (Dynniq) with the organisers

SCSP 2017 organisers (CTU) at the conference social event

MAVEN Stakeholder Consultation meeting in Brussels on 10 October 2017

MAVEN wants to support road authorities in understanding changes in their role and the tasks of traffic management systems.

In this respect, the project will hold the second Stakeholder Consultation Meeting on Monday, 10 October 2017 at the Polis network premises in Brussels, Belgium. The workshop targets cities and road authorities with the aim to gather views and get input for the MAVEN roadmap for the introduction of vehicle-road automation.

Travel costs reimbursement is available for eligible public authorities. If you are interested, please contact us.

MAVEN Consortium

MAVEN publication list

Blokpoel, R., Lu, M., Přibyl, O., Dariani, R. (2017). Interoperable architecture between simulation and pilots for cooperative and automated driving. Paper ID SP0849. In Proceedings: *The 12th European Congress on Intelligent Transport Systems*. Strasbourg.

Lu, M., Blokpoel, R. (2017). A sophisticated intelligent urban road-transport network and cooperative systems infrastructure for highly automated vehicles. Paper ID EU-TP0769. In Proceedings: *World Congress on Intelligent Transport Systems*, Montréal. (forthcoming)

Pereira, A.M., Anany, H., Přibyl, O., Přibyl, J. (2017). Automated vehicles in smart urban environment: a review. In Proceedings: *IEEE Smart Cities Symposium Prague 2017*. Prague.

Přibyl, O., Vreeswijk, J., Hoadley, S., Blokpoel, R., Horák, T. (2017). Incorporating stakeholder input in EU projects. In Proceedings: *IEEE Smart Cities Symposium Prague 2017*. Prague.

Vreeswijk, J., Přibyl, O., Hoadley, S. (2017). Managing automated vehicles enhances network. Paper TP0843. In Proceedings: *The 12th European Congress on Intelligent Transport Systems*. Strasbourg.

Vreeswijk, J., Přibyl, O., Blokpoel, R., Schindler, J., Rondinonee, M. (2017). Managing automated vehicle at signalized intersections. In Proceedings: *International Conference on Intelligent Transport Systems in Theory and Practice*, mobil.TUM, Munich.

Contact

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You can also follow us via our

- Web site: www.maven-its.eu
- LinkedIN: *https://www.linkedin.com/groups/8571587/profile*
- Twitter: *@MAVEN_its*

Newsletter No. 3 (April 2018)

Introduction

MAVEN (Managing Automated Vehicles Enhances Network) was launched on 1 September 2016. The project investigates future traffic management of connected, cooperative and automated transport. It will provide:

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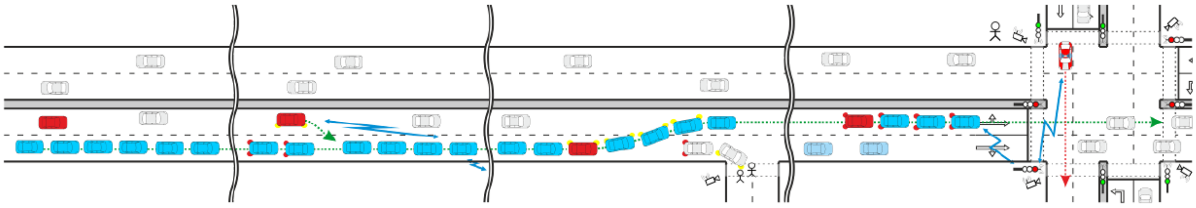
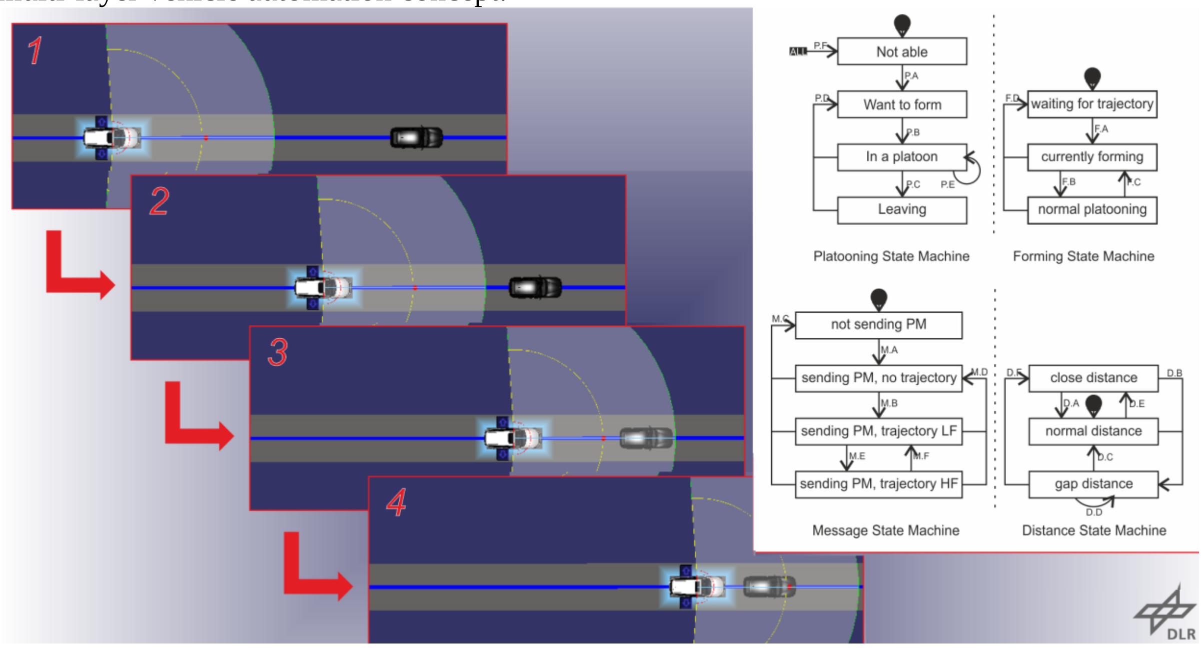


Illustration of MAVEN use cases

Recent achievements of MAVEN

Vehicle automation

The figure below shows the platooning state machine, which is part of the newly developed multi-layer vehicle automation concept.



Platooning state machine for fully-automated cooperative vehicle

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

This multi-layer concept splits the automation into two levels. The trajectory planning ensures the vehicle drives an optimal path within the lane on a short horizon. The tactical level takes input from Vehicle to Vehicle or Infrastructure (V2X) communication and platoon algorithms to control the vehicle on a higher level. This is where platooning, lane changes and optimal speed for approaching an intersection are the main targets. For platooning a detailed algorithm based on a state-machine and supported by the new message sets was developed.

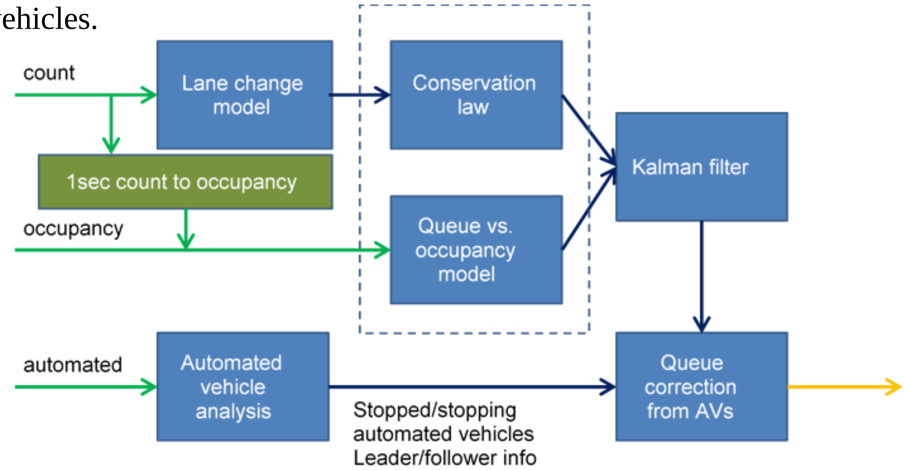
In addition to the detailed development and implementation, the simulation platform "Dominion" has been prepared for simulating the automation behaviour in the defined 16 MAVEN use cases (UC1-UC16). The table below presents MAVEN use cases and their categorisations. The automation functionality, including all desired interfaces, procedures for trajectory planning and vehicle control is under development.

Platoon management **UC1**: Platoon initialisation **UC2**: Joining a platoon **UC3**: Travelling in a platoon **UC4**: Leaving a platoon **UC5**: Platoon break-up **UC6**: Platoon termination	Longitudinal and lateral management **UC7**: Speed change advisory (GLOSA - Green Light Optimal Speed Advisory) **UC8**: Lane change advisory **UC9**: Emergency situations	Signal optimisation **UC10**: Priority management **UC11**: Queue length estimation **UC12**: Local level routing **UC13**: Network coordination – green wave **UC14**: Signal optimisation	Intersection and other road user management **UC15**: Intersection negotiation **UC16**: Detect non-cooperative road users

Infrastructure automation

Simpla has been developed and released as open source by MAVEN, and allows users to simulate automated vehicles in SUMO (Simulation of Urban MObility). The extended Lcal Dynamic Map (LDM) enables the exchange of new essential information elements for the MAVEN use cases and the position simulation adds random noise to GPS (Global Positioning System) measurements from simulation for realistic queue modelling simulations.

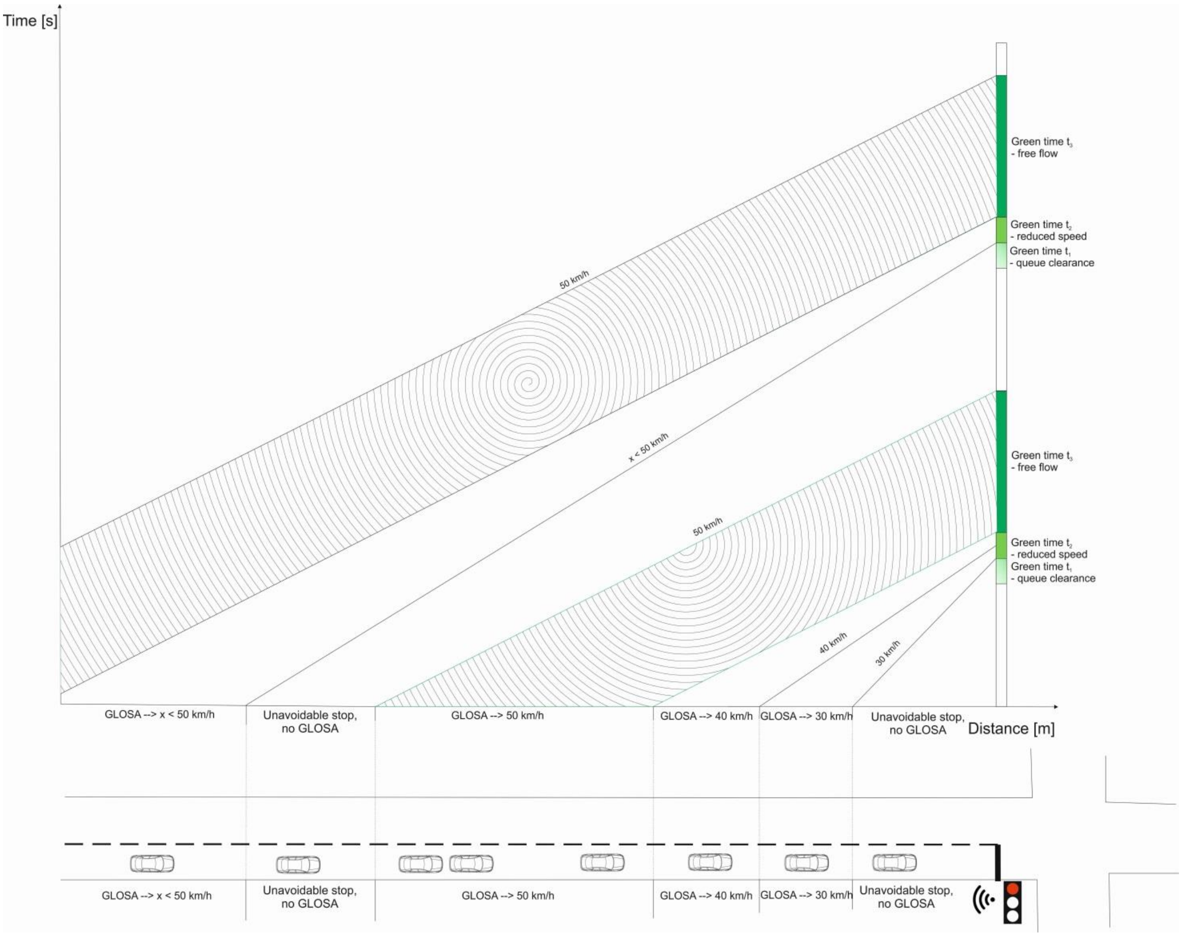
The research in queue modelling showed that data fusion of information from traditional detectors and automated vehicles resulted in up to 40% reduction for the average error of the queue length estimation. The largest benefits were visible for high traffic volumes, because the chance of receiving vehicle information increases. Having better queue model information, results in both more efficient traffic control and more accurate speed advice for automated vehicles.



MAVEN queue length model schematic structure

Another important factor for speed advice is the predictability of the control plan. A new stabilisation cost function was added to the adaptive control algorithm, which resulted in 25% reduction of average prediction error, while maintaining similar traffic efficiency. More advanced parameters were added to combat specific side effects, like the prediction stagnating at a certain value due to a green extension. This resulted in a small further improvement, but most notably in a solution for the stagnation problem. A patent was requested and granted for the solution of stabilizing the control by means of a new cost function for the algorithm.

The MAVEN consortium has also worked on actuated control, which is the most common form of traffic control in Europe, but is also known to be very unpredictable due to the ad-hoc decisions. MAVEN has developed solutions to provide measurements for the reliability of the forecast. With priority schemes for automated vehicle platoons, negotiations elements were added that can take several parameters into account. Both the actuated and adaptive control strategies developed in MAVEN show automatic formation of green waves when platoons progress through the network and controllers get connected to each other.

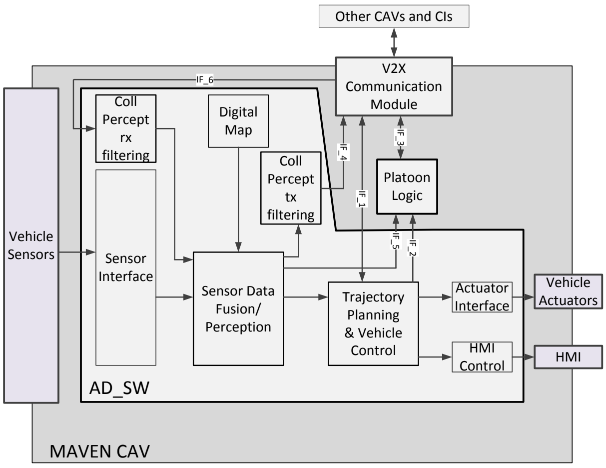


Actuated traffic control with GLOSA

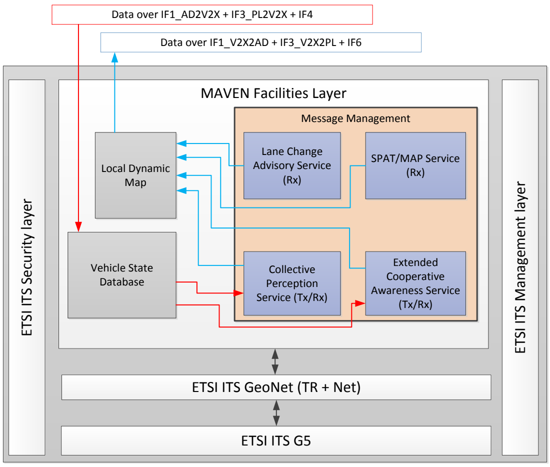
V2X communication for automated driving

To enable automated driving solutions, MAVEN-suitable V2X communication schemes and message sets have been developed. These include several contributions: for the cooperative infrastructure, an I2V Lane Change Advisory service and a dedicated profiling of the SPaT (Signal Phase and Time) and MAP (topology) for lane-specific GLOSA were developed. For the cooperative automated vehicles, extensions of standard CAM (Cooperative

Awareness Message) messages have been designed to allow interaction with cooperative intersections and to support management and control of platoons. Finally, the currently under standardization Collective Perception service has been adapted to the needs of MAVEN to support the applications of cooperative and automated vehicles aimed at increasing the safety of VRUs (Vulnerable Road Users) and vehicle drivers. The developed schemes are backward compatible as required by the car industry and to foster their future deployment. They are provided in terms of ASN.1 (Abstract Syntax Notation One) definitions and detailed message data specifications that can be openly accessed. The aforementioned communication schemes have been tested in small test benches aimed at evaluating the technical functionality of the developed solutions from a communication point of view, and hence their suitability for integration in infrastructure and vehicle prototypes. MAVEN has actively contributed to the European ETSI standardisation in this area, especially for the collective perception definitions. In addition, the rest of the aforementioned communications schemes were presented for further consideration in standardization and specifications organizations like the ETSI (European Telecommunications Standards Institute) ITS and the C2C CC (Car2Car Communication Consortium) in dedicated events.

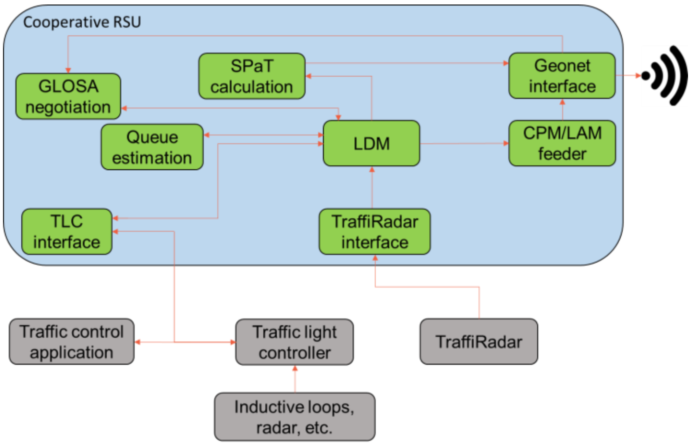


MAVEN cooperative and automated vehicles communication architecture and interfacing

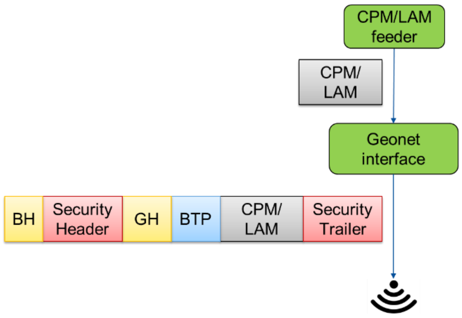


MAVEN V2X communication module architecture

Another technology under study within MAVEN is ADAS functions for VRUs and driver protection on MAVEN vehicles. Work has been done in the definition of the concept for ADAS inclusion in more generic automated driving frameworks. First, it was jointly agreed not to consider ADAS solutions based on retrofitting VRUs with C-ITS technology to let them cooperatively advertise their presence. Due to positioning limitations of these retrofitting solutions, the resulting ADAS would not be reliable and create uncertainty in the automated driving algorithms' reactions. Second, it was agreed that ADAS functions in the context of automated driving cannot be treated as separate functions but have to be integrated in the overall algorithms for environmental perception and path planning. For example, ADAS functions relying on cooperative sensing (collective perception) can be seen as complementing extensions of functions relying on on-board sensors. System reactions will be directly influencing the path planning (e.g. slow down and braking) when the confidence of the advertised detected object is good enough to justify them, or when the advertised object was not yet present in the environmental perception module databases because no local sensor has detected it yet.



Intersection communication architecture



Geonet interface overview

The third technology investigated in MAVEN is HD (High Definition) maps and their usage to optimally support the MAVEN use cases. In this context, MAVEN started using the HD maps provided by TomTom, analysed the current format and identified suitable improvements. A dedicated workshop was held, and the definition of a process to evaluate the capability of extended HD maps to support MAVEN automated driving was agreed. MAVEN will further investigate how the extended HD map formats can enable trajectory planning (or improve its quality), focusing on complex scenarios like road intersections, where current HD maps not always provide all the data needed by automated driving algorithm implementations. Dedicated HD maps extension requirements, including standardisation aspects have been developed.

MAVEN transition roadmap

MAVEN hosted the second stakeholder consultation "Vehicle automation: implications for city and regional authorities" on 10 October 2017 in Brussels, Belgium, which was a joint action together with two related EU-funded projects TransAID and CoEXist, to gather the views and requirements of local authorities and other urban transport stakeholders.

The second MAVEN stakeholder consultation "Vehicle automation: implications for city and regional authorities" on 10 October 2017 in Brussels - Joint Workshop with TransAID / CoEXist

In the initial version of the MAVEN transition roadmap, expert views and recommendations for the transition of traffic management at signalised intersections along urban corridors from the present conventional transport world into a connected, cooperative and automated world are presented. The roadmap considers political, institutional and organisational aspects, and identifies priorities related to the safety and comfort of special category road users such as public transport vehicles, VRUs, logistics vehicles, and emergency vehicles. Moreover it identifies steps to be taken by policy makers, road authorities, standards-development organisations and other stakeholders on the route to a high penetration of highly or fully infrastructure-supported automated vehicles. The initial transition roadmap will be completed and available for public at the end of the MAVEN project in August 2020.

Main (joint) events plan

The main upcoming (joint) MAVEN events are:

- MAVEN Special Session on "Automated transport for smart cities" in May 2018 at IEEE (Institute of Electrical and Electronics Engineers) Smart Cities Symposium Prague (SCSP), Prague.
- The third MAVEN stakeholder consultation "Vehicle automation: implications for city and regional authorities", August/October 2018. (TBC)
- Joint Workshop with TransAID, C-MobILE and IEEE 5G Initiative on "Cooperative and automated driving" at IEEE ITSC (Intelligent Transportation Systems Conference on 4 November 2018, Hawaii.
- Joint Demo with TransAID, in conjunction with European Congress on Intelligent Transport Systems on 3-6 June 2019, Eindhoven/Helmond. (TBC)
- Joint Workshop with TransAID, in conjunction with IEEE IV'19 (Intelligent Vehicles Symposium) on 9-12 June 2019, Paris. (TBC)

MAVEN Consortium

Contact

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You can also follow us via our

- Web site: www.maven-its.eu
- LinkedIN: *https://www.linkedin.com/groups/8571587/profile*
- Twitter: *@MAVEN_its*

Enhancing intelligent urban road transport network and cooperative systems for highly automated vehicles

Newsletter No. 4 (October 2018)

Introduction

MAVEN (Managing Automated Vehicles Enhances Network) was launched on 1 September 2016. The project investigates future traffic management of connected, cooperative and automated transport. It will provide:

- management regimes for automated driving in urban areas;
- monitoring, support and orchestration of movements of road users to guide vehicles at signalised intersections; and
- further enhancement for ADAS (Advanced Driver Assistance Systems) and C-ITS (Cooperative Intelligent Transport Systems) applications.

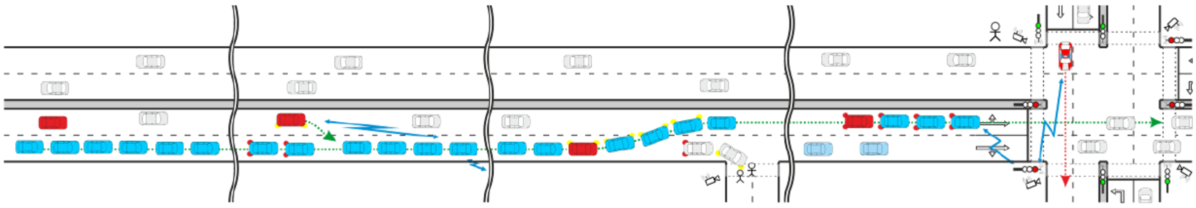
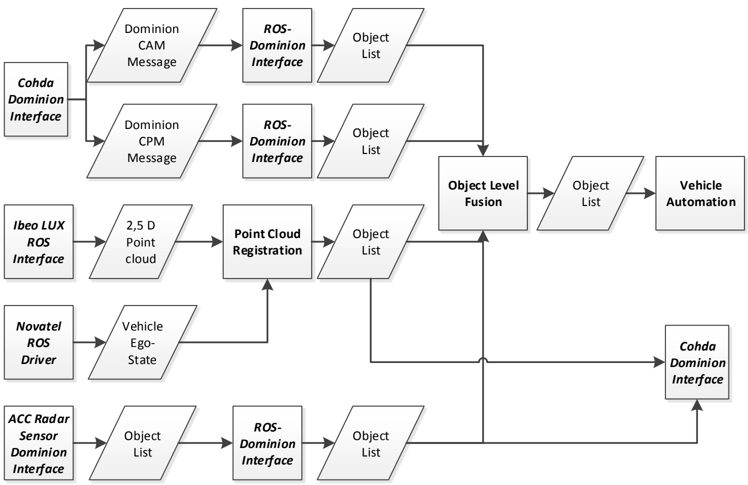


Illustration of MAVEN use cases

MAVEN achievements update

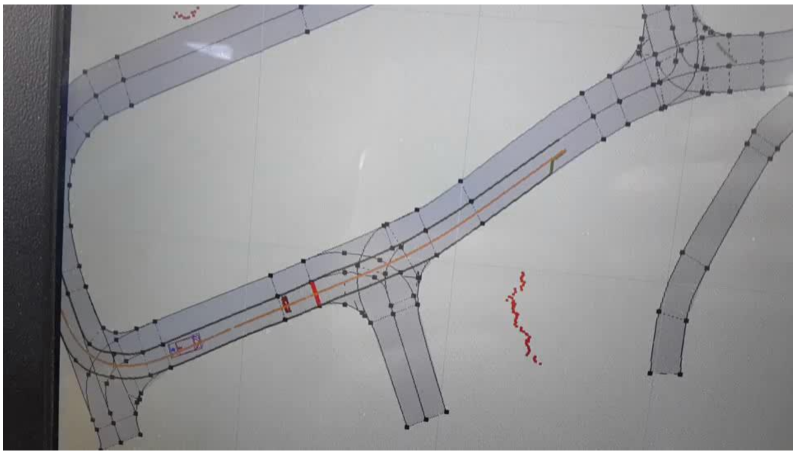
Vehicle automation

MAVEN has made further progress on the development of cooperative environment perception and of cooperative trajectory planning. The goal of cooperative environment perception for the Highly Automated Driving (HAD) vehicle is improving the range of the view on its environment. The environment model is composed of non moving obstacles and moving road users. The cooperative aspect means that in addition to the on-board LIDAR (Light Detection And Ranging), Radar and Camera sensors, CAM (Cooperative Awareness Message) and CPM (Collective Perception Message) are considered.

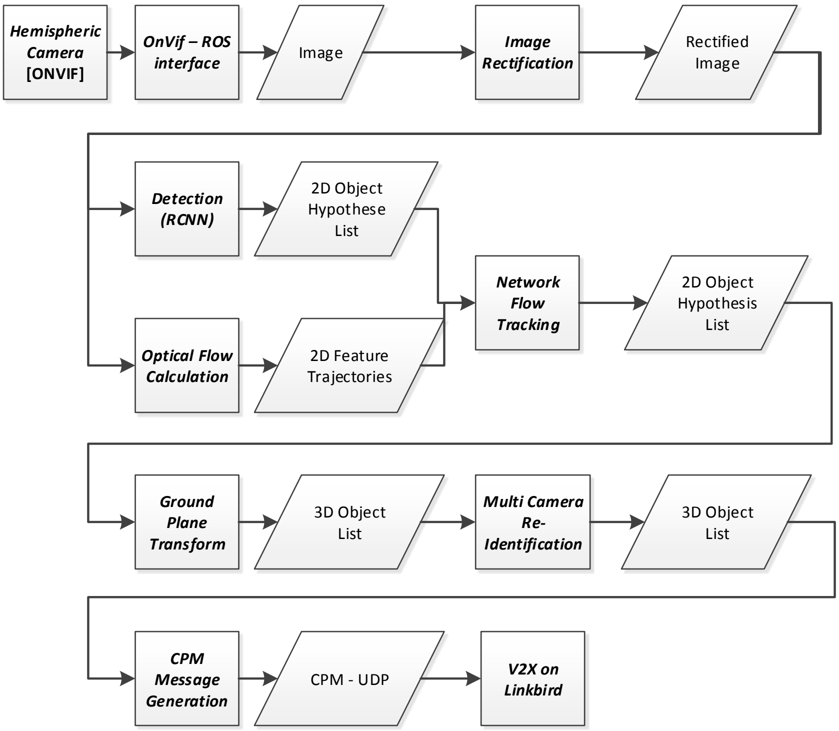


Cooperative Environment Perception

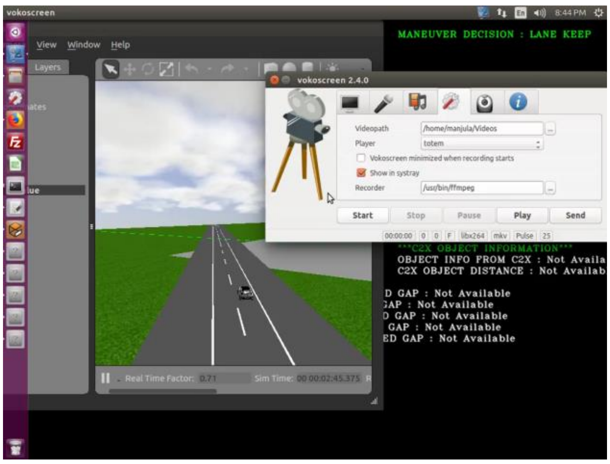
MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727



Fusion with CAM messages testing at the ADAC Übungsplatz test track

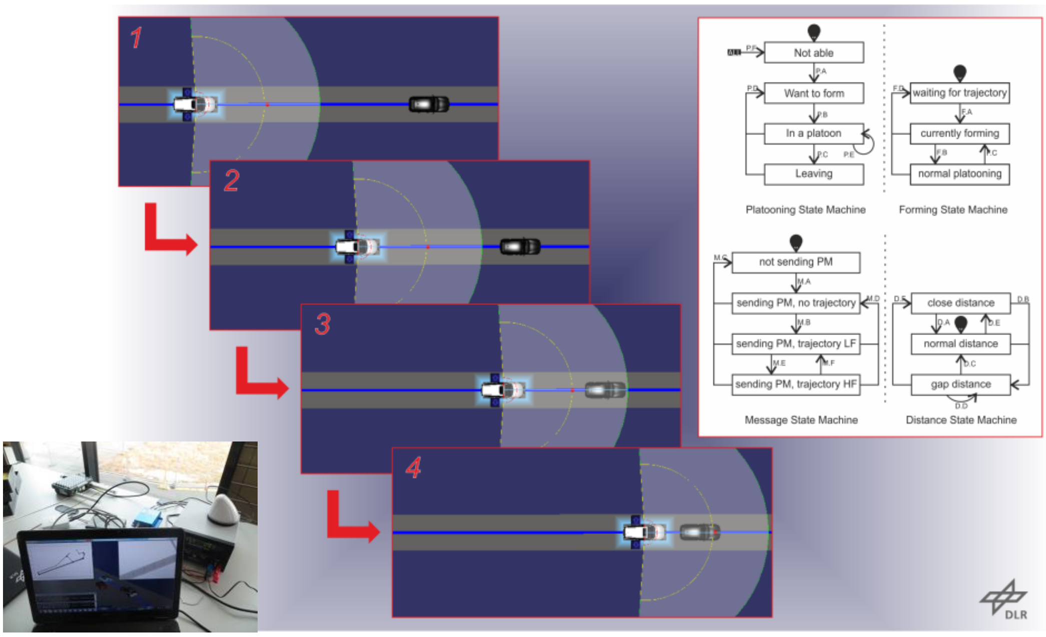


Cooperative Environment Perception

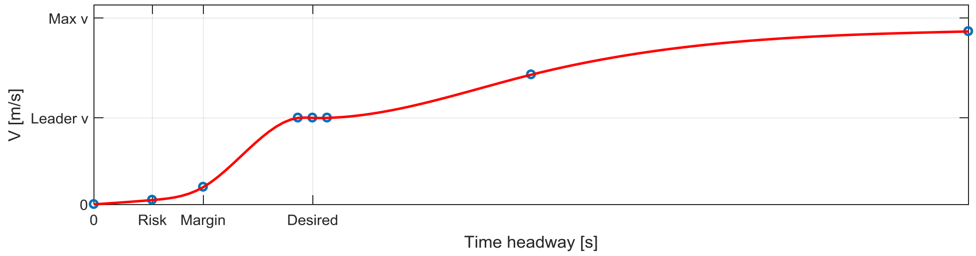


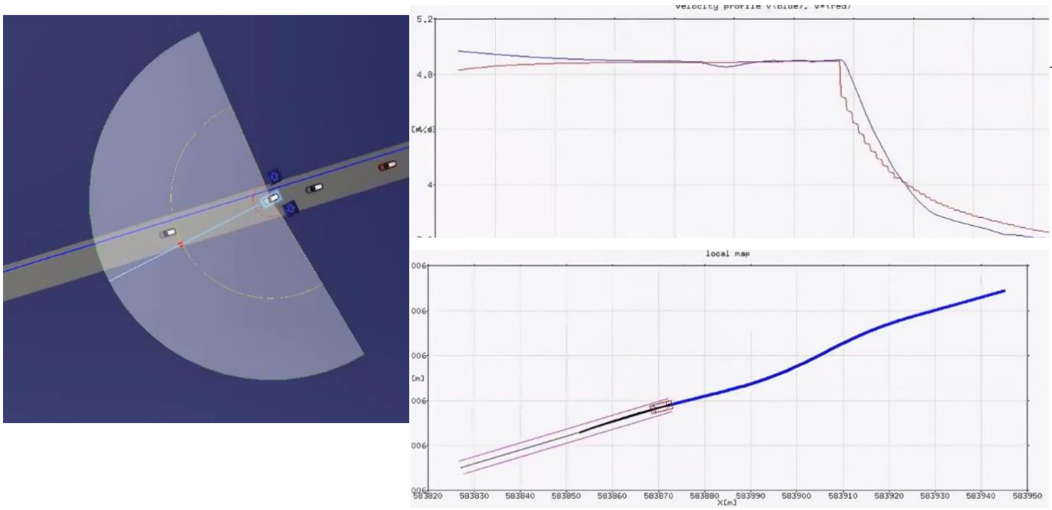
Hyundai developments - simulation of ADAS functions based on V2V CPMs

The main idea of cooperative trajectory planning, is that inputs received via V2X by other traffic participants and infrastructure are also considered in the planning algorithms. Results of cooperative trajectory planning are highlighted in the figures below.

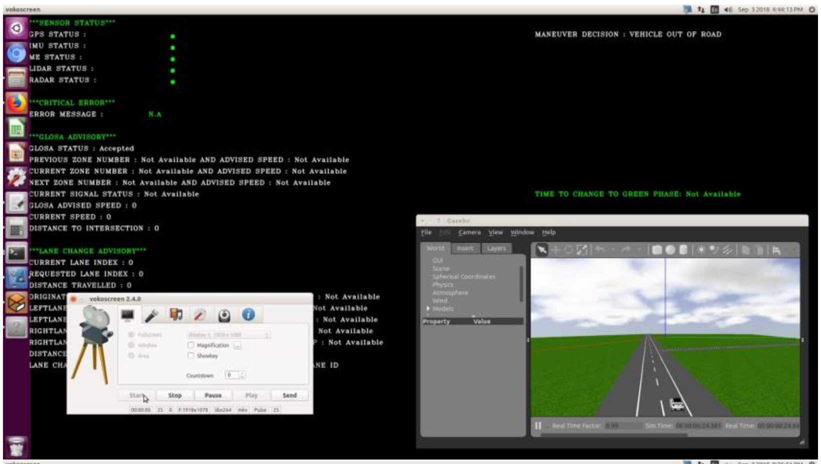


Cooperative trajectory planning

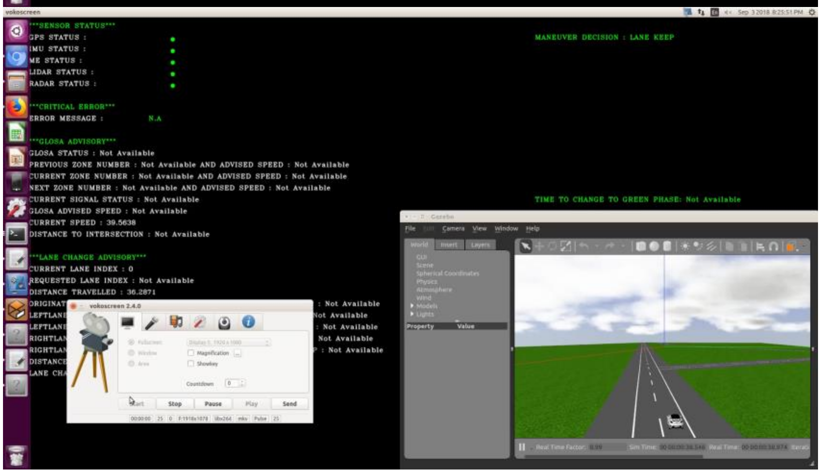




Lane change



Hyundai developments - Simulation of GLOSA on SPAT/MAP



Hyundai developments - Simulation of lane change based on LAM (Lane Advice Message)

Road automation

MAVEN has developed scheduling and signal timing strategy prototype and conducted three demonstrations:

1) Improved countdown stability of the adaptive traffic control algorithm. This has been tested in Groningen, in conjunction with XCycle, which has a special dynamic sign connected to display the countdown. XCycle (Advanced measures to reduce cyclists' fatalities and increase comfort in the interaction with motorised vehicles) is an EU-funded project under Horizon 2020 Research and Innovation Framework Programme.

2) Complete MAVEN system deployed in Helmond. The key element is the external queue model interface and the response of the control algorithm to the new MAVEN inputs. This is demonstrated by equipping a vehicle with a V2X On-board unit communication module transmitting the new V2X messages designed in MAVEN to provide intended turn direction to the algorithm.

3) AGLOSA (Agent-based Green Light Optimal Speed Advisory) system. The algorithm is implemented in SUMO, and is directly running on the traffic control hardware on the street. Therefore vehicles in the SUMO simulation represent real vehicles detected by the road sensors and V2X communications. As a result of these detections, the RSU attached to the traffic light controller provides AGLOSA information to the approaching vehicles.

Please find more details in Deliverable D4.3 "Scheduling and signal timing strategy field prototype", which one can down load from the MAVEN web site.

Enabling technologies

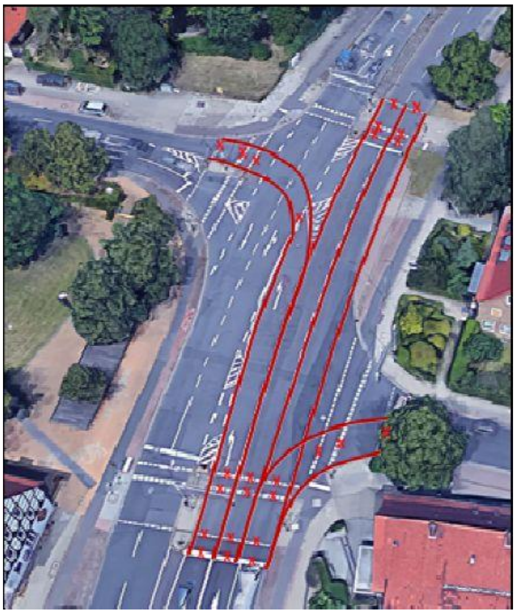
The MAVEN project has developed functions for protection of Vulnerable Road Users (VRUs) and drivers of cooperative automated vehicles. Two classes of solutions are considered in this regard:

i) Individual vehicle sensors data-assisted ADAS: when detection, classification, risk assessment, and reaction rely on information achieved from different sensors of the ego-vehicle only; and

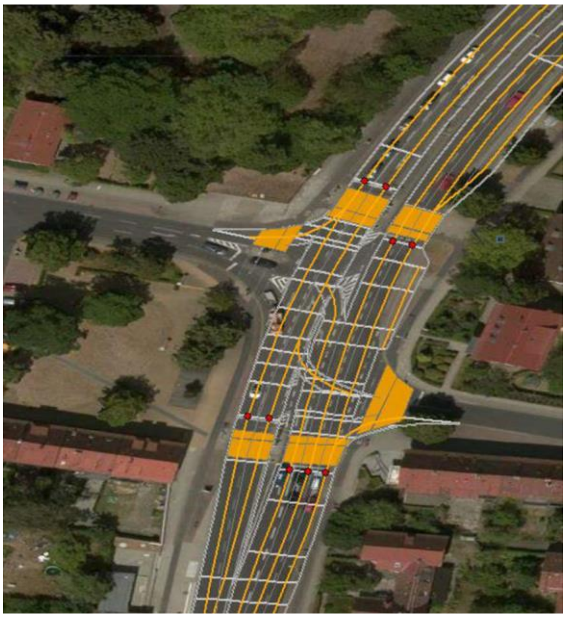
ii) Cooperative sensor data-assisted ADAS: when detection, classification, risk assessment, and reaction rely on V2X information received from other vehicles or infrastructure. The main results are presented in the table below.

Functions for individual vehicle sensors data-assisted ADAS	- Automated vehicle functionality for safe consideration of VRUs and obstacles with application for automated detection and reaction when turning at road intersections. This functionality reduces the risk of collision with VRUs by performing a threat assessment that considers objects detected and tracked by the sensor fusion and crossed with information about drivable lanes and planned route outputs. In parallel, it calculates a feasible manoeuvre and accordingly plans a vehicle reaction in terms of lane change, deceleration or braking. - Automated vehicle functionality for safe handling of situations in which a non-cooperative manually driven vehicle tries to interfere in a platoon of MAVEN cooperative automated vehicles. This functionality allows safely managing such situations by estimating other vehicles' intention to change lane (by recognizing the indicator light setting, or a road topology with merging lanes) and reacts by controlling the safe distance at which a platoon vehicle should follow its preceding vehicle.
Functions for cooperative sensor data-assisted ADAS	- Improved CAV functionality for safe consideration of VRUs and obstacles, with application for automated detection and reaction when turning at road intersections based on V2V CPM receptions. - Improved CAV functionality for safe consideration of VRUs and obstacles, with application for automated detection and reaction at road intersections based on CPM receptions from the cooperative infrastructure - Cooperative intersection functionality for consideration of VRUs interfering with vehicles over an unprotected right turn. This functionality aims at increasing safety by reducing the probability of rear-end collision occurrences as a result of reducing the vehicles' stops when arriving along a lane where other vehicles are queued waiting for a pedestrian to cross. - Cooperative intersection functionality for limiting an uneven distribution of vehicles over parallel intersection-ingressing lanes. The safety advantage here is achieved by preventing large imbalance between parallel queues. - Cooperative intersection functionality for enhanced vehicle probing which supports the previous two functionalities. This new probing approach enhances original loop-based adaptive intersection control by relying on floating car data from MAVEN CAM extensions received from CAVs.

Another enabling technology further developed for the MAVEN objectives are HAD maps. For this purpose an iterative evaluation process has been run through which a suitable level of HAD map precision has been identified to support the MAVEN automated driving scenarios. Commercially available HAD map databases of the designated test sites, provided by TomTom, have been considered. Based on these databases, the requirements for MAVEN vehicle automation in terms of HAD map format extensions have been identified. In particular, the project has detected the need of a "corridor" representation for road intersections as a pair of "virtual boundary lines" that connect the boundary lane markings of inbound lanes to boundary lane markings of outbound lanes. This information is necessary to AD SW system implementations because it indicates the boundaries to respect to perform a given intersection crossing manoeuvre without invading zones where conflicting situations with other road users can occur. With the MAVEN extensions embedded in the reference HAD maps, an evaluation of the impact of the resulting HAD map accuracy on the AD vehicle trajectory and control calculation has been performed. By comparing the results obtained with the new MAVEN extended format with those obtained with the original format, this evaluation demonstrates that the resulting extended HAD maps are suitable for MAVEN automations as they permit trajectory calculation with sufficient quality. As complementary activity, a thorough investigation of the state of the art on HAD map standardization is performed. This investigation permits identifying the minimum set of generic requirements for HAD maps, as well as a comparison with the adopted MAVEN HAD map format and extensions. As a result of this comparison, the MAVEN extensions in terms of intersection corridor approach are identified to be a possible input for standardization.



Ideal MAVEN intersection corridor representation for the Braunschweig Tostmannplatz test site (visualized on GoogleMaps)



MAVEN extended HAD map format for the Braunschweig Tostmannplatz (visualized on GoogleMaps)

Please find more details in Deliverable D5.2 "ADAS functions and HD maps", which you can down load from the MAVEN web site.

MAVEN expert-group meeting

MAVEN held an expert group meeting on 23 October 2018 in Greenwich (London), UK, to validate the MAVNE approach and results and to gather external expert input. Three topics are addressed:

1) Validation and impact assessment of cooperative and automated driving

Participants exchanged experience and best practices in impact assessment of cooperative automated driving, such as simulation tools, user involvement, verification, driver models, critical issues for simulating urban environment with mixed traffic, calibration of the simulation model, scenarios, and (especially safety related) KPIs (Key Performance Indicators).

2) Transition to the traffic management of connected and automated vehicles

The participants discussed the key dimensions to be considered in the phases of transition towards MAVEN from a city authority and traffic managers perspective (e.g. technological, organisational, legal/liability, cultural, financial, and policy), authorities involvement, ideal environment for implementing the MAVEN use cases (e.g. spatial, traffic characteristics, and policy), "low-hanging fruits" (i.e. technologies, use cases, governance models, requiring the least effort and showing a reasonable rate of return in the short-term), external factors to the city authorities that will influence the transition (e.g. vehicle penetration levels, legal framework, and user acceptance), and a scenario that city authorities do nothing

3) Management of connected, cooperative and automated vehicles in smart cities

The discussions under this topic focused on realistic use cases for remote management and control of automated vehicles in cities, new ways to balance demand and supply to manage scarce space and road capacity, new concepts for management of unmanned vehicles (e.g. goods and empty vehicles) and service vehicle (e.g. waste, cleaning and inspection), operationalisation of use cases (by considering pre-conditions, constraints, limitations, and ethics), transferability to passenger transport (including shared vehicles), impact on the shape and form of cities (e.g. land use and mobility), and further research and innovation activities.

Participants extensively discussed related projects, e.g. INTRAMIX, CO-EXIST and TransAID, related projects at Technical University of Delft and in the USA, as well as the further cooperation opportunities.


MAVEN expert group meeting on 23 October 2018 in Greenwich (London)

MAVEN stakeholder consultation workshop

MAVEN hosted the third stakeholder consultation workshop "Automated vehicles and urban traffic management" on 24 October 2018 in Greenwich (London), UK, which was a joint action together with related EU-funded projects TransAID, CoEXist, and INFRAMIX to gather the views and requirements of local authorities and other urban transport stakeholders.


The third MAVEN stake-holder consultation workshop on 24 October 2018 in Greenwich (London)

Mr. Trevor Dorling (Managing Director, Digital Greenwich) introduced Greenwich in the spotlight: Living Lab and MOVE-UK project. Prof. Matthew Barth (University of California) presented recent research results in the USA on traffic management through C-ITS and automated driving, deploying digital infrastructure, and impact assessment. The MAVEN partners provided information about MAVEN, an overview about how automation may change the shape and form of cities, as well as some preliminary results of a survey on impact assessment. In addition, three issues are discussed in parallel sessions:

1) Strategic planning for automated and connected vehicles.
2) The role of the traffic manager in an increasingly connected and automated transport system.
3) Do cities and regions need a traffic technology/ITS strategy?

Main upcoming (joint) events

The main upcoming (joint) MAVEN events are:

- Joint Workshop with TransAID, C-MobILE and IEEE 5G Initiative on "Cooperative and automated driving" at IEEE ITSC (Intelligent Transportation Systems Conference on 4 November 2018, Hawaii.
- Joint Demo with TransAID, in conjunction with European Congress on Intelligent Transport Systems on 3-6 June 2019, Eindhoven/Helmond. (TBC)
- Joint Workshop with TransAID on 9 June 2019, in conjunction with IEEE IV'19 (Intelligent Vehicles Symposium) on 9-12 June 2019, Paris.

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You can also follow us via our

- Web site: www.maven-its.eu
- LinkedIN: *https://www.linkedin.com/groups/8571587/profile*
- Twitter: *@MAVEN_its*

Collaborative Innovation Days

2nd Workshop on Infrastructure Cloud – Operation and Services | workshop 09/06 2017

European Commission

MAVEN

Managing Automated Vehicles Enhances Network (MAVEN)

Introduction

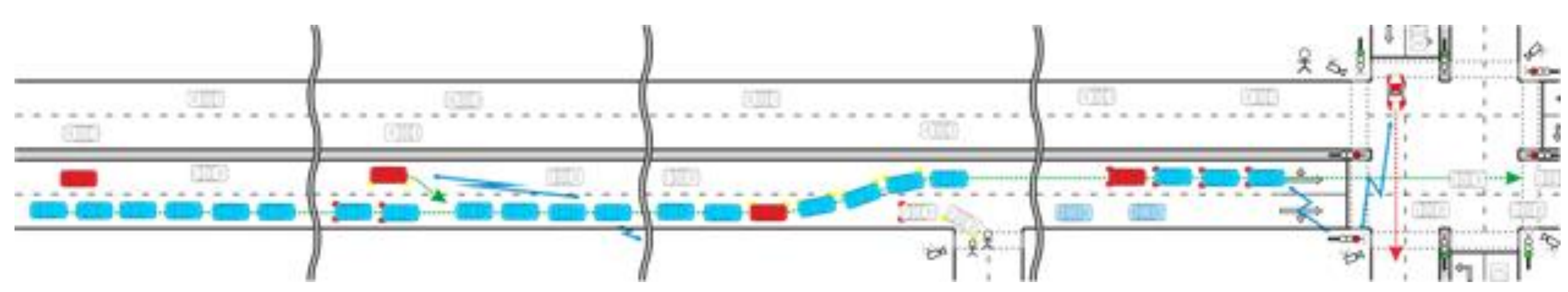
In the future, automated road transport in urban areas will be dependent on connectivity and information exchange between automated vehicles and the road infrastructure. Maven is preparing for this future by researching solutions that will provide:

- Management regimes for automated driving in urban areas
- Monitoring, support and orchestration of movements of road users to guide vehicles at signalized intersections
- Further enhancement for ADAS, C-ITS applications and automated transport

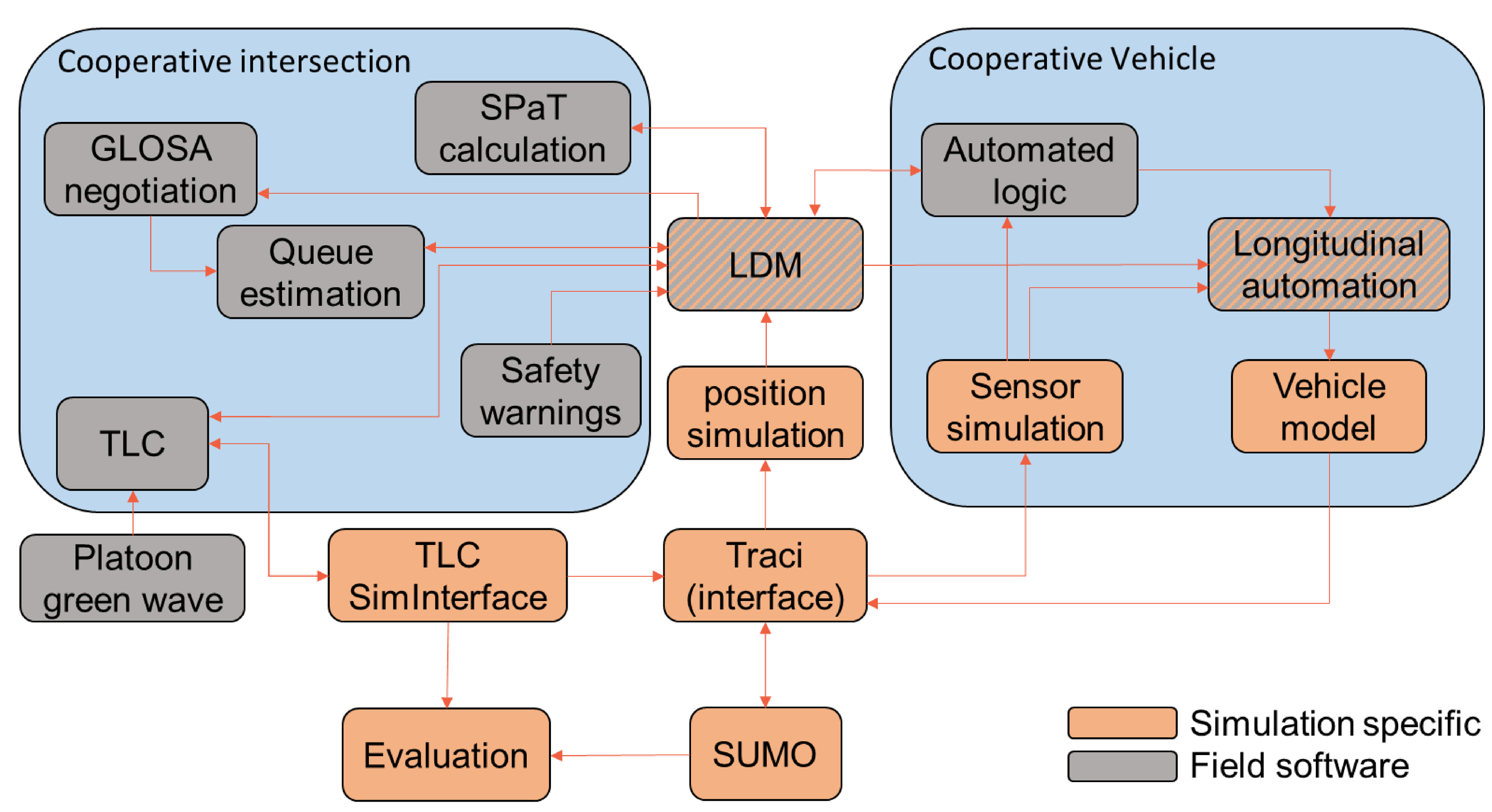
dynniq · DLR · HYUNDAI MOTOR GROUP · ROYAL borough of GREENWICH · POLIS · TOMTOM · CTU Czech Technical University in Prague · MAP TRAFFIC MANAGEMENT · Gemeente Helmond

Use Cases

- platoon orchestration (e.g. initialisation, lane change, termination)
- Green Light optimal Speed Advice
- enhanced queue modelling
- green wave with platoon priority



Architecture



Collaboration opportunities

- Helmond site – All major intersections equipped with RSUs and adaptive traffic control
- Braunschweigh – Extensive infrastructure detection on AIM site
- Simulations – SUMO scenario's Helmond, Braunschweigh, Prague and Greenwich
- Simulation software – Simpla released as open source to simulate CAV vehicle impact c
- Live data availability – Helmond and Braunschweigh RSUs transmit MAP/SPaT Possible to extend to connected through C-MobILE

MAVEN is looking for collaboration!

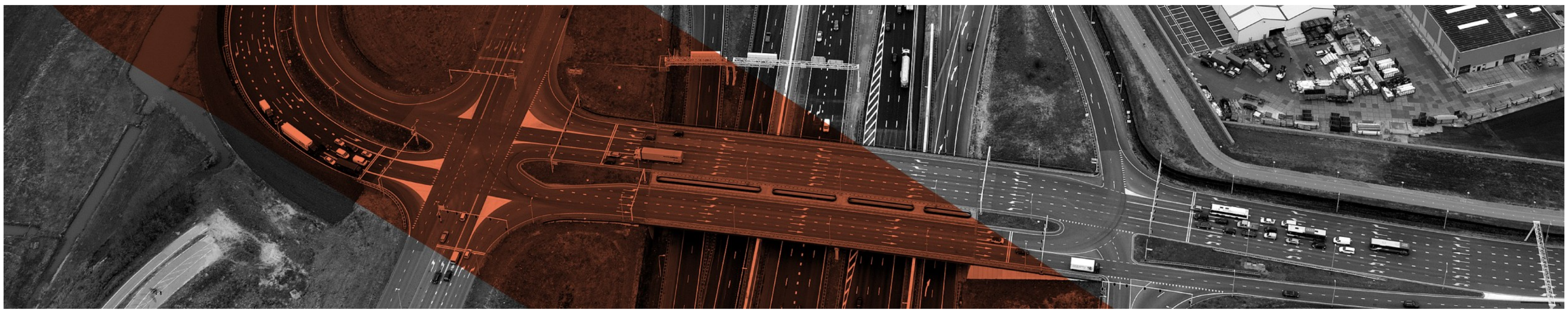
Contact: http://maven-its.eu/

MAVEN

Managing Automated Vehicles Enhances Network

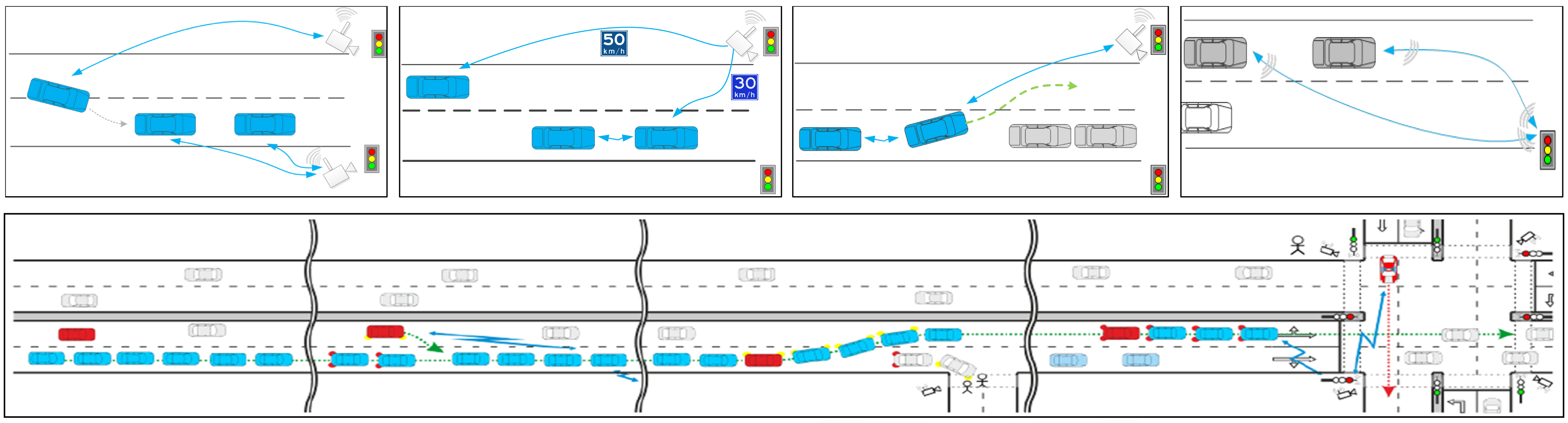
The 3-year EU-funded MAVEN project aims to develop solutions for managing level-4 HAVs at (urban) signalized intersections. It will develop algorithms for infrastructure-initiated guidance of HAVs using negotiation protocols between vehicles and the infrastructure. Iteratively, HAVs receive advice and/or commands from the road infrastructure to adjust their trajectory and maneuvering policies, while the infrastructure dynamically adapts the traffic light timing of single or multiple signalized intersections based on the anticipated vehicle arrival pattern. The MAVEN project will build a system prototype that will be used both for field tests and modelling.

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727



INFRA-ASSISTED AND INFRA-INITIATED USE CASES

- I2V interactions
  - Negotiation (signal timing vs. vehicle arrival pattern)
  - Speed change advisory
  - Lane change advisory
- Platoon management
  - Forming a platoon
  - Joining a platoon
  - Platoon progression
  - Leaving a platoon
  - Breaking a platoon
- Traffic control optimization
  - Signal optimization
  - Priority management
  - Queue estimation
  - Green wave
- Conventional traffic and VRUs
  - Detection of non-cooperative vehicles
  - Vulnerable road users
  - Emergency situations



PROJECT CONSORTIUM

DLR | dynniq energising mobility | HYUNDAI MOTOR GROUP | MAP TRAFFIC MANAGEMENT | TOMTOM | CTU Czech Technical University in Prague | POLIS | Royal borough of Greenwich | Gemeente Helmond

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MAP TRAFFIC MANAGEMENT
www.maptm.nl

MAVEN (Managing Automated Vehicles Enhances Network)

Project Introduction

MAVEN Consortium

November 15, 2016

Robbin Blokpoel, project coordinator

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

European Commission

General information of MAVEN

- **Full title**
  - ✓ Managing Automated Vehicles Enhances Network
- **Project period:**
  - ✓ 01-09-2016 ~ 31-08-2019
- **Funded by EC Horizon2020 Research & Innovation Programme**
  - ✓ Budget: EUR 3,149,661.25
  - ✓ Nine partners from five countries: DE, NL, CZ, BE, UK
- **Main goal**
  - ✓ Enhancing intelligent urban road transport network and cooperative systems for highly automated vehicles

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

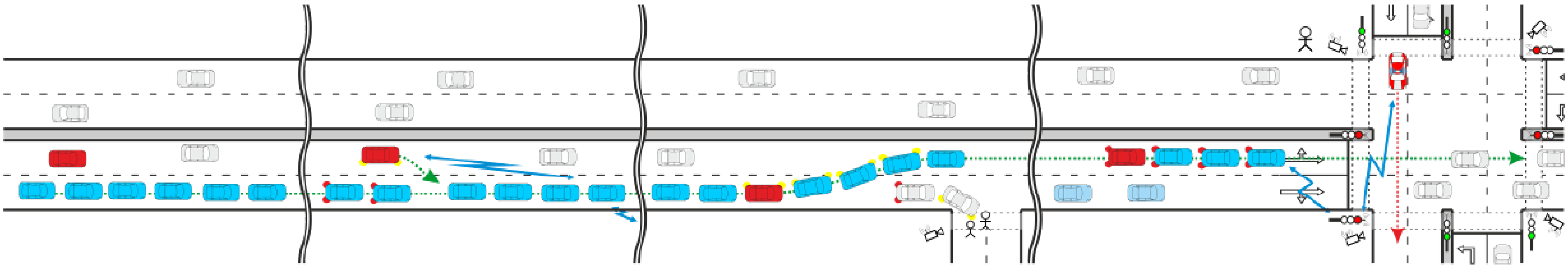
European Commission

Consortium Partners

MAVEN is funded by the EC Horizon 2020 Research and Innovation Framework Programme, under Grant Agreement No. 690727

Project summary

- MAVEN will develop management regimes for highly automated driving in urban areas.
- Road infrastructure will be able to monitor, support and orchestrate vehicle and VRU movements to guide vehicles at signalized intersections and corridors in urban areas.
- With the new possibilities of automated vehicles the project will go beyond the state-of-the-art of Advanced Driver Assistance Systems (ADAS) and C-ITS applications such as Green Light Optimal Speed Advisory (GLOSA), by adding cooperative platoon organization and signal plan negotiation to adaptive traffic light control algorithms.



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Summary scope and concept

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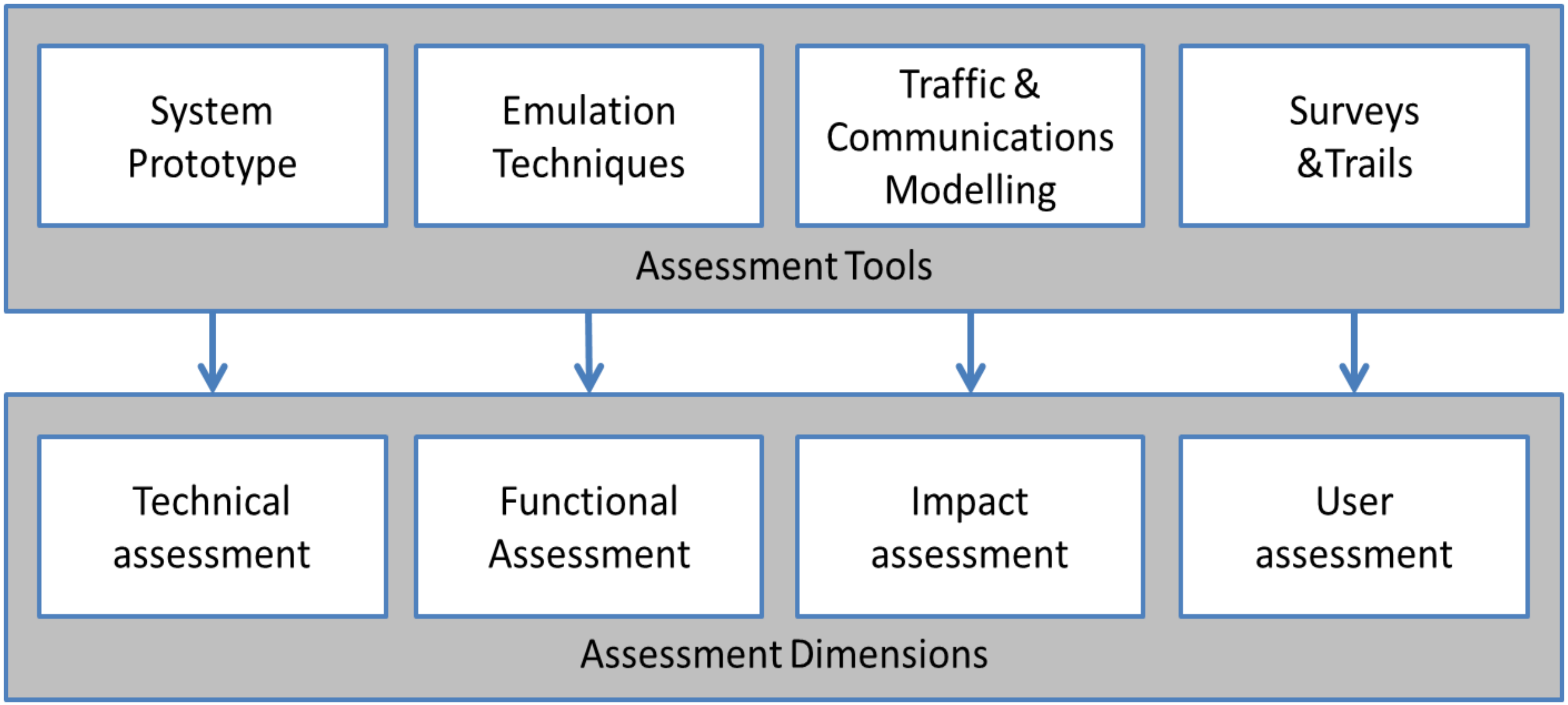
Assessment methodology



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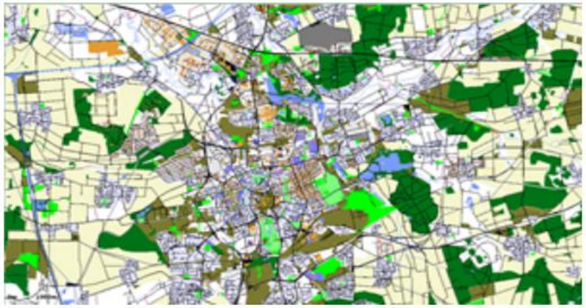
Facilities

- 2 DLR autonomous vehicles
- 2 Hyundai autonomous vehicles
- Braunschweig infrastructure pilot site
- Helmond infrastructure pilot site
- DLR Mobile RSU for controlled tests
- Prague simulation scenario
- Greenwich smart city perspectives
- SUMO simulation software
- Wireless simulation
- Policital support



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Expected impacts

- **Improved efficiency, safety and reduction of emissions**
  - ✓ Reduce fuel consumption and emission
  - ✓ More effective traffic lights and more efficient intersections
  - ✓ Vulnerable road user safety
- **Robustness and performance of sensor and data analysis systems**
  - ✓ Less occlusion, more robust, more reliable
  - ✓ From warnings to directives
- **Development costs, competitiveness**
  - ✓ Standards development (adoption, replication and scalability)
  - ✓ Effective local authority investment decisions
  - ✓ Affordable on-board sensors & cooperative sensing
  - ✓ Effects at low penetration rates

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What does MAVEN mean for …?

❑ MAVEN for OEMs

- ✓ MAVEN cooperative automation is expected to ensure safety by releasing the driver role in safety-critical road network zones like intersections.
- ✓ The collaborative detection capabilities of infrastructure and vehicles would allow the implementation of advanced safety functions for vulnerable road users and drivers protection while avoiding the necessity of expensive sensor technologies.
- ✓ Cooperative platoon organization combined with traffic light signal timing negotiations is expected to increase the efficiency in road usage. This leads to reduction of driving time as well as fuel consumption and emissions.

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What is MAVEN for …?

❑ MAVEN for infrastructure service providers

- ✓ MAVEN addresses the challenge of road infrastructure-based cooperative systems for future transport and traffic management in the urban area
- ✓ Infrastructure service providers will play an important role for future deployment of automated driving managing aspects such as:
  - ✓ Traffic control efficiency and enhanced GLOSA
  - ✓ Safety by sharing VRU and non-equipped vehicle detections
- ✓ MAVEN will not only provide technical solutions, but also solutions that are efficient, cost-effective and based on the needs of local authorities and end users

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What is MAVEN for …?

❑ MAVEN for cities

- ✓ No automation without connectivity!
- ✓ Cities see a huge potential of automated vehicles to support safe, sustainable and affordable mobility systems for all citizens and efficient use of public space.
- ✓ Will only work when vehicles are connected with other road users and are integrated in the traffic management systems of cities.
- ✓ MAVEN is an important step for cities, as it will give good insight in the impacts and requirements in this transition towards integrated, safe and sustainable automated vehicles.

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What is MAVEN for …?

❑ MAVEN for academia

- ✓ MAVEN focusses on most recent and innovative traffic research.
- ✓ Bringing together infrastructure and vehicles in simulation enables accurate cooperative simulation.
- ✓ For real-world prototypes, new emulation techniques will enable building more knowledge about platoons without a large fleet.
- ✓ Most MAVEN results will be published in a freely accessible way.
- ✓ This offers great opportunities for next generation researchers of various fields, particularly engineering, computer science and communication.

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Thank you!

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