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MAVEN

Managing Automated Vehicles Enhances Network

WP02: Generic concept, use cases, requirements and specifications

Deliverable nº: 2.1

User needs, conceptual design and requirements

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Executive Summary

This deliverable provides materials for general and joint understanding of the MAVEN project, mainly its objectives and its scope, as well as descriptions of the use cases and the requirements on the MAVEN system. To that end, this document describes: abbreviations and terminology used, the process of requirements collection and use case analysis, system decomposition, results from stakeholder consultation, use case descriptions and finally system requirements.

The MAVEN project distinguishes the following sixteen use cases, which are detailed in this document:

- 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
- 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
- UC15: Negotiation
- UC16: Detect non-cooperative road users

The entire methodology to capture and manage requirements is provided together with the resulting requirements for work packages 3, 4 and 5.

This document is crucial for all future MAVEN deliverables, as they elaborate on the results of this document. This includes the deliverable *D2.2: System architecture, specifications and verification criteria,* where the architecture is detailed, *D7.1: Impact assessment plan*, where the particular use cases and requirements are tested and evaluated, but of course also all the technical deliverables in work packages 3, 4 and 5.

1 Abbreviations and definitions

Abbreviation / Term	Definition
Acceptance criteria	The criteria that a product must meet to successfully complete a test phase or meet delivery requirements.
Acceptance test	Formal testing conducted to determine whether or not a system satisfies its acceptance criteria and to enable the acquirer to determine whether to accept the system or not.
ADAS	Advanced Driver Assistance Systems
Architecture	The organisational structure of a system, identifying its components, their interfaces, and a concept of execution amongst them.

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C-ITS	Cooperative Intelligent Transport Systems
CAM	Cooperative Awareness Message
CEN/ISO	European Committee for Standardization / International Organization for Standardization
Conflict	Two traffic streams are conflicting and traffic will collide if one does not yield for the other, generally this situation is prevented by traffic lights.
CPU	Central processing unit
Design	Those characteristics of a system or components that are selected by the developer in response to the requirements.
Dynamic green wave	Green wave that is not based on fixed cycle times and offsets, but based on current traffic demand.
EC	European Commission
ETSI	European Telecommunications Standards Institute
FCD	Floating Car Data
GLOSA	Green Light Optimised Speed Advisory
GPS	Global Positioning System
HAD map	Highly Automated Driving map
HGV	Heavy Goods Vehicles
HMI	Human Machine Interface
HW	(Hardware) Articles made of material, such as cabinets, tools, computers, vehicles, fittings, and their components [mechanical, electrical and electronic]. Computer software and technical documentation are excluded.
I2C	Infrastructure-to-car
I2V	Infrastructure-to-vehicle
ICT	Information and Communication Technologies
ID	Identifier
KPI	Key Performance Index
LDM	Local Dynamic Map
MAVEN	Managing Automated Vehicles Enhances Network
OBU	On-board Unit
Partial conflict	In this case a signal group has multiple movements (e.g. straight and right turn) of which one conflicts with another signal group. Common partial conflicts that have green light at the same time are VRUs together with straight/right turn of vehicles and straight/left turn of opposing vehicle signal groups.
PMT	Project Management Team
R-ITS-S	Roadside ITS Stations or roadside unite (RSU) as part of the Cooperative Intersection
ReMP	Requirements Management Plan
RSU	Road Side Unit
Saturation flow	The maximum flow in vehicles per hour that can be achieved. Often used in queue modelling to predict the speed at which a queue discharges during green after 6 seconds of acceleration/ reaction time.
Signal group	Set of signal heads that are always green at the same time. There can be multiple lanes in one signal group, for example 2 left turn lanes will be in the same signal group, but also two directions can be in one signal group when they are on the same lane, like one lane that allows both right, straight and left turns.

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Specification	A document that describes the essential technical requirements for items, materials or services including the procedures for determining whether the requirements have been met or not.
Spillback	Phenomenon that a queue is long enough to block an upstream intersection. Effectively this means switching the light to green upstream will not result in any flow due to the intersection being blocked by waiting vehicles.
SRS	System Requirements Specification
Stage	Set of signal groups that are usually green at the same time. Most traffic light controllers optimize stage-based, but small differences in timing between signal groups can occur due to constraints of the conflict matrix. When one signal group has no more traffic, some control strategies allow alternatives for it during a stage.
Stakeholders	The people for whom the system is being built, as well as anyone who will manage, develop, operate, maintain, use, benefit from, or otherwise be affected by the system.
SUMO	Simulation software (Simulation of Urban Mobility)
SW	(Software). Computer programmes and computer databases.
TLC	Traffic light controller
TMC	Traffic Management Centre
Traceability	Ability to trace the history, application or location of that which is under consideration.
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-anything
VRU	Vulnerable road user
WP	Work Package

2 Introduction

This document provides insight into the MAVEN (Managing Automated Vehicles Enhances Network) project topics that need to be addressed before any further work on the project can be carried out [1]. First, the project itself is introduced and justification is given with respect to its focus (highly-automated vehicles communicating with intelligent infrastructure), motivation and objectives. Second, in order to define scope and detailed future work assignments, the project is decomposed using the system theory approaches and its main interfaces are identified. Finally, to ensure that the project reflects the needs of its future users, collection of these needs and their elaboration into requirements and use cases is provided.

2.1 Structure of this document

This User Needs, Conceptual Design and Requirements Plan contains the following chapters:

- Introduction – providing a short overview and objectives of this document.
- Conceptual design – focusing on project introduction and system decomposition as well introduction of the MAVEN project.
- User needs and requirements management plan –describing how the requirements and use cases have been collected as well as reporting one important step - Stakeholder consultations.
- MAVEN Use Cases – listing the high level functionality which is in scope of the MAVEN project and providing dependencies among the Use Cases
- MAVEN Requirements – listing requirements which will be covered by the MAVEN project
- Conclusions
- Appendix A – MAVEN stakeholder consultation
- Appendix B – MAVEN Use Case Descriptions
- Appendix C – Traceability of Use Cases and Requirements

2.2 Objectives of this document

This document has several objectives. First, in the conceptual design, the following issues are addressed:

- Motivation for MAVEN project
- Objectives of MAVEN project
- High level system decomposition together with main interfaces

The main objective of the system concept is **to provide a general and joint understanding of the MAVEN project**, its objectives and its scope. It should allow the MAVEN project partners as well as the different MAVEN stakeholders to gain a common understanding as a basis for further specifications. MAVEN stakeholders include, but are not limited to, users (“drivers” and other city traffic participants), decision makers, city authorities, city service organizations, scientific and general public or company representatives.

Next objective is **to provide descriptions of the use cases** (high level expectations of the MAVEN stakeholders) **and** the particular **requirements** on the MAVEN system. This is an important part as it is the basis for further specifications and technical solutions. In this part, the process for user need and requirements collection is provided (Requirements Management Plan) and next, the MAVEN requirements are listed and discussed.
The requirements are solution independent (they address the needs of the project and not the solutions). However, they will be addressed by the particular Work Packages (WPs) where a suitable solution must be developed and provided.

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Readers of this document should have a joint understanding about:

- The scope of MAVEN project,
- the terminology in the project,
- the major subsystems in MAVEN and
- the basic functionality (through use cases and requirements).

3 Conceptual design

The first two paragraphs of this chapter are based on the MAVEN project proposal as it addresses the motivation and objectives of the project. In order to reach these objectives, MAVEN as a system is defined and a high-level decomposition is performed.

3.1 Motivation for the MAVEN project

Highly automated and fully automated vehicles, connected with an intelligent environment, could significantly contribute to meeting the EU objective of reconciling growing mobility needs with more efficient transport operations, lower environmental impacts and increased road safety. The coming years will see an increase in the automation of driving tasks and the introduction of highly automated vehicles, with the role of the human driver diminishing. At the same time, the deployment of Cooperative ITS technology (C-ITS), will not only be a key enabler for distributed coordination of highly automated vehicles, but combined with intelligent traffic management and control applications will also enable road infrastructure to monitor, support and orchestrate vehicle movements [2, 3].

To date, in most C-ITS applications, communication capabilities have predominantly been used in a unidirectional manner, enabling dedicated features at the receiving end. For example, vehicles receiving Cooperative Awareness Messages for collision avoidance applications or vehicles receiving Signal Phase and Timing data for trajectory planning applications. Actual cooperation between two communicating entities - based on two or more applications operating bilaterally - has been rare. What if two vehicles about to use the same scarce infrastructure resource were to negotiate their respective trajectories simultaneously, or if a traffic light and a vehicle would negotiate their signal timing and trajectory respectively? Moreover, the rapid progress currently being made in network and satellite technologies - in network latency and geospatial accuracy - is making it increasingly feasible for highly automated vehicles to interact reliably with pervasive infrastructure systems. Intelligent infrastructure can provide these vehicles with a wider awareness of road capacity, signals and other road users in the context of their planned journey [4].

Though vehicle technologies related to self-driving, fully or highly automated vehicles receive most of the attention of the general public, the foundation of the MAVEN project is that infrastructure applications will continue to play a vital role in the management of the traffic network. Similar to today's operation of traffic networks, traffic management and traffic control systems will have a coordinating, orchestrating and sometimes dictating influence on traffic flow and dynamics in support of societal and collective objectives. However, with the increasing autonomy and self-organizing capabilities of vehicles, the need for weighty involvement of infrastructure applications shifts to infrastructure-initiated scenarios which are further implemented by vehicles [5, 6]. For example, infrastructure applications may organise the formation of dynamic platoons, set targets for such platoons, but leave the details of its progress to the platoon as a self-organising unit. In MAVEN and as opposed to road trains, dynamic platoons exist on the fly and have a collective intelligence that is able to negotiate internally and externally and then make a collective decision. As such platoon leader is a position and not a management role meaning the platoon leader is the vehicle in front but is not necessarily in charge. In the remainder of this document 'platoon' refers to a dynamic platoon as defined here.

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3.2 Objectives of the MAVEN project

To bring the potential of cooperative automated driving at signalized intersections and corridors into reality, the MAVEN project explores the paradigm of a hierarchical self-organizing system: multi-level, top-down guidance of self-organising dynamic platoons of cooperative automated vehicles. With this approach, MAVEN fosters road transport automation at different interfacing levels as depicted in Figure 1. This figure also suggests the focus of the MAVEN project. While it covers topics from the Cooperative Vehicle and Traffic Management Centre (TMC) perspective, it focuses mainly on the management of automated vehicles, i.e. on the Cooperative Intersection (CI) level.

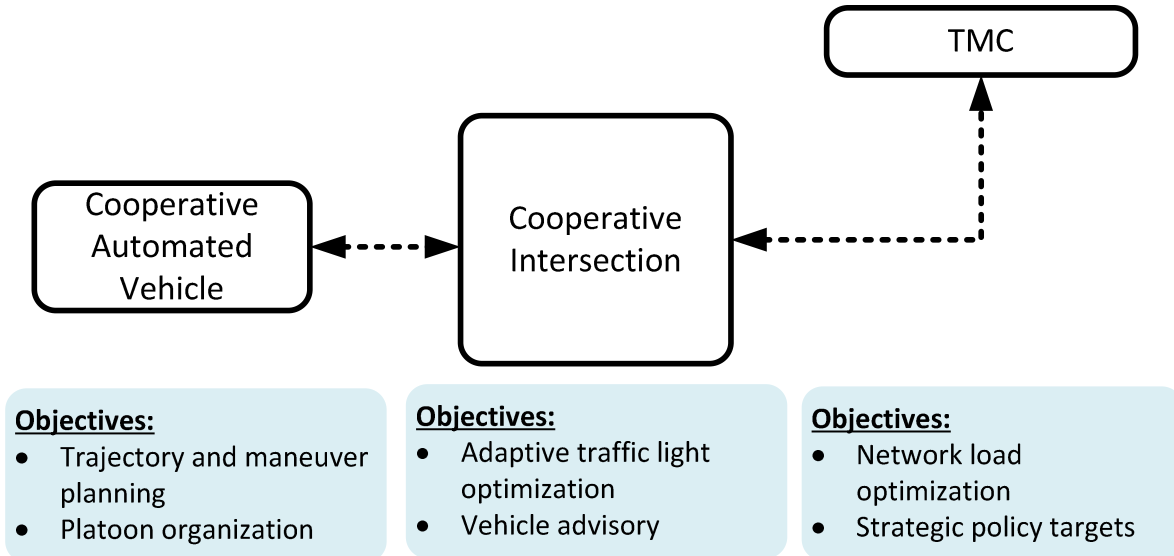

Figure 1 MAVEN hierarchical self-organizing road transport concept

The originality of MAVEN is to develop and exploit cooperative automated driving applications at the crossing of (1) infrastructure versus vehicle systems' authority; (2) global versus local and societal versus individual users' objectives, and (3) traffic light optimization versus vehicle trajectory and manoeuvre optimization. This contributes to maximising the economic benefit of traffic flow while reducing energy consumption and environmental impact as well as ensuring traffic safety. Beyond the level of intersections and corridors, MAVEN will cyclically adapt routing strategies for automated vehicle clusters to local conditions and control strategies and vice versa. On the vehicle level this may imply for example automated lane change manoeuvres and automated detours. To complement this system, MAVEN will develop optimised ADAS technologies that exploit the benefits from integration with traffic management and infrastructure, and allow further simplification of the vehicle interface in order to reduce human error. The objectives of the MAVEN project are the following:

- Develop a generic multi-level system for the guidance of highly automated vehicles, applied to dynamic platoons at signalized intersections and signalized corridors. The system supports decentralized management functions at both vehicle and infrastructure level, with vehicles and traffic systems operating as interacting agents. At vehicle level, examples of such functions are infrastructure-assisted organization of dynamic platoons and platoon progression. From the road infrastructure perspective, adaptive traffic light control solutions based on cooperative vehicular data are considered. These functions will be based on transport policy goals, constraints and targets set in a top-down manner and weighted against local conditions and individual road users' preferences.
- Contribute to the development of C-ITS communication standards, in particular message sets for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) interactions to support vehicle platooning and negotiation and scheduling algorithms. Additionally, MAVEN aims at exploiting

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the increased accuracy and robustness of satellite navigation systems as well as high quality maps by harvesting lane-dependent state information and providing traffic light optimisation and guidance to vehicles with lane level precision.

- Develop and integrate ADAS techniques to prevent and/or mitigate dangerous situations taking into account Vulnerable Road Users (VRUs, e.g. pedestrians and/or cyclists). A mix of on-board vehicle sensors, infrastructure sensors and V2X communication will enable detection of VRUs. In safety critical situations, information about VRUs presence will affect vehicle manoeuvre algorithms and infrastructure management policies.
- Develop, test, demonstrate and evaluate the MAVEN system for signalized intersections and signalized corridors, including local level routing strategies, traffic light optimization and trajectory planning, by means of a real-world prototype vehicle and traffic simulation studies. Additionally, compare this MAVEN system to alternative approaches, such as bottom-up self-organization, and demonstrate that the MAVEN system is capable of improving network performance, energy use and safety, while increasing drivers' satisfaction.
- Produce a roadmap for the introduction of MAVEN-type systems. Identify 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 automated vehicles.

3.3 Expected impact

This section summarises the added value of the MAVEN project to specific categories as well as the added value to stakeholders and the H2020 programme (call MG3.6. specifically). This section deliberately does not repeat impact estimates from literature or earlier projects as impact figures are heavily dependent on the baseline conditions and situational variables. Subject to these, effects on for example throughput, delay and emission generally range from zero to as much as 25 % [7, 8]. However, consensus seems that C-ITS applications and more sophisticated traffic light control optimization will yield positive benefits, especially if synergies are found and exploited [9]. By excluding the human factor in the dynamic of these systems, highly automated driving are expected to increase the effectiveness even further. The sections below will mainly address the wider contribution and relevance of the MAVEN concept and methodology, especially to cities.

3.3.1 Improved efficiency, safety and traffic flow and reduction of emissions

- Balancing a traffic network is well established in theory. User-equilibrium is, however, by its nature non-optimal, while system-equilibrium has been a non-achievable target. Automation can shift network balancing towards system-equilibrium, which leads to a better use of the existing infrastructure capacity and increasing it, while reducing environment impact.
- Earlier research as part of the eCoMove project as well as other projects showed that adaptive (cooperative) traffic light control and trajectory and manoeuvre planning both can reduce fuel consumption considerably. Moreover, a simulation study showed that when combined, assuming 100 % penetration rate and perfect user compliance, the impact was considerably larger than the sum of both systems alone [10].
- Platoon organization in parallel to signal timing negotiation will lead to denser vehicle platoons passing traffic lights in more effectively utilised green windows. This will increase lane utilisation and reduce delay time.
- Trajectory and manoeuvre planning result in more homogenous driving and a reduction in the number of stops at traffic lights. This primarily decreases emissions but also reduces delay time and benefits the comfort of individual vehicle drivers and passengers.
- The combined intelligence of infrastructure and vehicles can decide on a very low-latency response which will benefit the safety of VRU's in particular.
- The MAVEN approach improves the prediction of the traffic state significantly, which will decrease time-loss due to non-optimum decision making by the intersection control.

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3.3.2 Robustness and performance of sensor and data analysis systems

- The distributed and cooperative sensing approach envisioned by MAVEN will overcome the intrinsic limitations of the current on-board sensor technologies such as occlusion, especially in case of vulnerable road users. Cooperative use of vehicle and infrastructure sensing capabilities will ensure more robust and reliable decisions exploitable by ADAS and automated driving.
- From a road operator's viewpoint, several projects have explored advice and hazard information based on a cooperative infrastructure. With increasing automation and MAVEN's negotiation approach, warnings can evolve into directives as the probability of improper responses diminish.

3.3.3 Optimised HMI and advice strategies

- The MAVEN approach will enhance the range of the vehicle sensors and therefore enhance the "situation awareness" of the automated vehicles. This leads to a broader scope of action for the individual automated vehicle and therefore to better informed and more effective advice strategies.

3.3.4 Development costs, competitiveness and breakthrough technological solutions.

- MAVEN will contribute to replication and scalability of solutions for urban transport automation by making use of further development of international standards. These include the MAVEN platoon management and negotiation use cases, the traffic light adaptation techniques, the adopted C-ITS message sets, the traffic data collection schemes, and the cooperative sensing and ADAS techniques.
- From a city and a road operator perspective, the MAVEN approach ensures that current and investments in the next coming years in C-ITS infrastructure done by public authorities will not become obsolete, but on the contrary will pave the way for future deployment of automated road transport. Thus, investments in C-ITS infrastructure will enable large scale deployment of C-ITS services and accelerate road automation
- MAVEN aims at high performance ADAS solutions based on a mix of affordable on-board sensors and a distributed cooperative sensing approach. By decreasing the requirements of sensing precision of vehicles, MAVEN will stimulate a shift towards cheaper designs which in turn will foster the adoption of automated vehicles of different classes.
- By the cooperation between traffic lights and individual vehicles, MAVEN will provide benefits for vehicles equipped with communication hardware even at low V2X penetration, as already a single equipped intersection will benefit from the movement of the equipped vehicles.
- MAVEN intends to build on the top of the European standardization results of the C-ITS Release 1 provided by ETSI and CEN/ISO as part of mandate M/453 of the European Commission and provide inputs for the extension and development of the currently underway C-ITS Release 2 supported by the European Commission Rolling Plan for ICT Standardization.

3.3.5 Stakeholder perspectives

This section summarizes the stakeholder business perspectives of MAVEN. The term stakeholder an individual, group, or organization who may affect, be affected by or perceive itself to be affected by a decision, activity, or outcome of a project (PMBOK guide – [11]). The different perspectives of the most relevant MAVEN stakeholders are provided below:

- **Cities** face the challenge to ensure mobility of their residents without traffic jams, unnecessary delays and accidents. Building a new infrastructure is for most cities not the first option, because of lack of space, financial constraints and unwanted environmental impact of attracting even more car traffic. The solution lies for many cities in a combination of a shift towards more sustainable modes of transport and at the same time optimisation of the use of the existing infrastructure. Examples in the city of Helmond (NL) showed a 20 % increase of road capacity by optimisation and innovation of the traffic light network. Optimisation of the

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road network will remain a key focus also in the next decades with the introduction of automated road transport and in view of the fact that cities are increasingly reassigning road space to other modes (cyclists, public transport, pedestrians, etc.). Cities will therefore need instruments to ensure that also in mixed (automated/non-automated) and automated traffic scenarios the optimisation of the existing infrastructure is not lost. Adoption of the MAVEN approach will offer them: (1) improved traffic flow and lower environmental impact supports growth; (2) improved safety lowering societal costs and increasing attractiveness and (3) increased network performance reducing the need for extra physical road infrastructure. Finally, new opportunities arise, such as MAVEN 'as a service' to facilitate, schedule and prioritize based on road user type at a certain location, time of day and travel purpose. Public transport is likely to be an early adopter of automated driving. Especially Public Transport (PT) could benefit from smooth guidance through city road network and thus increasing attractiveness of public transport for users and lowering operational costs. Also, Heavy Goods Vehicles (HGVs) could be handled as special road user types with special level of priority. Better flow of HGVs on main corridors through the city could improve the network performance. On the other hand, lower priority for HGVs on not desired routes could be an effective way to truly manage traffic flows according to the city's mobility policy without the need of a costly enforcement.

- **Vehicle drivers and road users** will experience: (1) improved quality of driving and fuel saving through enhanced traffic flow; (2) improved comfort for individual drivers due to automated and more homogenous driving on urban corridors and (3) improved safety for drivers and other road users (e.g. VRUs) by enhancing the sensor range.
- **Vehicle-makers** will be able to provide new safety, efficiency and comfort functions for their customers and enhance competitive advantage. Offering MAVEN-compliant services to customers will result in a better reputation as a provider of enhanced functions for safety and comfort to enjoy the time spent in a car.
- **Infrastructure service providers** will enter a higher value business compared to a classical hardware-oriented business and will be able to offer intelligent intersections as a service based on Service Level Agreement (SLA) in line with their policy objectives.

Apart from positive benefits, there are also potential barriers and intermediate scenarios which will influence and possibly temper the aforementioned impacts. For example, the framework condition regarding mixed traffic, i.e. a mix of highly automated and non-equipped conventionally driven vehicles. MAVEN will address this scenario and similar ones in the traffic simulation activities (WP7) as well as in the development of a transition roadmap (WP8).

3.3.6 Users of the results of MAVEN project

Users of the system are in general **local authorities and road operators**. They will profit from the use cases as they are related mainly to a cooperative intersection. They have been addressed in the different workshops and stakeholder consultation meetings through the entire project duration. Their responses are qualitative.

Additionally, to demonstrate impact of the system, we will also address different so-called target groups:

The **participants of the field tests and demonstrations** will be addressed using a short survey. Here different questions will be asked to the perception and behaviour in the field test. The number of the drivers as well as passengers in the test vehicles is rather low (expected less than 25) and the results serve only for qualitative analysis.

Additionally, **general public**, i.e. future users of autonomous vehicles and participants of the traffic (drivers of conventional vehicles, VRU and others) will be addressed through an online survey.

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Due to the nature of the survey distribution, this group will also include some experts, city authorities and people interested in the topic of autonomous driving. They are however not targeted primarily. The results will be quantitative.

3.4 High level system decomposition

In order to be able to describe the particular components and their interactions in more details, we provide few essential definitions adopted within this document:

System – a set of MAVEN subsystems cooperatively interacting for the realization of the MAVEN use cases

Subsystem – a component of the MAVEN system dedicated to the active implementation of the functions needed to realize the MAVEN use cases.

Actor – an external entity (person or system) interacting with one or more MAVEN sub-systems and needed for the realization of the MAVEN use cases, but not contributing with active implementation of dedicated functions.

Interface - defines the way MAVEN subsystems interact with each other or with external entities.

Based on the definitions, this chapter provides a high level decomposition of the MAVEN system, mainly the

- MAVEN subsystems,
- MAVEN actors (i.e. entities interacting with the MAVEN system), and
- MAVEN interfaces

as depicted in Figure 2.

Together, they define the scope of MAVEN (denoted through MAVEN boundary in the figure).

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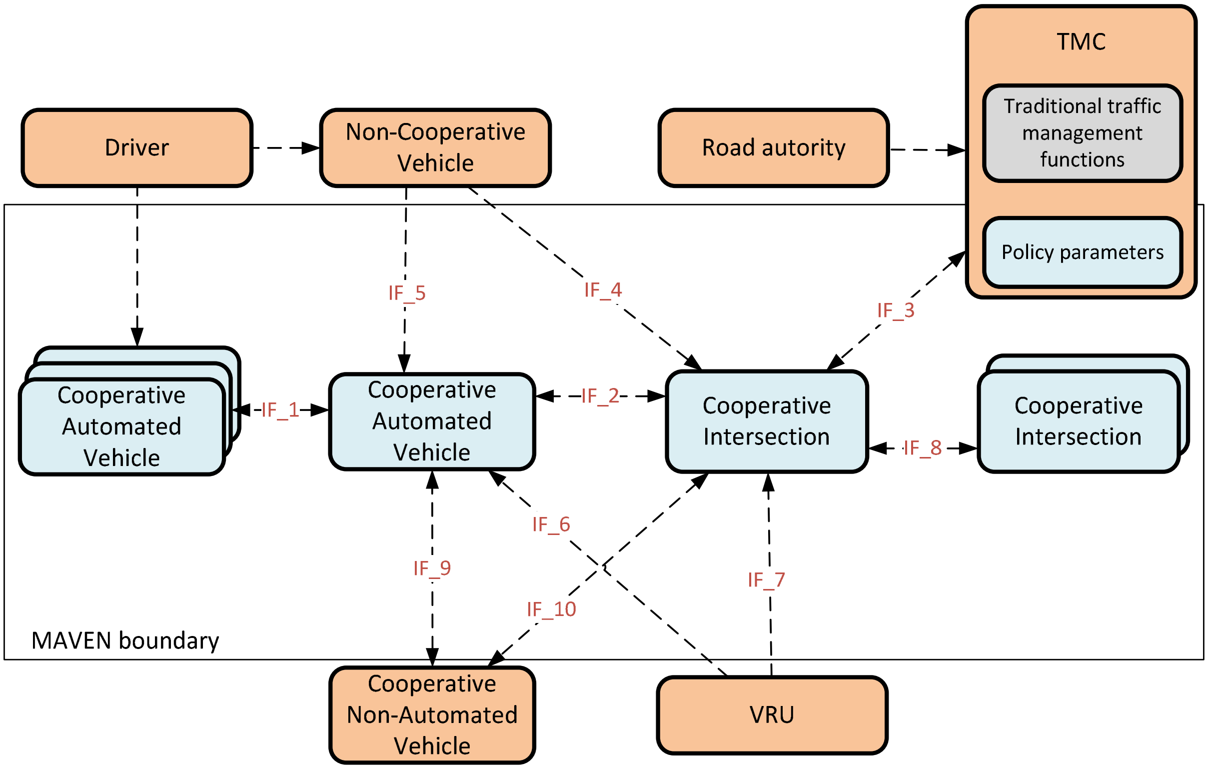

Figure 2 MAVEN – High level system decomposition and main actors (MAVEN subsystems on light blue background, for MAVEN actors on orange background)

Please note, that more detailed system architecture is the content of deliverable 2.2: "System architecture, specifications and verification criteria", where more detailed architecture as well as description of particular subsystems are provided.

3.4.1 System decomposition – Subsystems

Figure 2 shows the high level decomposition of the MAVEN system. Actors with which the MAVEN system interacts are placed outside the MAVEN boundary. Inside the MAVEN boundary are Cooperative Automated Vehicles (CAVs) and Cooperative Intersections. Note that properties like platoon and roles such as platoon leader and follower do not imply distinct subsystems.

Cooperative Automated Vehicle - A CAV is assumed to be an ETSI ITS G5 (ETSI EN 302 663) equipped vehicle with automated driving capabilities. In this sense, it is an improved version of a cooperative vehicle. It uses vehicle sensors and V2X receptions to monitor the surroundings of the vehicle, and V2X communications to interact with other cooperative vehicles, CAVs and with CIs. It uses the acquired flow of information for trajectory and manoeuvre planning, platoon organization and implementation of improved ADAS functions. A CAV can be any type of vehicle, for example a car, bus or truck and any vehicle class, for example a regular passenger vehicle, priority vehicle or emergency vehicle. Multiple CAVs may form a platoon and assume one out of two roles: platoon leader or follower. The platoon leader interacts with the environment on behalf of the platoon, whereas the followers primarily interact with the platoon leader.

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Cooperative Intersection - A CI is assumed to be an ETSI ITS G5 equipped traffic light controller at a signalised intersection. Besides infrastructure sensors such as inductive loops and cameras to detect any type of road user, it uses V2I communication to exchange data with cooperative vehicles and CAVs. The CI uses the flow of information for the adaptive optimisation of the timing of traffic lights while taking into account policy parameters (including priorities) and traffic demand (including vulnerable road users). In addition, it uses V2I communication to interact with cooperative vehicles, for example to provide advisory information like speed advice and lane advice. Multiple CIs may be connected to enable traffic light coordination along a specific traffic corridor.

3.4.2 Actors in the MAVEN project

In general the term *actor* refers to those entities (both people and systems) that interact with the system in place, in our case MAVEN. Entities such as cooperative vehicles belong to the scope of the MAVEN project and are thus not listed among actors. Similarly, entities with no direct interaction with the system, but having a potential interest in the MAVEN system, are stakeholders and not actors. Stakeholders are briefly described in section 3.3.5.

In the MAVEN project we identified the following actors:

Non-Cooperative Vehicles (nonCVs) – are those traditional vehicles not equipped with the communication interface. They however still interact with MAVEN system. First, they are detected by the road infrastructure in several ways (cameras, induction loops, floating car data (FCD), etc.) as they form a traffic flow which is one of the most important inputs for the optimization algorithms. Second, they are detected by CAVs by their on-board sensors.

Cooperative Non-Automated Vehicles (CnAVs) – are assumed to be an ETSI ITS G5 equipped vehicle without automated driving capabilities. In MAVEN, CnAV uses V2X communication to announce its presence, status and dynamics to other cooperative vehicles and to CIs. A cooperative vehicle can be any type of vehicle, for example a car, bus or truck and any vehicle class, for example a regular passenger vehicle, priority vehicle or emergency vehicle.

Vulnerable Road Users (VRUs) – are other users of road infrastructure such as pedestrians or cyclists. Safety and traffic optimization are the key aspects to be considered in connection to these VRUs. One of the objectives of the MAVEN project is to increase safety at intersections mainly (but not only) with respect to VRUs. An optimal mix of on-board vehicle sensors, infrastructure sensors and V2X communication will enable detection of VRUs. In unexpected safety critical situations, information about VRUs presence and advanced ADAS techniques will affect vehicle manoeuvre algorithms and infrastructure management policies. VRUs will be also considered in the intersection control algorithms as they influence the flow at the intersection and the general traffic conditions.

Traffic Management Centre (TMC) – aims at providing a strategic guidance to the CIs. This is done mainly through setting of so called policy parameters. Here the strategic importance of certain policies (e.g. priorities of particular vehicle types, optimum signal cycle length and others) aims at improving also coordination among different intersections in an area. Additionally, TMC also collects and analyses data from particular intersections to understand the traffic situation in a larger area and to provide users with traffic information. As Figure 2 suggests, TMC is covered by the MAVEN project only partially. The MAVEN project addresses new issues related to the relevant automated driving policies while the traditional TMC functionalities are out of MAVEN's scope.

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Drivers – Drivers of cooperative as well as non-CVs are interacting with the MAVEN system through their vehicles. They bring in the human factor. While automated driving can minimise their influence on the system, drivers are still important at least in emergency situations. In non-automated vehicles, the drivers play even more essential role as they directly react to the imposed control mechanism and they interact with the vehicle platoons.

Road Authority – is the organization which is able to set and provide the necessary policies needed by the control and optimization algorithms of the MAVEN project. This is done through the TMC.

3.4.1 System decomposition - Interfaces

In the MAVEN system decomposition, only the interfaces between MAVEN subsystems and the identified complementing systems are specified. There are 8 such interfaces:

IF_1: V2V communication between Cooperative Automated Vehicles: interface between cooperative automated vehicles based on ITS G5 wireless communication. In principle it is used for transmission of vehicle-related information such as position or speed to enable the vehicle's detection. It is based on ETSI ITS standards (Cooperative Awareness Messages – CAM). In MAVEN, V2V will be also used to implement the MAVEN use cases (e.g. platooning, cooperative road user detection, etc.). For this purpose, extended and/or dedicated message sets will be developed.

IF_2: V2I/I2V communication between Cooperative Automated Vehicles and Cooperative Intersections: interface between cooperative automated vehicle and cooperative intersection based on ETSI ITS G5 wireless communication. In principle, V2I communication is used for transmission of vehicle-related information such as position or speed to enable the vehicle's detection. It is based on ETSI ITS standards (Cooperative Awareness Messages – CAM). On the contrary, I2V is also used for the transmission of advisory information and traffic light signal timing information is based on SAE standards, for example the Signal Phase and Timing message (SPaT). In MAVEN, V2I/I2V will be also used to implement the MAVEN use cases (e.g. negotiation, platooning, cooperative road user detection, etc.). For this purpose, extended and/or dedicated message sets will be developed.

IF_3: Cooperative Intersection to TMC: the cooperative intersection receives strategic policy targets as input to the adaptive traffic light optimisation. In reverse, the cooperative intersection provides performance indicators related to these strategic policy targets.

IF_4: Detection of non-cooperative vehicles at cooperative intersections: using infrastructure sensors such as inductive loops and cameras, the cooperative intersection detects all vehicles in its vicinity, including non-cooperative vehicles.

IF_5: Detection of non-cooperative vehicles at cooperative automated vehicles: using vehicle sensors which monitor the immediate surroundings of the vehicle, the cooperative automated vehicle detects all other vehicles, including non-cooperative vehicles.

IF_6: VRU detection by cooperative automated vehicles: using vehicle sensors which monitor the immediate surroundings of the vehicle, the cooperative vehicle detects vulnerable road users.

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IF_7: VRU detection by cooperative intersection: using infrastructure sensors like cameras, radars and push buttons, the cooperative intersection detects vulnerable road users.

IF_8: Intersection to intersection communication: exchange of commands, expected signal timing and performance indicators between neighbouring cooperative intersections, which are relevant for the adaptive traffic light optimisation algorithm to enable network optimisation and traffic light optimisation.

IF_9: Detection of cooperative vehicles at cooperative automated vehicles: using V2X receptions, the cooperative automated vehicle detects other cooperative vehicles in its communication range

IF_10: Detection of cooperative vehicles at cooperative intersections: using V2X receptions, the cooperative intersection detects cooperative vehicles in its communication range

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4 User Needs and Requirements Management Plan

Understanding the user needs and requirements is a complex task, which is however essential for a successful accomplishment of the entire project. It must be clearly stated that it is not a one-time task, but an ongoing activity. This chapter describes the user needs and requirements management process.
This chapter establishes a systematic methodology by which the goals of requirements management will be achieved. The plan principally communicates essential information to project participants and helps them and newcomers to quickly understand the processes.

4.1 Motivation

Requirements management process is a very important step within the system lifecycle. It has been proved in practice that a large number of projects fail due to improper requirements management (CHAOS report provided by the Standish Group). The most common problems of improper requirements management are listed below:

- The system may cost more than projected.
- The system may be delivered later than promised.
- The system may not meet the users' expectations and that dissatisfaction may cause them not to use it.
- Once in production, the costs of maintaining and enhancing the system may be excessively high.
- The system may be unreliable and prone to errors and downtime.
- The reputation of the IT staff on the team is tarnished because any failure, regardless of who is at fault, will be perceived as a mistake by the team.

There are also clear economic aspects which should motivate each company to pay attention to requirements management. [12] provides a good overview of the relative cost of change during a project lifecycle as shown in the table below. The table clearly demonstrates the need to capture requirements and to agree on them with the customer in the early stages.

Table 1 Relative cost of change

Phase in which errors discovered	Cost Ratio
Requirements	1
Design	3-6
Coding	10
Development Testing	15-40
Acceptance Testing	30-70
Operation	40-1000

The output of the requirements management process is the so-called System Requirements Specification (SRS). Here, all the requirements are presented in a clear and structured way. The following criteria must be considered for all requirements to achieve the desired objectives. The requirements need to be:

- Consistent – requirements are not conflicting or ambiguous.
- Complete – requirements describe all possible system inputs and responses.

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- Feasible – requirements can be satisfied based on the available resources and constraints.
- Required – requirements are truly needed and fulfil the purpose of the system.
- Accurate – requirements are stated correctly.
- Traceable – requirements directly map to the functions and features of the system.
- Verifiable – requirements are defined so they can be demonstrated during testing.

4.2 MAVEN – System Analysis Process

System Analysis in general is a process of studying a procedure or business in order to identify its goals and purposes and creating systems and procedures that will achieve them in an efficient way. The output of this phase typically consists of requirements, which can be used as a basis for system design. The requirements must be however put into a wider perspective of the whole project. For this reason, prior to collecting requirements, we must focus on needs of the customer/user.

There are two key terms which are essential for understanding the principle described in this document:

User Needs
High-level needs expressed by the client concerning the delivered system. A very high level of detail is not necessarily needed. User needs express basic principles and wishes.

In the MAVEN project, User Needs are expressed through Use Cases.

Requirements
Contrary to user needs, requirements must have a sufficient level of details, as they are also the base for testing. In the MAVEN project, the main steps needed to understand the user needs and to collect requirements are presented in Figure 3.

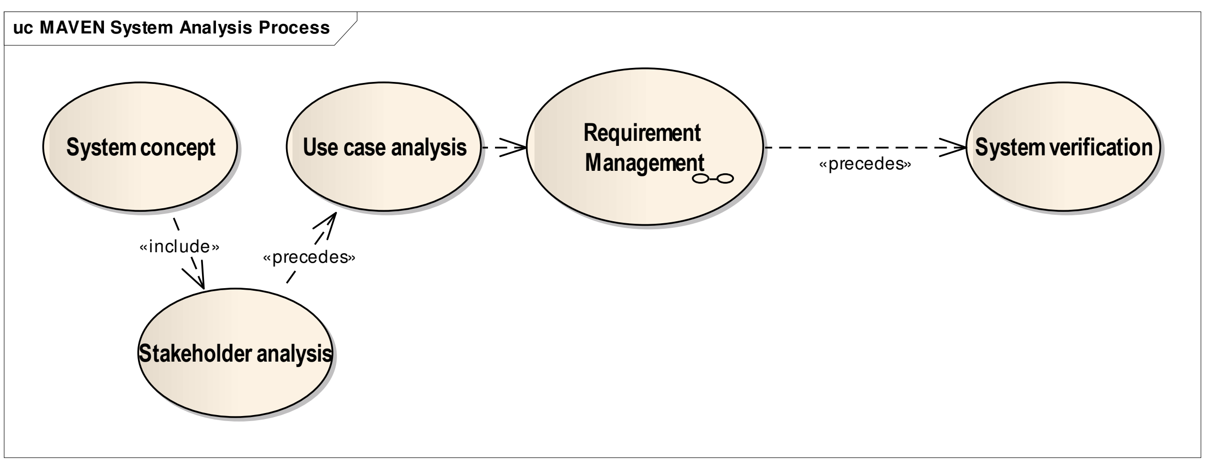

Figure 3 Basic steps in management use cases and requirements in the MAVEN project

4.2.1 System concept

In order to get a qualified input from different stakeholders, it is important to provide an overview of the project objectives, current state and scope of the MAVEN project. These topics were prepared in the MAVEN system concept document and are included as the second chapter of this deliverable.

4.2.2 Stakeholder analysis

In order to get input from the relevant parties, the MAVEN stakeholders have been identified. Since the project team is built mainly by technology-oriented parties, especially the external road authority's and city's perspective was important.

4.2.3 Use Case analysis

A detailed analysis of use cases is provided in Chapter 5. This is an important step as it helps to assure that there will be no missing requirements.

4.2.4 Process for requirements capturing and analysis

The process of requirement management was based on theoretical as well as practical experiences from commercial and research projects. The process of requirements capturing and analysis is depicted in Figure 4 and briefly discussed in the following paragraphs.

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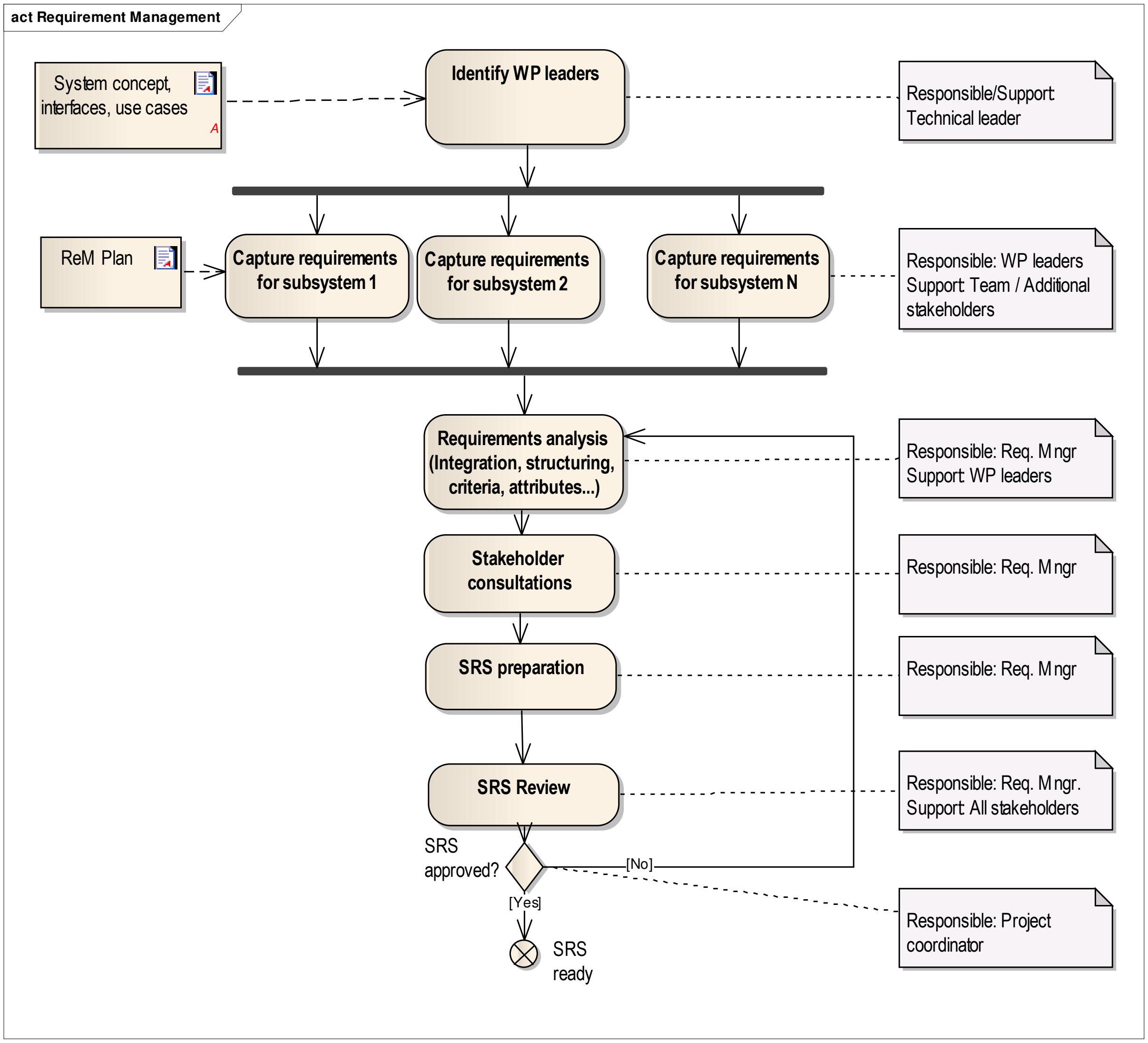

Figure 4 Process for capturing and management of requirements in the project MAVEN

Identify WP leaders

The first task is to decompose the entire system into consistent and homogenous subsystems. This will be broadly based on the particular project's WPs, but focusing on a further level detail is encouraged. The focus will be on use case analysis performed within the WP2. The technical leader of the project will be in charge, but working close with particular WP leaders.

Capture user needs and requirements for subsystem 1

Based on this plan and available MS Excel template (provided by Requirements Manager), the leaders of particular WPs/subsystems will capture detailed features (functions) of a given subsystem. The following steps are recommended:

1. Write down all features/functionalities of a given system (level of user needs – high level functionality)
2. If needed, split certain functionality and provide more details (level of System Requirements - SR)

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3. Add non-functional requirements (for example: Usability - aesthetics, consistency in the user interface, Online/context-sensitive help, wizards and agents, user documentation; Reliability - frequency and severity of failure, recoverability, accuracy; Performance – efficiency, availability, accuracy, throughput, response time; Supportability - testability, adaptability, compatibility, configurability).
4. Aggregate the particular SRs into groups in order to verify the suitability and completeness of the user needs from Step 1.

Template in MS Excel will be used for this step.
Particular WP/subsystem leaders are responsible for this task. Involvement of other stakeholders/field experts is strongly recommended.

Requirements analysis (Integration, structuring, criteria, attributes, ...)

Requirement manager will collect requirements from particular WPs/subsystems and aggregate them into one coherent document. The focus is on the particular criteria as discussed above.
On request, the particular WP/subsystem leaders will be required to clarify/enhance/complete the requirements.

Stakeholder consultations

An important step that will significantly influence the requirements within the project MAVEN is a stakeholder consultation. Here, mainly the municipalities and residents representatives will be asked to provide feedback to the proposed requirements/use cases as well as new requirements.
The MAVEN team believes that it will be more straightforward to involve the residents and municipality representatives after the first system overview is prepared. To work with requirements is often a complex task. For this reason, it is easier (i.e. requires less time) to learn about an existing system and to think about the differences from the expected/target system. In this way, the stakeholders will be consulted in this step. First, the system decomposition and high level use cases will be presented and feedback will be incorporated in the SRS.

SRS preparation

Based on the various inputs, the Requirements Manager will provide the first version of the SRS. This document will have a formal structure and all attributes as well as for example traceability will be included.

SRS Review

The stakeholders will be asked to review the SRS document. In case of any comments, the document/particular requirement will be added or modified.

4.2.5 System verification

It is important to note that the system requirements are not collected just to generate a nice deliverable. They are important in later project phases to verify that the project objectives and goals are met.
For this reason, during the MAVEN system verification phase, verification of the particular requirements will be conducted. The detailed procedure for system verification will be described in the *Impact Assessment Plan* deliverable.

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4.3 Formal Aspects

4.3.1 Tool used for Requirements Management within the project MAVEN

A *MS Excel Template* will be used for capturing requirements by different stakeholders and partners. In this template, the requirements together with their attributes will be made available for further use in the project.

Once collected, the requirements will be imported into a tool *Enterprise Architect* from the company Sparx systems (http://www.sparxsystems.com/products/ea/). This will allow for better visualization of the requirements and their relationships. Using this tool, the requirements will be assigned to particular subsystems and use cases. In this way any missing or conflicting requirements can be identified.

4.3.2 Attributes of requirements

Each requirement will have the following attributes:

ID Each requirement must have a unique ID which allows for its identification.

Short name Each requirement will be assigned a short name. This name does not have to be unique (even though it is recommended). It should describe the nature of the requirement (self-explaining name)

Description This is the description of the requirement. Here it must be specified in a clear way and with a sufficient level of details.

Version In order to allow for tracking of changes in requirements, the version of the requirement will be recorded as well.

Type In order to make sure, which requirements denote functionality of within the MAVEN project, the performance or functional requirements will be distinguished.

Priority The following priorities are managed by the MAVEN project[1]:

- **High** - requirements which have to be covered by the MAVEN system in full. Not meeting such requirement has a critical impact on the MAVEN project.
- **Medium** – requirements which shall be covered, but with lower impact on the final MAVEN outcome. They are not critical for the MAVEN project.
- **Low** – requirements which are good to have and which, if implemented, will increase the customer satisfaction. It has to be decided on the management level whether to implement these or not.

[1] Priorities collected from the MAVEN perspective and not based on the actual impact as perceived in the real world. For example, from the project's perspective requirements related to the accidents of automated vehicles might have lower priority, even though their impact in real world is very high. Accidents are outside of MAVEN's scope and may be better covered in other projects.

4.4 Roles and Responsibilities within Requirements Management

There are many different actors (entities) who actually interact with the requirements management process. The aim of this chapter is to provide a basic overview of the major ones (otherwise, there are many participants who are asked to support the requirements capturing process):

Requirements Manager - is responsible for the design of the entire process of requirements management, i.e. requirements management plan (this document). S/he is also especially responsible for requirement analysis, i.e. selection, structuring and

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resolving conflicts) and participates in all other steps within the process (including fact finding and review with stakeholders).

Field experts - are responsible for the fact finding activity, i.e. the actual content of the SRS.

WP leads - are responsible for the design, review and approval of the requirements. It will be her/his responsibility to implement these and for this reason her/his review and approval is essential.

4.5 MAVEN – Stakeholder consultation

The stated aim of this first MAVEN stakeholder consultation workshop was to discuss and review the preliminary MAVEN system concept, use case descriptions, and assessment and demonstration plan. The workshop audience of 34 persons was made up primarily of local authority representatives (representing 2/3) – 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 disbenefits 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. The complete workshop report is included in Annex A.

Use cases:

- The scenarios should be investigated at both peak and off-peak hour
- The use cases are too technical and should be linked to real world transport problems, such as how to deal with high volumes of tourist buses along specific corridors?
- There should be use cases describing the transition between what we have now and pervasive C-ITS
- Where the business logic/demonstration is held at the higher level (control centre or zonal level), the feasibility of running the MAVEN use cases needs to be explored.
- The viewpoint of the non-automated vehicles and other road users (cyclist, pedestrian) should be described in the use cases

Demonstrations/emulation:

- The effects of different mixes of automated and non-automated vehicles should be demonstrated – especially as non-automated vehicles will predominate for many years
- The emulations should take account of many different scenarios, such as congested conditions, multiple junctions, presence of VRUs (especially cyclists) or specific fleets.
- The viewpoint of the non-automated vehicles and other road users (cyclist, pedestrian) should be described in the emulations
- The city model used for the simulation should be based on a representative network.

Impact assessment:

- The impact of automated driving is likely to beyond the mobility domain, notably toward the freight sector and land use
- There is a need to have a better understanding of the benefits in terms of safety, travel time, environmental effect.
- The infrastructure needs and liability issues have to be clarified and the business case has to be spelt out.
- MAVEN should also address users' (citizens) needs
- Scalability of MAVEN system needs to be addressed, ie, from local junction to city-wide

A snapshot of the other key issues that emerged from the discussion included:

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- **Vulnerable road users/VRU:** the interaction with and impact on VRU (pedestrians and cyclists) is a key consideration for all project activities.

- **Transition phase**: It was agreed that it is safer to assume the co-existence of manually driven and automated cars will be the norm for many decades because some people will drive older (especially classic) cars for many years. Legislation could be used to prohibit older cars but this would need to be implemented across all Member States

- **Human factors**: Concerning the operation of the platoons, there was concern that alerting other road users to the presence of automated platoons could lead to behaviour of trying to disrupt the platoon.

- **Traffic manager's role**:
  - Who makes platooning happen? All actors should be included in the chain
  - General agreement that the traffic manager should be able to communicate directly with an automated vehicle and give directions. Opinions were more cautions on road authorities having an active role in investing to facilitate automated driving as a form of traffic management and on the need for traffic management to become simpler and requiring less interventions. Most agreed that the traffic manager will still be needed despite the fact that automated vehicles may manage themselves as a system.
  - General support for the assertion that traffic management will become more strategic in the future, translating policy goals into operations, and that while more operational decisions will be made by systems, these will be guided by policy.
  - It should not be overlooked that traffic management systems are mainly installed in big cities; smaller cities do not tend to have them.

- **Deployment**
  - What happens at the administrative boundaries especially where one area has not implemented the system? This could be mid-way along a road.
  - What happens in case of malfunction?
  - Who is going to pay for automation especially as a drop in income from parking fees is anticipated when full automation is there?
  - Financial resources can vary differently depending on the size of a city: generally, the bigger the city, the more resources and skills available to invest in new technology and systems.
  - There was general agreement that current C-ITS investments are not a waste of money
  - All investments have to be future proof. Cities are concerned about making investments now and having to upgrade systems later – standardisation link
  - Overwhelming support for potential of automation in public transport, followed by taxies and delivery services. The reality of what cities want to happen and what will happen is quite different: automated private cars will be on the road on a larger scale than public transport and technology will develop quicker than cities have time to react and quicker than they can adapt their infrastructure. Market forces will push cities down a route faster than they can follow
  - Automation has to be implemented incrementally for public acceptance reasons.

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5 MAVEN Use cases

5.1 Definitions

For making use case descriptions the MAVEN project adopted the following definitions [13]:

- **Situation**: describes relevant scenery (everything present within a static snapshot) considering (driving) function-related goals and values.

- **Scenario**: describes temporal development in a sequence of situations (e.g. initial and after) based on events and actions. It is story telling.

- **Use case**: function of the system, the desired behaviour (of the system and actors), specification of system boundaries and definition of one or more usage scenarios.

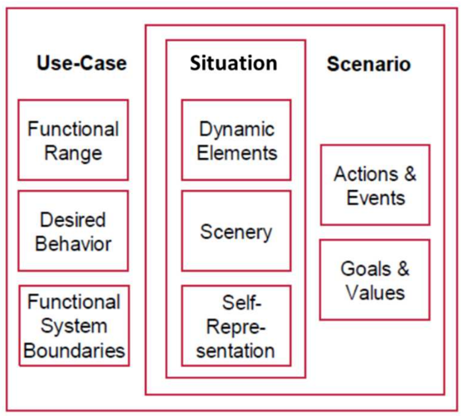

Figure 5 schematic view on situation, scenario and use case

The resulting structure for describing use cases is largely consistent with the ongoing work of the CODECS project [14] to develop a European standard for describing ITS use cases. In this document the following structure has been used:

- Introduction use case
  - Use case ID
  - Background
  - Objective (function)
  - Desired behaviour (of the system and actors)
  - Expected impact
- Use case description
  - Situation(s)
  - Actors and relations
  - Scenario(s)
  - Link to other use cases

5.2 MAVEN global perspective

MAVEN's vision is illustrated in the use case in Figure 6: Your fully automated vehicle turns onto an urban signalized corridor. While gaining speed your vehicle starts to overtake a platoon of six vehicles coming from an upstream intersection (A). When your vehicle and the platoon enter the communication range of the next intersection controller, your vehicle is instructed to join the platoon. As the last two vehicles of the platoon will leave the corridor at the next intersection, the platoon leader initiates a merging scenario. Your vehicle slightly decreases speed while the fifth vehicle in the platoon increases its headway to allow your vehicle to merge (B). Immediately after completing the merge your vehicle turns to following mode. The platoon leader registers the new platoon

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formation at the intersection controller, which in turn reiterates the start and duration of the green phase and returns updated platoon progression instructions. A few seconds later and due to a right of way situation involving pedestrians, traffic flow on the right lane will be low. Therefore, the intersection controller instructs the platoon leader to move to the left lane (C). The platoon leader cascades the instruction and initiates the lane change manoeuvre. The last two vehicles continue driving on the right lane, leave the platoon and return to individual mode. Shortly before reaching the intersection your vehicle slows down and stops (D). The intersection controller has given priority to an emergency vehicle coming from the left, now safely passing the green light. Right at the onset of green the platoon departs from the intersection with minimum start delay, heading for the next intersection.

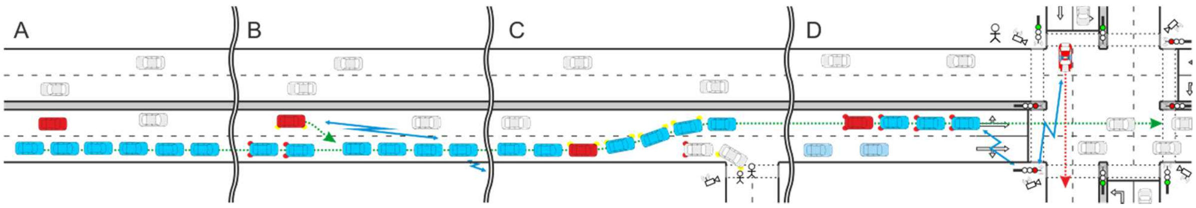

Figure 6 MAVEN global perspective

5.3 Use case overview

The MAVEN project distinguishes the following sixteen use cases. The objectives of these use cases are stated here, while detailed descriptions are provide in **Appendix B**. Those descriptions are written in an implementation neutral language which led to functional requirements provided in chapter 5.

- Platoon management
  - **UC1: Platoon initialisation**: One or more HAVs are triggered/recommended by the infrastructure to form a platoon directly or indirectly with other cooperative vehicles.
  - **UC2: Joining a platoon**: After triggering, a single non-platooning HAV or a platooning HAV from another platoon joins an existing platoon.
  - **UC3: Travelling in a platoon**: The HAV drives (follows/leads) in platoon until one of the following situations happen: leaving platoon (UC4), breaking-up (UC5), platoon termination (UC6) or any emergency situation (UC9).
  - **UC4: Leaving a platoon**: A platooning HAV is triggered by the infrastructure or by the platoon leader to leave the platoon, or decides internally to leave the platoon, e.g. due to driver commands, route changes or technical needs.
  - **UC5: Platoon break-up**: Platooning HAVs will react to a non-cooperative/non-automated vehicle by splitting up the platoon and allowing the lane change.
  - **UC6: Platoon termination**: Platooning HAVs will react to this request and drive individually.
- **UC7: Speed change advisory (GLOSA)**: To calculate a speed advice based on signal phase and timing information and to enable a vehicle or platoon to pass a signalised intersection in the most efficient manner.
- **UC8: Lane change advisory**: To distributed vehicles over the available lanes to make optimal use of the road capacity.
- **UC9: Emergency situations**: To mitigate the risks of unexpected events and to ensure traffic safety.
- Signal optimisation
  - **UC10: Priority management**: The objective of this use case is to balance the priorities according to the policies set by the road operator.

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    - **UC11: Queue length estimation**: With this improved queue length estimation a better control strategy should be possible and more accurate speed advice for GLOSA.
    - **UC12: Local level routing**: The objective is to give vehicles an advice on a small horizon of <5 minutes which route to take.
    - **UC13: Network coordination – green wave**: The objective of this use case is to create a dynamic green wave for HAVs in close cooperation with GLOSA speed advice with less impact on other traffic than traditional green wave systems have.
    - **UC14: Signal optimisation**: Improve controller performance (reduced average delay and stops for all traffic) by using the new data and functionality of other use cases.
- **UC15: Negotiation**: Performing a bidirectional exchange of information for negotiations using communications from infrastructure and vehicles and back.
- **UC16: Detect non-cooperative road users**: Detection and characterization of complementing non-cooperative road users (vulnerable road users, non-cooperative vehicles) for their inclusion in relevant use cases.

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The figure below shows the relation between the use cases and the actors. These relations are described in more detail in the use case descriptions.

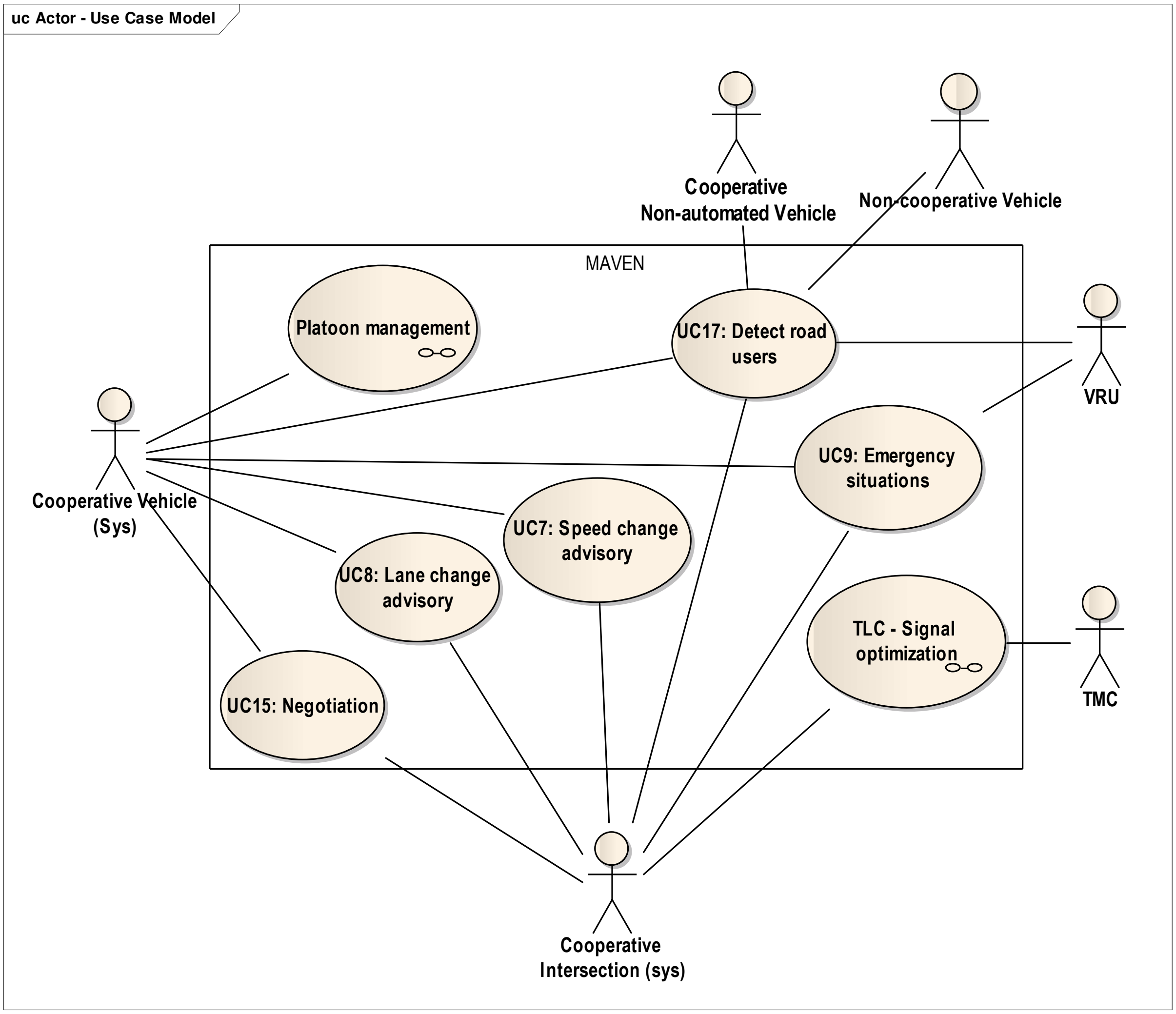

Figure 7 MAVEN use case relations

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Figure 8 shows the relation between the infrastructure-related use cases of the MAVEN project. UC14 Signal optimisation algorithms is at the core of this cluster of use cases and is linked to several traffic control specific use cases as well as to several use cases that link this cluster to the cluster of vehicle-related use cases (Figure 9).

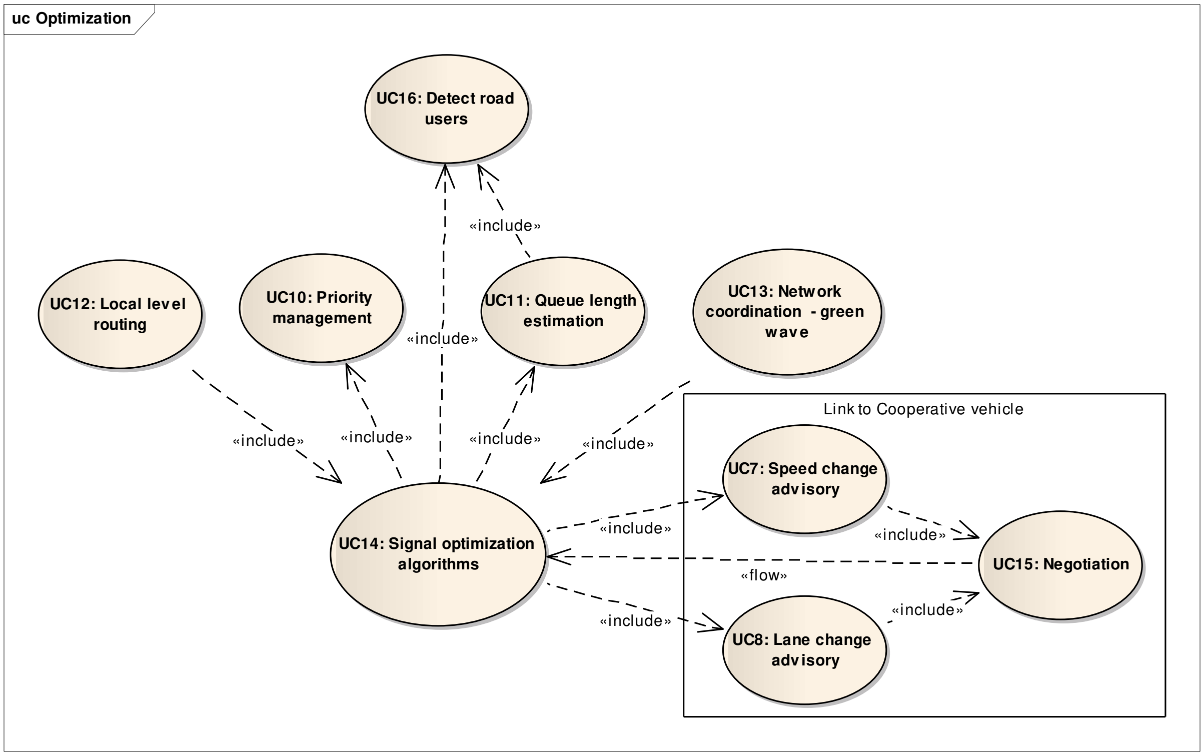

Figure 8 MAVEN infrastructure related use cases

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Figure 9 shows the relation between the vehicle-related use cases of the MAVEN project. UC3 Travelling in a platoon is at the core of this cluster of use cases. Although multiple use cases may be triggered through by a cooperative intersection, the main interaction with the infrastructure-related use cases is through UC3.

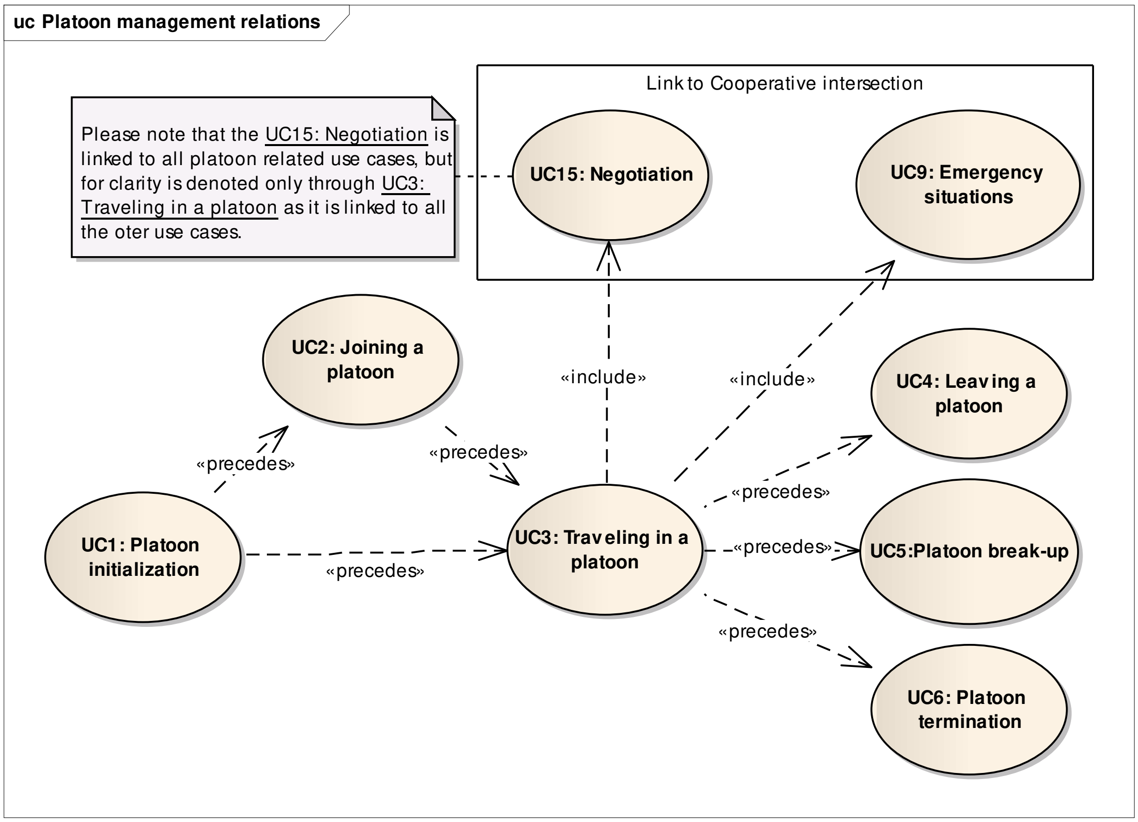

Figure 9 MAVEN vehicle-related use cases

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6 MAVEN Requirements

This section provides results of the Requirements management process as described in Chapter 4 (For more details to the process, please refer to the referenced chapter).

The unique number of each requirements uses the following notation: *WP.G.Nr*, where *WP* corresponds to given work package, G corresponds to certain group of requirements (for better clustering of requirements) and *Nr* denotes its number. For example the requirement "*3.2.1: High precision positioning data available" belongs to WP3, Second group dealing with Sensing and is the first requirement.*

Please note, that requirements provided in the following chapter are resulting from the requirements management process, which includes deleting of requirements, splitting requirements into several requirements, moving requirements between groups or even work packages. This leads to the fact, that the numbering does not have to be continues, some groups might be missing etc. As the aim is to have a unique identifier and with respect to the fact that the used requirements management system allows to manage traceability and history of particular requirements, the numbers were not adjusted at the end.

As WP 1 and WP 2 have not generated any requirements, the numbering starts at the 3.X.X.

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6.1 Requirements Model

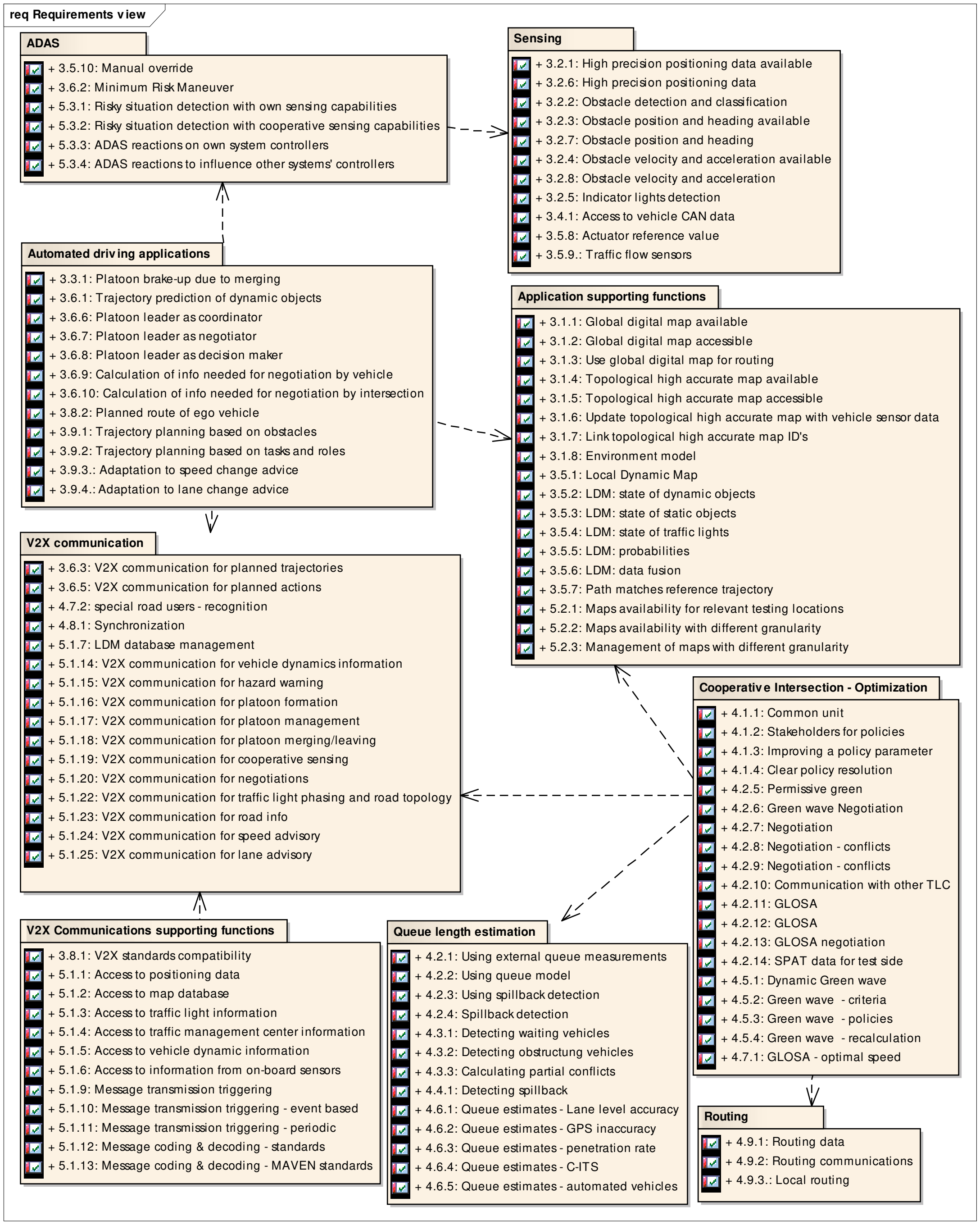

Figure 10 Requirements View

6.2 Requirements Overview

6.2.1 Sensing

3.2.1: High precision positioning data available

«Functional» *Priority:* High *Version: 1.0*

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The MAVEN vehicle system shall provide positioning data.

3.2.6: High precision positioning data

«Performance» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall provide positioning data as precise as possible with a maximum deviation from the real position of 10 cm.

3.2.2: Obstacle detection and classification

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall detect and classify obstacles surrounding the vehicle and along the planning horizon in 10 Hz.

3.2.3: Obstacle position and heading available

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall detect and track the position (therefore heading) of obstacles surrounding the vehicle.

3.2.7: Obstacle position and heading

«Performance» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall detect and track the position (therefore heading) of obstacles surrounding the vehicle and along the vehicle's planning horizon in 10 Hz and with a precision of less than 10°.

3.2.4: Obstacle velocity and acceleration available

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall detect and track the velocity (therefore acceleration) of obstacles surrounding the vehicle.

3.2.8: Obstacle velocity and acceleration

«Performance» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall detect and track the velocity (therefore acceleration) of obstacles surrounding the vehicle and along the vehicle's planning horizon in 10 Hz and with a precision of less than 0.5 m/s (0.5m/s^2 for acceleration).

3.2.5: Indicator lights detection

«Functional» *Priority:* Low *Version: 1.0*

The MAVEN vehicle system shall monitor the activity of indicator lights of vehicles in adjacent driving lanes.

3.4.1: Access to vehicle CAN data

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall have access to the following vehicle information: velocity, acceleration, heading, gear, applied steering angle, applied pedal positions and applied steering wheel angle.

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3.5.8: Actuator reference value

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall generate the actuator reference value in order to follow the reference trajectory.

3.5.9.: Traffic flow sensors

«Functional» *Priority:* Medium *Version: 1.0*

The Cooperative Intersection shall collect data about the traffic stream, at least the occupancy of a sensor, speed of passing vehicles and traffic flow.

6.2.2 ADAS

3.5.10: Manual override

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle shall provide the possibility that the driver can override the system actions at any time.

3.6.2: Minimum Risk Maneuver

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle shall be able to perform the minimum risk actions braking and enlarging headway automatically at any time.

5.3.1: Risky situation detection with own sensing capabilities

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (vehicle as well as cooperative intersection) shall be capable to detect risky situations when relying on its own sensing capabilities only.
Example 1: an RSU connected with traffic light and camera detects a pedestrian crossing while traffic light phase for vehicles is green.
Example 2: a car equipped with on-board sensors detects a pedestrian crossing while car is given the permission (by RSU) to cross the intersection.

5.3.2: Risky situation detection with cooperative sensing capabilities

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN system (vehicle as well as cooperative intersection) shall be capable to detect risky situations when relying also on other systems' sensing capabilities.
Example 1: an RSU connected with traffic light but not with a camera receives from a car the information that a pedestrian is crossing while traffic light phase for vehicles is green.
Example 2: a car equipped with on-board sensors, receives from an RSU the information that a pedestrian crossing while car is given the permission (by RSU) to cross the intersection. the vehicle was not capable to detect the pedestrian with its on-board sensors (e.g. because of visual obstructions).

5.3.3: ADAS reactions on own system controllers

«Functional» *Priority:* High *Version: 1.0*

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The MAVEN system (vehicle as well as cooperative intersection) shall be capable to react to detected risky situations operating on own system controllers.
Example 1: an RSU detecting a risky situation with a pedestrian suddenly changes traffic light phase for cars to avoid a possible accident.
Example 2: a car detecting a risky situation with a pedestrian operates an automated reaction to prevent an accident. Reactions can be slow down, braking, steering.

5.3.4: ADAS reactions to influence other systems' controllers

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN system (vehicle as well as cooperative intersection) shall be capable to react to detected risky situations suggesting or imposing actions for other systems' controllers.
Example 1: an RSU detecting a risky situation with a pedestrian informs the vehicles that can be implicated in a possible accident. Information can be a simple warning, or a command to slow down or stop.
Example 2: a car detecting a risky situation with a pedestrian operates an automated reaction to prevent an accident. At the same time, it informs other vehicles (e.g. other components of a platoon) for them to undertake similar reactions.

6.2.3 Automated driving applications

3.3.1: Platoon brake-up due to merging

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall trigger platoon brake-up in case a non-cooperative vehicle wants to merge into the platoon.

3.6.1: Trajectory prediction of dynamic objects

«Functional» *Priority:* Low *Version: 1.0*

The MAVEN vehicle system shall predict the trajectory of dynamic objects until the probability of the prediction becomes less than 50%.

3.6.6: Platoon leader as coordinator

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall be able to take the role as platoon leader in terms of planning and coordinating platoon movements.

3.6.7: Platoon leader as negotiator

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall be able to take the role as platoon leader in terms of negotiating between infrastructure and platoon members' needs.

3.6.8: Platoon leader as decision maker

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall be able to take the role as platoon leader in terms of coordinating behavioural decisions of the platoon.

3.6.9: Calculation of info needed for negotiation by vehicle

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle shall be capable of calculating information needed to be communicated to the cooperative intersection for negotiation algorithms (e.g. expected time of arrival at the intersection stop line when driving alone or in platoon mode).

3.6.10: Calculation of info needed for negotiation by intersection

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN cooperative infrastructure shall be capable to calculate information needed to be communicated to the MAVEN vehicles as a result of negotiation (e.g. Individual speed advice, lane changes, platoon initialization, etc.).

3.8.2: Planned route of ego vehicle

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall be aware of the planned route of the ego vehicle.

3.9.1: Trajectory planning based on obstacles

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall plan the trajectory of the vehicle based on obstacles in the vicinity of the vehicle and along the planning horizon.

3.9.2: Trajectory planning based on tasks and roles

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall take into account its tasks in MAVEN use cases and role inside a platoon while planning the trajectory of the vehicle.

3.9.3.: Adaptation to speed change advice

«Functional» *Priority:* Medium *Version: 1.0*

The automated vehicle (or in case of a platoon of automated vehicles the platoon leader) shall adjust speed based on the recommended speed from the cooperative intersection and the following negotiations.

3.9.4.: Adaptation to lane change advice

«Functional» *Priority:* Medium *Version: 1.0*

The automated vehicle (or in case of a platoon of automated vehicles the platoon leader) shall change lanes based on the recommended speed from the cooperative intersection and the following negotiations.

6.2.4 Application supporting functions

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3.1.1: Global digital map available

«Functional» *Priority:* High *Version: 1.0*

A unique global digital map of the environment with all updated road data shall be available to the MAVEN system.

3.1.2: Global digital map accessible

«Functional» *Priority:* Low *Version: 1.0*

A unique global digital map shall be accessible to MAVEN cooperative vehicles and cooperative intersections.

3.1.3: Use global digital map for routing

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN cooperative vehicle shall use a unique global digital map for routing.

3.1.4: Topological high accurate map available

«Functional» *Priority:* Medium *Version: 1.0*

A topological high accurate map with detailed information about road, paths, intersection, traffic rules, etc. shall be available to the MAVEN system.

3.1.5: Topological high accurate map accessible

«Functional» *Priority:* Medium *Version: 1.0*

A topological high accurate map shall be accessible to MAVEN cooperative vehicles and cooperative intersections.

3.1.6: Update topological high accurate map with vehicle sensor data

«Functional» *Priority:* Low *Version: 1.0*

The topological high accurate map shall be updatable with data from vehicle sensors.

3.1.7: Link topological high accurate map ID's

«Functional» *Priority:* Medium *Version: 1.0*

ID's of the unique global digital map and the topological high accurate map shall be mapped/linked.

3.1.8: Environment model

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall generate a model of the vehicle environment by adding information from vehicle sensor data to the topological high accurate map.

3.5.1: Local Dynamic Map

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall generate a local dynamic map (LDM) which includes information about dynamic entities (e.g. other vehicles, traffic lights and obstacles) which are the vicinity of the vehicle and along the vehicle's planning horizon.

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3.5.2: LDM: state of dynamic objects

«Functional» *Priority:* Medium *Version: 1.0*

The LDM shall provide the classification, position, heading, velocity and acceleration of all dynamic objects.

3.5.3: LDM: state of static objects

«Functional» *Priority:* Medium *Version: 1.0*

The LDM shall provide the classification and position of all static objects.

3.5.4: LDM: state of traffic lights

«Functional» *Priority:* Medium *Version: 1.0*

The LDM shall provide the position and signal timing of traffic lights.

3.5.5: LDM: probabilities

«Functional» *Priority:* Low *Version: 1.0*

The LDM shall provide the probability of position, velocity and acceleration data following ETSI standards.

3.5.6: LDM: data fusion

«Functional» *Priority:* Medium *Version: 1.0*

The LDM shall merge data from vehicle sensors with V2X data received from other cooperative vehicles and cooperative intersections.

3.5.7: Path matches reference trajectory

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall provide low level control to guarantee that the covered path by the vehicle matches with reference trajectory.

5.2.1: Maps availability for relevant testing locations

«Functional» *Priority:* High *Version: 1.0*

HAD maps shall be provided for the testing locations used during the MAVEN system development as well as for the demo test location.

5.2.2: Maps availability with different granularity

«Functional» *Priority:* Medium *Version: 1.0*

HAD maps shall be provided with different level of granularity/precision in order to evaluate the impact of this precision on the MAVEN system performance.

5.2.3: Management of maps with different granularity

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall support the capability to run the same algorithms with HAD maps having different level of granularity/precision.

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6.2.5 V2X communication

3.6.3: V2X communication for planned trajectories

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall be able to communicate and negotiate with the platoon leader about planned trajectories.

3.6.5: V2X communication for planned actions

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN vehicle system shall be able to communicate and negotiate with the platoon leader about planned actions.

4.7.2: special road users - recognition

«Functional» *Priority:* High *Version: 1.0*

Special road users (automated vehicles) shall submit their type (e.g. emergency vehicles, public transport) and a request for priority (no priority flag = no special intervention) to the TLC.

4.8.1: Synchronization

«Functional» *Priority:* High *Version: 1.0*

All clocks shall be synchronized to either GPS or a central timing provider in a simulation environment.

5.1.7: LDM database management

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) system shall be able to manage (i.e. insert, modify or delete entries in) so called LDM (Local Dynamic Map) including entries (other vehicle, VRUs, obstacles) that are obtained via V2X receptions.
Note: V2X receptions can be from other systems informing about their presence (e.g. other vehicles' CAMs), or from other systems informing about the presence of objects detected via on-board sensors (cooperative sensing mechanisms).

5.1.14: V2X communication for vehicle dynamics information

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall be capable to exchange (send and receive) messages indicating its status and dynamics (e.g. position, speed, etc.).
Note: The exact specification will be provided later during the research work in WP5.

5.1.15: V2X communication for hazard warning

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall be capable to transmit (send and receive) messages indicating hazards (e.g. pedestrian crossings).

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Note: The exact specification will be provided later during the research work in WP5.

5.1.16: V2X communication for platoon formation

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall be capable to exchange (send and receive) messages needed for platoon formation
Note: The exact specification will be provided later during the research work in WP5.

5.1.17: V2X communication for platoon management

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall be capable to transmit (send and receive) messages needed for platoon management (start, stop the platoon, enlarge inter-vehicle gaps...)
Note: The exact specification will be provided later during the research work in WP5.

5.1.18: V2X communication for platoon merging/leaving

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall be capable to exchange (send and receive) messages needed for platoon merging and leaving (e.g. If a vehicle wants to leave a platoon)
Note: The exact specification will be provided later during the research work in WP5.

5.1.19: V2X communication for cooperative sensing

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall be capable to exchange (send and receive) messages indicating objects detected with on-board sensors (e.g. Pedestrian, obstacles, etc).
Note: The exact specification will be provided later during the research work in WP5.

5.1.20: V2X communication for negotiations

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall be capable to exchange (send and receive) messages for negotiations (e.g. a platoon leader informs a traffic light RSU about the characteristics – size/speed/expected crossing time etc. of the platoon that wants to cross a given intersection)
Note: The exact specification will be provided later during the research work in WP5.

5.1.22: V2X communication for traffic light phasing and road topology

«Functional» *Priority:* High *Version: 1.0*

The MAVEN cooperative intersection shall be capable to exchange (send) messages indicating the traffic light phase and duration info of a given intersection, as well as the road topology of that intersection

Note: The exact specification will be provided later during the research work in WP5.

5.1.23: V2X communication for road info

«Functional» *Priority:* Low *Version: 1.0*

The MAVEN cooperative intersection shall be capable to exchange (send and receive) messages indicating static and dynamic road information (e.g. speed limits, etc)
Note: The exact specification will be provided later during the research work in WP5.

5.1.24: V2X communication for speed advisory

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN cooperative intersection must be able to transmit speed change advisory.

5.1.25: V2X communication for lane advisory

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN cooperative intersection must be able to transmit lane change advisory.

6.2.6 V2X Communications supporting functions

3.8.1: V2X standards compatibility

«Functional» *Priority:* High *Version: 1.0*

The MAVEN cooperative vehicle and intersection shall support transmission and reception of the currently available relevant ETSI, ISO and SAE standard messages over the ETSI ITS communication stack.

5.1.1: Access to positioning data

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system shall support the capability to retrieve positioning data with precision and frequency as will be specified in later project phases during the work on particular WPs/use cases.
Note: This information will be the basis for MAVEN application and communication logics.

5.1.2: Access to map database

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system shall support the capability to retrieve information from on-board digital maps.
Note: This information will be the basis for MAVEN application and communication logics.

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5.1.3: Access to traffic light information

«Functional» *Priority:* High *Version: 1.0*

The MAVEN cooperative intersection system shall be able to retrieve information regarding the status of the traffic light (current and next phases + durations).
Note: This information will be the basis for MAVEN application and communication logics.

5.1.4: Access to traffic management center information

«Functional» *Priority:* Medium *Version: 1.0*

The MAVEN cooperative intersection system shall be able to retrieve information regarding the rest of the road network (other traffic lights) from the traffic management center.
Note: This information will be the basis for MAVEN application and communication logics.

5.1.5: Access to vehicle dynamic information

«Functional» *Priority:* High *Version: 1.0*

The MAVEN vehicle system shall be able to retrieve information regarding the vehicle status and dynamics (CAN bus signals).
Note: This information will be the basis for MAVEN application and communication logics.

5.1.6: Access to information from on-board sensors

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system shall be able to retrieve information from vehicle on-board sensors (camera, radars, etc.).
Note: This access will be the basis for MAVEN application and communication logics.

5.1.9: Message transmission triggering

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) system shall support the capability to trigger transmissions of V2X messages.

5.1.10: Message transmission triggering - event based

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) system shall support event-based (e.g. the platoon leader has to inform the other platoon components about a sudden hard braking) triggering of the transmissions of V2X messages.

5.1.11: Message transmission triggering - periodic

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) system shall support the periodic (e.g. periodic exchange of vehicle speed, position, etc.) triggering of the transmissions of V2X messages.

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5.1.12: Message coding & decoding - standards

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) system shall support the capability to code (at transmitter side) and decode (at receiver side) V2X messages according to currently available international ETSI, ISO and SAE standards.

5.1.13: Message coding & decoding - MAVEN standards

«Functional» *Priority:* High *Version: 1.0*

The MAVEN system (automated vehicle or cooperative intersection) shall support the capability to code (at transmitter side) and decode (at receiver side) V2X messages according to MAVEN-specific standards (these will apply for the message sets developed specifically for MAVEN purposes).

6.2.7 Cooperative Intersection - Optimization

4.1.1: Common unit

«Functional» *Priority:* High *Version: 1.0*

The policy parameters (e.g. decrease delay of platoons) shall have a common reference unit, e.g. delay seconds * vehicle, to make it understandable for traffic engineers to configure the system.

4.1.2: Stakeholders for policies

«Functional» *Priority:* High *Version: 1.0*

The policy parameters shall be able to influence performance of the control strategy for each individual actor and their roles as identified in the MAVEN context.

4.1.3: Improving a policy parameter

«Functional» *Priority:* High *Version: 1.0*

Improving a policy parameter, while leaving all other parameters equal, shall result in an improved performance (e.g. less delay, stops, etc) for the intended stakeholders.

4.1.4: Clear policy resolution

«Functional» *Priority:* High *Version: 1.0*

The policy parameters shall give a clear solution when a conflict of interest occurs between conventional prioritized road users and the newly introduced MAVEN platoons and GLOSA.

4.2.5: Permissive green

«Functional» *Priority:* High *Version: 1.0*

The traffic light control algorithm shall be able to use information about permissive green to adjust modelling of the saturation flow.

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4.2.6: Green wave Negotiation

«Functional» *Priority:* High *Version: 1.0*

The traffic light control algorithm shall be able to reserve green phases supplied by an external green wave application based on negotiation.

4.2.7: Negotiation

«Functional» *Priority:* Medium *Version: 1.0*

The traffic light control algorithm shall be able to adjust the timing of green phases as requested by a platoon based on negotiation.

4.2.8: Negotiation - conflicts

«Functional» *Priority:* Low *Version: 1.0*

The cooperative intersection shall provide the reason for not accommodating a request (e.g. violation of safety constraints or due to conflicting priorities).

4.2.9: Negotiation - conflicts

«Functional» *Priority:* Low *Version: 1.0*

The cooperative intersection shall offer alternatives in case a request cannot be accommodated (e.g. earliest possible realization of green or longest possible green phase).

4.2.10: Communication with other TLC

«Functional» *Priority:* Medium *Version: 1.0*

The traffic control algorithm shall be able to exchange data about signal timing and queue model status.

4.2.11: GLOSA

«Performance» *Priority:* High *Version: 1.0*

The traffic control algorithm shall provide signal timing predications which are 95% probable for a 10 second horizon and 75% probable for a 15 second horizon.

4.2.12: GLOSA

«Functional» *Priority:* Medium *Version: 1.0*

A policy parameter shall be available to define the importance of a high probability of signal timing predications.

4.2.13: GLOSA negotiation

«Functional» *Priority:* High *Version: 1.0*

The traffic control algorithm shall be able to use dynamic parameters for GLOSA negotiation, which is based on extra information acquired by the vehicle that justifies a different outcome of the optimization process.

4.2.14: SPAT data for test side

«Functional» *Priority:* Medium *Version: 1.0*

SPAT data from the Helmond testsite shall also be available through a TMC.

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4.5.1: Dynamic Green wave

«Functional» *Priority:* High *Version: 1.0*

The green wave component shall be able to create dynamic green waves for platoons, which allow vehicles to pass green without stopping given they respect GLOSA speed advice.

4.5.2: Green wave - criteria

«Functional» *Priority:* High *Version: 1.0*

The green wave component shall create dynamic green waves, which disturb other traffic as few as possible.

4.5.3: Green wave - policies

«Functional» *Priority:* High *Version: 1.0*

The green wave component shall be able to take policy inputs in order to weigh between different actors.

4.5.4: Green wave - recalculation

«Functional» *Priority:* High *Version: 1.0*

The green wave component shall be able to recalculate a green wave when a conflict with controller constraints or a priority of another actor interferes with the optimal plan.

4.7.1: GLOSA - optimal speed

«Functional» *Priority:* Medium *Version: 1.0*

GLOSA shall be able to interpret TLC queue measurements and planned timing to calculate the most optimal speed for individual vehicles and platoons.

6.2.8 Routing

4.9.1: Routing data

«Functional» *Priority:* Medium *Version: 1.0*

Routing component shall be able to calculate route advice based on signal predictions and queue state received from TLC.

4.9.2: Routing communications

«Functional» *Priority:* Medium *Version: 1.0*

Routing advice can be communicated through 802.11p, possibly using new message format.

4.9.3.: Local routing

«Functional» *Priority:* Medium *Version: 1.0*

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The Cooperative Intersection shall provide a recommendation about the best suitable route based on the knowledge of the traffic situation, the signal timings and a recommended set of routes.

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6.2.9 Queue length estimation

4.2.1: Using external queue measurements

«Functional» *Priority:* High *Version: 1.0*

The traffic light control algorithm shall be capable of using external queue measurements to incorporate in its internal queue model which is the basis for signal plan optimization.

4.2.2: Using queue model

«Functional» *Priority:* Medium *Version: 1.0*

The traffic light control algorithm shall use a queue model.

4.2.3: Using spillback detection

«Functional» *Priority:* Low *Version: 1.0*

The traffic light control algorithm should be able to use spillback detection information to give non-priority and inhibit flows towards the area where spillback is detected. This should include adjusting the predicted saturation flow accordingly.

4.2.4: Spillback detection

«Functional» *Priority:* Low *Version: 1.0*

Spillback detection information shall be available.

4.3.1: Detecting waiting vehicles

«Functional» *Priority:* High *Version: 1.0*

The permissive green component shall detect the presence of vehicles blocking a lane as they wait due to a permissive green, despite having a green light.

4.3.2: Detecting obstructung vehicles

«Functional» *Priority:* High *Version: 1.0*

The permissive green component shall detect the presence of vehicles with right-of-way causing others to wait due to a permissive green and predict when gaps occur.

4.3.3: Calculating partial conflicts

«Functional» *Priority:* High *Version: 1.0*

The permissive green component calculates the estimated saturation flow for a signal group that has to yield due to permissive green.

4.4.1: Detecting spillback

«Functional» *Priority:* High *Version: 1.0*

The spillback detection component shall detect when spillback impedes the normal saturation flow of a signal group.

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4.6.1: Queue estimates - Lane level accuracy

«Performance» *Priority:* High *Version: 1.0*

The FCD queue estimation algorithm shall estimate lane level accurate queue lengths.

4.6.2: Queue estimates - GPS inaccuracy

«Performance» *Priority:* High *Version: 1.0*

The FCD queue estimation algorithm shall be able to deal with 20m GPS inaccuracy.

4.6.3: Queue estimates - penetration rate

«Performance» *Priority:* High *Version: 1.0*

The FCD queue estimation algorithm shall be able to deal with varying penetration degrees ranging from 5% to 100%.
Note: The relation between penetration rate and the accuracy will be estimated based on simulation.

4.6.4: Queue estimates - C-ITS

«Functional» *Priority:* High *Version: 1.0*

The FCD queue estimation algorithm shall be able to deal with regular (802.11p) C-ITS vehicles which only transmit their current GPS location through CAM.

4.6.5: Queue estimates - automated vehicles

«Functional» *Priority:* Medium *Version: 1.0*

The FCD queue estimation algorithm shall be able to deal with automated vehicles which share extra sensor measurements.

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7 Conclusions

The main objective of this deliverable was to provide a general and joint understanding of the MAVEN project, its objectives and its scope. To that end, the MAVEN system as well as its particular subsystems were provided and discussed. The abbreviations and major terminology were provided and defined as well. Next, the process of requirements collection and use case analysis (including stakeholder consultation) were described, and detailed use case descriptions provided. Finally, the results of requirements collection and analysis were provided in the form of a requirements list. The requirements were collected not only for particular subsystems, but also based on the use cases descriptions and findings from stakeholder consultation.

The main challenge in the process of requirements collection was to ensure that the requirements completely cover the entire use cases. In many cases a use case actually covers requirements from several WPs. For this reason, the process of collection of requirements included not only the phase of requirements collection itself, but also several rounds of discussions and feedback among all WP leaders to refine the use case descriptions and system concept. Verification of requirements is part of the field tests, which will be organised on the basis of test protocols. A test protocol consists of a number of test cases, with each test case covering one or more requirements and (part of) a use case. As each integration sprint will build upon the results of the previous integration sprint, the use case implementation incrementally matures up to full implementation in the last integration sprint.

This document serves as the basis for further activities in MAVEN tasks and work-packages. Deliverable 2.2 - System architecture, specifications and verification criteria will provide a detailed system design including design decisions and verification criteria based on the collected requirements. Work packages 3 – Vehicle automation, 4 – Road automation and 5 – Enabling technologies will start their development activities, while Task 7.1 – Development of impact assessment plan will further detail the assessment and demonstration activities in D7.1 – Impact assessment plan.

These activities, and others, will build on the notation and specification provided in this document.

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8 References

[1] MAVEN Managing Automated Vehicles Enhances Network. MG-3.6a-2015 H2020-MG-2015_TwoStages - Project Proposal, 2015.

[2] iMobility Forum (2013), Roadmap Automation in Road Transport, Version 1.0, prepared by the Working Group Automation in Road Transport

[3] EPoSS (2015), European Roadmap Smart Systems for Automated Driving, Version 1.2, prepared by European Technology Platform on Smart Systems Integration

[4] Center for Urban Transportation Research (2013), Adapting Infrastructure for Automated Driving, prepared for Tampa Hillsborough Expressway Authority, prepared by Zhang, Y., Department of Civil and Environmental Engineering, University of South Florida.

[5] UK Department of Transport (2015), The Pathway to Driverless Cars, Summary report and action plan, available online at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/401562/ pathway-driverless-cars-summary.pdf

[6] ERTRAC (2015), Automated Driving Roadmap, Version 5.0: final for publication, prepared by ERTRAC Task Force “Connectivity and Automated Driving”. Available at: http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf

[7] Lidström, K.; Sjöberg, K.; Holmberg, U.; Andersson, J.; Bergh, F.; Bjäde, M.; Mak, S., "A Modular CACC System Integration and Design," in Intelligent Transportation Systems, IEEE Transactions on , vol.13, no.3, pp.1050-1061, Sept. 2012

[8] Gasser, T., Westhoff, D. (2012) BASt-study: Definitions of Automation and Legal Issues in Germany

[9] "Technology readiness levels (TRL)" (PDF). European Commission, G. Technology readiness levels (TRL), HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes, Extract from Part 19 - Commission Decision C(2014)4995.

[10] Islam, F., Vreeswijk, J., Blokpoel, R. (2014), Combinations of ITS applications and their impact assessment, Proceedings of the 10th ITS European Congress, Helsinki, Finland

[11] Project Management Institute. (2004). A guide to the project management body of knowledge (PMBOK guide). Newtown Square, Pa: Project Management Institute.

[12] B. Whitten. “System Analysis and Design Methods”, 7th Edition. McGraw-Hill. 2007.

[13] Ulbrich, S., Menzel, T., Reschka, A., Schuldt, F. and Maurer, M. (undated), Defining and substantiating the terms scene, situation and scenario for automated driving

[14] CODECS project, URL: http://www.codecs-project.eu/

[15] Korte Afstands Radio (Short Distance Radio). URL: https://nl.wikipedia.org/wiki/KAR

[16] VECOM. URL: http://www.record-toegangstechniek.nl/Content/ImtechTrafficNederland/Brochures/Vecom_waysidevehiclecommunicationsystem_13032014_loosepages.pdf

[17] Robbin Blokpoel, et al. (review Michele Rondinone). Project H2020 MAVEN - Deliverable 2.2: System architecture, specifications and verification criteria. Version 1, 28-2-2017.

[18] Ondřej Přibyl, et al. (review Meng Lu). Project H2020 MAVEN - Deliverable *D7.1: Impact assessment plan*. Version 1.5, 8-10-2018.

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9 Appendix A - MAVEN – Stakeholder consultation

This section records the findings from the first MAVEN stakeholder consultation workshop that took place in Barcelona on 15 November 2016. Local authorities and other urban road stakeholders were invited to share their views on the role and impact of increasingly automated vehicles on urban roads and traffic management. Feedback was gathered through an online real-time voting tool to engage the audience.

The aim of this first MAVEN stakeholder consultation workshop was to discuss and review the preliminary MAVEN system concept, use case descriptions, and assessment and demonstration plan. The workshop addressed the role and responsibilities of cities and traffic management in the context of highly automated driving, including political, institutional and organisational aspects as well as the broader perspective of passenger transport in smart/future cities.

9.1.1 Initial remarks

The audience

The workshop was attended by 34 registered participants, of which some two-thirds were representing local government. More than half of the workshop participants who responded to the first question on the online voting system said they were attending the MAVEN workshop to have a better understanding of technical aspects regarding automation whereas around one third said they wanted to have a better understanding of the policy impact.

For instance, the city of Amsterdam's interest in automation has been prompted by a discussion about whether to build new underground parking garages. Such an investment is significant and should last many decades. The advent of automated vehicles begs the question as to whether parking will be required. This led to a discussion about whether cities should be accommodating automated cars or not, given that some studies suggest an increase in km travelled. Most agreed that cities should try to influence this process by for instance penalising empty self-driving cars. Copenhagen has recently been given permission to test automated vehicles, similar to the shuttle services being piloted in Aalborg. For Copenhagen, it is important to consider the priorities of cities, such as social inclusion.

A majority admitted they were new to the subject of automation; the rest of the audience had previous knowledge. To many participants, automation is understood as vehicles driving themselves in specific environments. The remaining participants understood automation as being either a vehicle that drives itself from door to door or a vehicle that only automates specific driving tasks. Information from projects, conferences and workshops are seen as the main sources of information related to automated vehicles.

9.1.2 Setting the scene

Recent developments in automated driving, Jaap Vreeswijk, MAPtm

The main reason for introducing automated driving is to reduce accidents caused by human error which today represent 93 % of all road accidents. Automation has attracted lots of media attention lately; however it is not new: There was already an automated platoon demonstration on the San Diego highway in 1998. More recent initiatives are being led by Google and Tesla. The European co-funded projects CityMobil and CityMobil2 have piloted automated shuttles. Truck platooning has already been tested on the highways. (European) Lawmakers have also looked into automated driving, with one of the notable output being the Declaration of Amsterdam on Cooperation in the

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field of connected and automated driving which was adopted under the Dutch presidency of the Council of the EU in April 2016.

Different levels of automation have been identified: Level 1 (Driver assistance) & Level 2 (Partial automation) are already there today. Level 3 (Conditional automation) is an interesting level as the vehicle monitors the environment but the driver is always the fall-back. Then there is Level 4 (High automation) and Level 5 (Full automation). Studies show that the driver needs between 8 and 32 seconds to resume driving task. For this reason, MAVEN holds the view that Level 3 automation is unlikely to happen, i.e. that there will be a jump from Level 2 to Level 4.

There are still many issues that need to be thoroughly investigated such as how to interact with drivers in the vehicle and with other road users outside? There is an expectation that automated vehicles will reduce injuries and accidents, but how do you deal with an accident involving an automated vehicle whose software has malfunctioned? Regarding ethics: what level of risk is acceptable?

In the automated driving landscape, there are 4 types of vehicles: traditional, automated, connected and cooperative-automated. It is likely that there will be a mix of these vehicles in the coming years, and that the mix will change over time.

During the discussion, a number of questions and points were raised, including the possibility of retrofitting manually driven vehicles to make them automated. Given the substantial computational power that would be needed for automation, retrofitting would be very challenging, albeit not impossible. The key issue is safety. It was agreed that the co-existence of manually driven and automated cars will be the norm for many decades because some people will drive older (especially classic) cars for many years.

Introduction to the MAVEN project, Robbin Blokpoel, Dynniq

MAVEN's focus is the urban environment which has not been the subject of much research in relation to automated vehicles. Four vehicles in total will be piloted by DLR and Hyundai. Because of the difficulty to operate platooning in a real road environment, MAVEN will instead conduct emulations while performing field tests. MAVEN will build a model of a city based on the open source SUMO software which offers advanced simulation to override normal drivers' behaviour e.g. vehicles can platoon very close. The project comprises 2 pilot sites in Braunschweig and Helmond. MAVEN wants to verify that what it creates is also politically feasible.

MAVEN use cases & high level requirements, Ondrej Pribyl, Czech Technical University

Most of the MAVEN use cases are based on platooning. Feedback collected shows that they are a good starting point though some believe that they would be difficult for drivers to accept. Once the algorithms are ready, they will be applied to a real intersection simulation with different penetration rates. A question from the audience raised the point on whether higher automation would lead to platooning. For Ondrej Pribyl (CTU), the cooperation perspective is more efficient than the automation perspective. Another question related to the role of the cyclist in the platoon and how it would interact with the vehicle platoon? Is a cyclist more important than a platoon?
The audience said that these use cases reflected somewhat the needs of a road authority but should not be implemented just tomorrow. In fact, the project's purpose is to understand first the impact of the scenarios. It was recommended that the scenarios be investigated at both peak and off-peak hour.

Some members of the audience felt that the use cases were technology driven and too theoretical and that they should relate to real-life case studies. There is a need to show cities what is in it for them by linking the use cases to real world transport problems (e.g. How to deal with high volumes of tourist buses along specific corridors?). It was suggested that the scenarios are run with pedestrians and that there be a dedicated workshop with freight players.

It was queried how the platooning use cases with vehicle-infrastructure interaction could be implemented when the business logic/intelligence is held at the higher level of the control centre (or at least the zonal/area level) rather than at the traffic signal controller, requiring low-latency highly reliable communication. There was no clear answer to this question.

Concerning the operation of the platoons, some members of the audience held doubts about whether to alert other road users about automated platoons as this may lead to behaviour of trying to disrupt the platoon.

To the question “What technical requirements or non-technical requirements do you want to have for MAVEN use cases?”, suggestions from the audience were clustered as follows:

Data/technology

- Data usage should be feasible even at 100% penetration rate
- Standards for messaging (V2V, V2I).
- How to manage the (large quantities of) data?
- Make use of other projects (e.g. PPA)
- How to manage data traffic (high volumes of data)?
- Technical standardisation, interoperability, clarity about communications, technology (4G vs G5); cost-benefit analysis first, impact assessment (KPI based)

Human behaviour component/vulnerable road users/evaluation

- Should be checked in congestion situation, with a lot of VRUs at the same time
- Human behaviour in relation to platooning.
- Cyclist numbers need to be taken into account.
- Driver behaviour.
- Scalability
- Mix traffic users.
- People safety need always to be assured

Transition phase

- Use cases that describe the transition between what we have now and pervasive C-ITS
- Step-by-step approach in the emulation considering that non-automated vehicles are predominant before fully automated vehicles will flow in our cities
- Effects of different mixes of automated and non-automated vehicles, failure of one or more components, reliability
- Describe in the use cases and tests also the viewpoint of the non-automated vehicles/road users

Network/infrastructure

- MAVEN should ensure use cases are as close to reality as possible
- Mixed traffic, safety, emergency,
- What happens in case of malfunction?
- Don’t just model cars, but also vehicle fleets – of interest for cities in terms of C-ITS

- Who makes platooning happen? Authority / City? Or others? Include all actors in the chain and study the strengths/weaknesses
- Need to have a better understanding of the benefits, safety, travel time, environmental effect!
- What are the infrastructure needs?

Policy

- MAVEN should not only solve technical issues but address user (citizen) needs and explore its potential for modal shift
- System performance, driver behaviour, strategic context (control, policy, etc), benefits quantification, scalability, future proof
- Business case: what's in it for the cities; liability issues; city policy to reduce car use

9.1.3 The perspective of a city authority

Phil Williams, Digital Greenwich, Royal Borough of Greenwich, London

Greenwich, one of London's boroughs, has a population of 275k over 40 km sq. 20 million visitors come to Greenwich every year. Population is expected to grow by one-third by 2028. The 65+ year age group is expected to rise by 57%. The travel situation is not going to get better by throwing automated cars at it. Nearly half of all car journeys are made inside the borough.

Greenwich has started thinking more in terms of accessibility, and giving people alternative modes to go where they need to go. Are cars really our future? Can we sustain more and more cars? London has good public transport, but need more of it because it is already saturated. The borough is looking at what automated vehicles means for Greenwich and how other cities are interacting with them.

Greenwich is involved in many projects, including one dealing with data and the communications networks (eg, fibre optics) that are needed for this. Others, such as GATEway and ATLAS, could be quite expensive solutions. The borough is looking to MAVEN to provide insights into how managed automated vehicles could work in Greenwich: it is thinking about shared spaces and last mile services.

Some key issues which require further thought: what happens at the boundaries between boroughs which have not implemented the system? This could be mid-way along a road. What are the advantages of automated vehicles in a congested environment, or at multiple junctions? Automation has to be implemented incrementally for public acceptance reasons.

Gert Blom, City of Helmond

According to Gert, cities should be involved in automated vehicle discussions and developments. Fatal accidents have an impact on cities, this is the main reason to be involved in automation. ITS could play a big role in mobility solutions. However, we should avoid having automated vehicles but instead should look to vehicles that are connected amongst themselves and with the infrastructure, traffic manager and other users. The Freilot project pilot showed a 13% fuel saving for truck drivers. Through its involvement in many projects, Helmond feels it now has enough piloting experience to move towards large-scale deployment. Key considerations are vulnerable road user safety and services such as ISA (intelligent speed adaption) for which there is a strong business/societal case for cities. The impact of automated vehicles goes beyond mobility domains such as freight to encompass wider issues such as land use. MAVEN offers an opportunity to bridge the missing link between automated vehicles and traffic management.

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9.1.4 Requirements arising from the workshop discussions and online questionnaire

The societal objectives of a city authority

The ambition of most cities is to build a city where people don't want to use cars. But the reality is that few want to give up their cars because they do not see an alternative that offers as much flexibility.

Among the most critical issues in cities related to mobility and infrastructure, parking and congestion are high on the agenda. Car parks can be already upgraded with cameras but not to level 5 automation. Other critical issues include vulnerable road users, cyclists and pedestrians along with liveability and public space. On the contrary, funding and costs were considered less critical. This aspect nonetheless raised the concern about who is going to pay for automation.

Considering automated vehicles operating in normal traffic, the key issue is safety. There is a need to have guarantees on safety. Security, liability, traffic regulations, and human factors were equally pointed out to be important aspects to be considered. Public awareness, infrastructure investment and identification of automated vehicles by inhabitants were identified as being the least important relatively speaking.

The transition phase

Automated vehicles penetration: A slight majority of participants said that their cities were NOT preparing for the introduction of automated vehicles. The level of automation influences the time horizon. In a full automation scenario, the majority of respondents replied that it is unlikely to be there for another 20-30 years from now, followed by 10-20 years, and 30+ years.

Concerning the retrofitting of older vehicles to make them more automated: if money is no object, anything is possible. But technically-speaking it would be very challenging. The technology has to operate in a complex system and needs to be reliable. Manufacturers are improving their products and learning from each generation of vehicles. Upgrading is therefore not the solution. Some enquired how long older cars could still be operating alongside automated cars. This is extremely difficult to answer and therefore it is safer to assume that it will be a very long time before we can ensure there is 100% penetration. Legislation could be used to prohibit older cars but this would need to be implemented across all Member States.

Standardisation is a slow process. Cities cannot wait forever but they do worry about the lack of standardisation. They are concerned about making investments now and having to upgrade their systems later. In terms of the direct effects of MAVEN, they are looking forward to having a good overview of the impacts of fully automated vehicles on the road network. They suggested that the city model used for the simulation and assessment be based on a representative network.
Expectations from associated project partners: MAVEN is not expecting data from associated partners, unless the project decides to scale up. MAVEN is primarily interested in having their opinions and views. Participants stated that they like to be involved on a regular basis and would welcome another workshop in about one year's time.

In terms of infrastructure, the assumption is that the MAVEN services will build on the C-ITS infrastructure that is already installed. This is the case in Helmond, which already has some C-ITS infrastructure from previous projects.

Several financing aspects came up in the discussion: firstly, the drop in income from parking fees and therefore less income to spend on infrastructure. Secondly, the financial resources can vary differently depending on the size of a city, i.e., generally the bigger the city, the more resources and skills available to invest in new technology and systems.

Impact assessment

Many agreed that the impact of automated driving goes beyond the mobility domain, notably toward the freight sector and land use, and that automated vehicles will have a major impact on safety, efficiency and air quality. The audience considered that the number of vehicles trips and km driven are less likely to be impacted by automation.

There cannot be automation without connectivity. Opinions were diverging when asked if automated driving is worth development support by public authorities or whether cities must strive to incrementally introduce automated driving services. Nonetheless, the majority seemed to agree that current C-ITS investments are not a waste of money.

Most participants believe that public transport is the vehicle class that has the most potential for automation, followed by taxies and delivery services. Some cities may introduce some C-ITS services. Taxis are the big issue in Amsterdam. When full automation is there, it is believed that taxis will work out cheaper than having a car. Automating public transport would make mobility more accessible to people. However, it was also argued that people may feel threatened by sudden changes (ie, no drivers in buses) and so there is a need for step by step approach.

The impact on society will largely depend on which automated services are being introduced and for whom. It is assumed that the cost of automating public transport will be met by the cities in terms of the vehicle fleet, infrastructure and loss of drivers. But there is a shared concern that cities will not have money for a new fleet and unemployed bus drivers. Other concerns were raised regarding the health effect of introducing automated driving which may lead to a reduction in walking and cycling, and increased isolation because people will interact less once they are in an automated vehicle. What is the social effect of these developments? We still want to create pedestrians and cycling communities. It is imperative for cities to understand what are the needs and what behaviour they want to change.

The reality of what cities want to happen and what will happen is quite different, ie, automated private cars will be on the road on a larger scale than public transport and technology will develop quicker than cities have time to react and quicker than they can adapt their infrastructure. Market forces will push cities down a route faster than they can follow.

On MAVEN's impact assessment, stakeholders are interested to learn about:

- Costs (for users and for infrastructure, gains) / Cost benefit analysis
- Impact (on safety, on car use, time reliability)
- Efficiency (travel time, emissions, energy savings)
- Transition / operational (best/worst use case, infrastructure requirements, capacity, restrictions, replicability, guideline)
- Robust results backed by numbers
- Scale
- Replicability / Guideline (for cities and manufactures)
- Applicability

The traffic manager's role and responsibilities

Many agreed that a traffic manager should be able to communicate directly with an automated vehicle and give directions. Opinions were more cautions on road authorities having an active role in investing to facilitate automated driving as a form of traffic management and on the need for traffic management to become simpler and requiring less interventions. Nearly everybody agreed that the traffic manager will still be needed despite the fact that automated vehicles may manage themselves as a system.

Regarding the changing role and responsibilities of a traffic manager, traffic management is becoming increasingly linked to policy; it is no longer just about cars but about accessibility. Additionally, it was observed that traffic management is becoming a strategic tool for delivering a whole range of transport policies, and the ultimate goal of becoming a liveable city, which is a qualitative rather than quantitative notion, i.e. it is more of a personal perception (less congestion, better air quality, walkable city). Overall the group supported the assertion that traffic management will become more strategic in the future, translating policy goals into operations, and that while more operational decisions will be made by systems, these will be guided by policy. One final note, it should not be overlooked that traffic management systems are mainly installed in big cities; smaller cities do not tend to have them. How to deal with the boundaries?

9.1.5 Impact on use cases and requirements

The stakeholder consultation workshop clearly confirmed that the project MAVEN is important for different stakeholders and that they believe it has an important and right focus. Still some of the conclusions had a direct impact on the use cases and requirements. The major findings are provided in the following paragraphs:

In general, the stakeholders mentioned that the presented use cases and requirements are too technical. For this reason, the description of the use cases must be improved in order to clearly describe the real world situations that are of interest to the end users of the MAVEN system.

Similarly, the use case descriptions must state their impact in a better and more precise way. It is also necessary to cover the real world situations and not only theoretical situations.

It is important to emphasize the influence of traffic managers through different policies.

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10 Appendix B –MAVEN Use Case Descriptions

10.1 UC1: Platoon initialisation

10.1.1 Use case introduction

Background

This use case is needed to start the forming of a platoon.

Objective (function)

One or more cooperative vehicles are triggered/recommended by the roadside unit (R-ITS-S) to form a platoon directly or indirectly with other cooperative vehicles.

Desired behaviour

Two or more cooperative vehicles form a platoon. This includes negotiation with the road side and performing of the needed manoeuvers to form the platoon, i.e. lane changes and speed/distance changes.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

10.1.2 Use case descriptions

Situation(s)

Situation 1: single lane road, two or more cooperative automated vehicles.

Situation 2: dual lane road, two or more cooperative automated vehicles.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react when the platoon initialisation happens. The driver may only generally specify in advance that the vehicle has to reject all platooning requests from the outside and will not initialise or join a platoon. Nevertheless, there should be an optional announcement that the vehicle is currently initialising or joining a platoon.
- **Vulnerable road user**: presence of vulnerable road user(s) may obstruct the creation of a platoon. No dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct creation of a platoon.
- **Non-cooperative vehicle driver**: Optional signalling by cooperative vehicles that they are currently in platooning mode.
- **Cooperative non-automated vehicle:** Non-automated vehicles will not have the possibility to join a platoon. Nevertheless, non-automated cooperative vehicles are informed about the action and may forward it as information to the driver, e.g. to make way for platoon forming. Non-automated cooperative vehicles can also forward the messages to other vehicles if needed.
- **Cooperative non-automated vehicle driver:** The driver may optionally be informed about the platoon actions.

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- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): after receiving the signal by the roadside unit (R-ITS-S) to initialize a platoon (including the proposed role inside the platoon, i.e. being leader or follower at a specific position) the cooperative vehicles negotiate with each other about the details (including planned manoeuvers needed for initialization) of the platoon to be formed and whether they can join or not.
- **Cooperative intersection** (sys): has the ability to trigger platoon initialisation subject to intersection control optimisation criteria.

Scenario(s)

Scenario 1 (based on situation 1): Some cooperative automated vehicles are driving on a single lane road. The vehicles share their goals with the road side unit. The road side unit decides that the vehicles should build a platoon, informing one vehicle to be the leader and the other to be the followers. The vehicles set up a V2V communication link for negotiating the details of the platoon forming. The vehicles agree and form a platoon accordingly. This information is given to the road side.

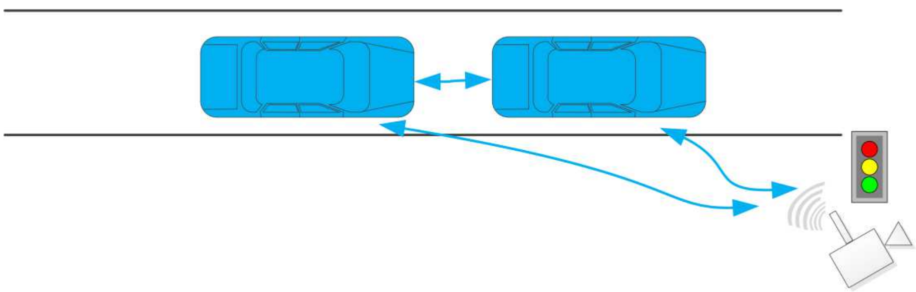

Figure 11 UC1 (Platoon initialisation)– Scenario 1

Scenario 2 (based on situation 1): Same as Scenario 1, but at least one vehicle rejects to build a platoon. Rejection can be due to driver desire or failure in V2X negotiation. The rejection is also communicated to the road side. There is no platoon formation in this scenario.

Scenario 3 (based on situation 2): Similar to Scenario 1, but there are cooperative automated vehicles which are spread on different lanes. Therefore, the negotiation includes the setting of a desired platoon order including the related lane changes, accelerations and braking manoeuverss. The platoon is formed.

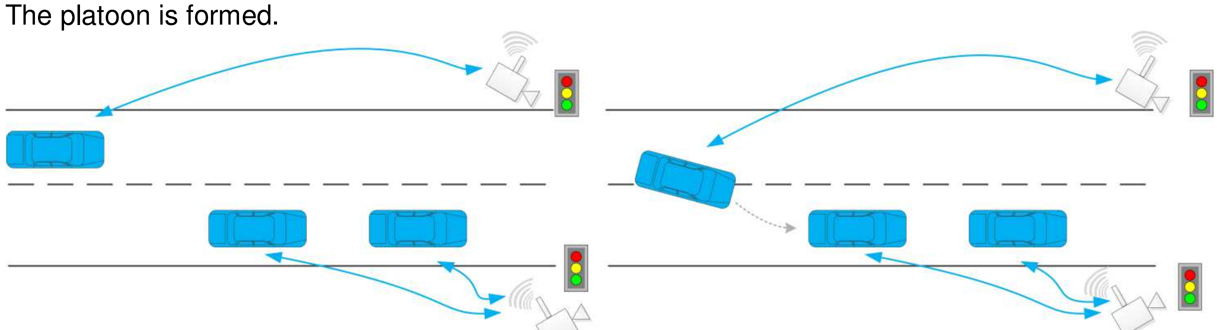

Figure 12 UC1 (Platoon initialisation) – Scenario 2 and 3

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Scenario 4 (based on situation 2): Similar to Scenario 3, but at least one vehicle is able to join the platoon. This changes the negotiation so that the remaining vehicles can form the platoon. This information is given to the road side.

Link to other use cases

As in this use case a platoon is initialized, all other platooning use cases are linked and relevant to this use case directly such as UC2, UC3, UC4, UC5 and UC6. Furthermore, speed advices (UC7) and lane changes (UC8) might be needed for platoon initialisation. Emergency situations (UC9) cannot be excluded. Platoon initialisation may be triggered by the cooperative intersection due to the results of the signal optimisation, also linking this use case to UC10, UC11, UC12, UC13 and UC14. Negotiation (UC15) of platoon formation details as well as the detection of non-cooperative road users (UC16) is needed for platoon initialisation.

10.2 UC2: Joining a platoon

10.2.1 Use case introduction

Background

A cooperative vehicle which was not platooning or platooning in another platoon is triggered to join a platoon.

Objective (function)

After triggering, a single non-platooning cooperative vehicle or a platooning vehicle from another platoon joins an existing platoon.

Desired behaviour

The road side suggests that one cooperative vehicle outside of an existing platoon should join the platoon at a given position. In addition, platoon details (e.g. who is the leader) are communicated. The cooperative vehicle establishes a V2V communication with the platoon leader and negotiate about the road side suggestion and the needed manoeuvers. The vehicle will join the platoon at the given position.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

10.2.2 Use case descriptions

Situation(s)

Situation 1: one cooperative vehicle and a platoon on a single lane road.

Situation 2: one cooperative vehicle and a platoon on a dual lane road.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react. Nevertheless, there should be an optional announcement that vehicle will join platoon.
- **Vulnerable road user**: presence of vulnerable road user(s) may obstruct the joining of a platoon. No dedicated signalling to vulnerable road users.

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- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct joining of a platoon.
- **Non-cooperative vehicle driver**: Optional signalling by cooperative vehicles that they are currently in platooning mode.
- **Cooperative non-automated vehicle:** Non-automated vehicles will not have the possibility to join a platoon. Nevertheless, non-automated cooperative vehicles are informed about the action and may forward it as information to the driver, e.g. to make way for platoon forming. Non-automated cooperative vehicles can also forward the messages to other vehicles if needed.
- **Cooperative non-automated vehicle driver:** The driver may optionally be informed about the platoon actions.
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): after receiving the signal by the road side unit (R-ITS-S) to join into the platoon (including the proposed position and role inside the platoon, i.e. being leader or follower at a specific position) the cooperative vehicles negotiate with each other about the details (including planned manoeuvers needed for the vehicles who join and the vehicles who need to make room for the joining).
- **Cooperative intersection** (sys): has the ability to trigger platoon joining subject to intersection control optimisation criteria.

Scenario(s)

Scenario 1 (based on situation 1): A vehicle is suggested by the R-ITS-S to join a platoon. A communication link with the platoon leader is established. The roles inside the platoon are negotiated. The vehicle joins the platoon. The R-ITS-S is informed about this action.

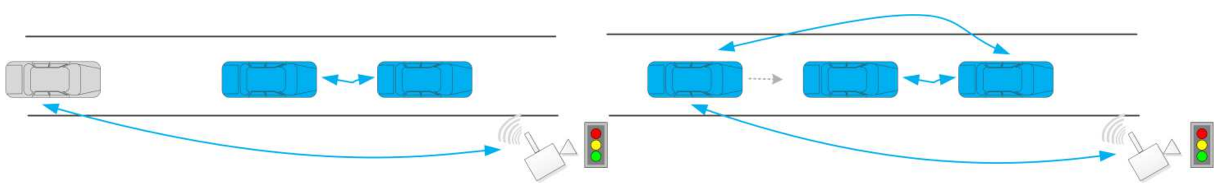

Figure 13 UC2 (Joining a platoon)

Scenario 2 (based on situation 1): Similar to Scenario 1, but the vehicle or the platoon reject the joining. Rejection can be due to vehicle driver desire or failure in V2X negotiation. The platoon stays as it was. The R-ITS-S is informed about this action.

Scenario 3 (based on situation 2): A vehicle is suggested by the R-ITS-S to join a platoon driving on the other lane. A communication link with the former platoon leader is established and the details of the joining (position and role in the platoon, needed manoeuvers) are negotiated. When agreed to a procedure, the platoon leader triggers the vehicles in the platoon to make room for the joining vehicle. The vehicle joins the platoon when possible. The R-ITS-S is informed about this action.

Scenario 4 (based on situation 2): Similar to Scenario 3, but the vehicle or the platoon reject the joining. The platoon stays as it was. The R-ITS-S is informed about this action.

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Link to other use cases

As in this use case an existing platoon is joined, all other platooning use cases are linked and relevant to this use case directly such as UC1, UC3, UC4, UC5 and UC6. Furthermore, speed advices (UC7) and lane changes (UC8) might be needed for joining a platoon. Emergency situations (UC9) cannot be excluded. Platoon joining may be triggered by the cooperative intersection due to the results of the signal optimisation, also linking this use case to UC10, UC11, UC12, UC13 and UC14. Negotiation (UC15) of platoon formation details as well as the detection of non-cooperative road users (UC16) is needed for an optimal joining of a platoon.

10.3 UC3: Travelling in a platoon

10.3.1 Use case introduction

Background

A cooperative automated vehicle which is already established in a platoon continues its role as leader/follower by driving.

Objective (function)

The cooperative automated vehicle drives (follows/leads) in platoon until that one of the following situations happen: leaving platoon (UC4), breaking-up (UC5), platoon termination (UC6) or any emergency situation (UC9).

Desired behaviour

Every platoon member knows its role as leader/follower and V2V and V2I communication are set and leader transfers its planned trajectory to its followers.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

10.3.2 Use case descriptions

Situation(s)

Situation 1: A platoon of two or more cooperative automated vehicles drives in a corridor.

Situation 2: A platoon of two or more cooperative automated vehicles drives in a corridor and receives message from the road side and interacts properly.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react.
- **Vulnerable road user**: The presence of vulnerable road user(s) may effect platoon behaviour such as decelerating/accelerating or stop. No dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: The presence of non-cooperative vehicle(s) may affect platoon behaviour.

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- **Non-cooperative vehicle driver**: Optional signalling by cooperative vehicles that they are currently in platooning mode.
- **Cooperative non-automated vehicle:** Non-automated cooperative vehicles are informed about the actions and may forward it as information to the driver, e.g. to make way. Non-automated cooperative vehicles can also forward the messages to other vehicles if needed.
- **Cooperative non-automated vehicle driver:** The driver may optionally be informed about the platoon actions.
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): Cooperative vehicles in the platoon follow the trajectory planned by leader. The leader plans the trajectory for the followers.
- **Cooperative intersection** (sys) has the ability to inform platoon in case of any emergency situation or in case of transitioning to another related use case. Furthermore, the cooperative intersection can suggest lane changes and speed advices for the platoon. It therefore needs current position and optionally destination information from the platoon.

Scenario(s)

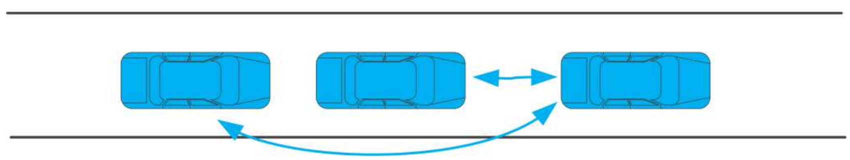

Figure 14 UC3 (Travelling in a platoon)

Scenario 1 (based on situation 1): Two or more cooperative automated vehicles drive in a platoon. The leader plans the trajectories based on the forehead situation and informs the followers.

Scenario 2 (based on situation 2): Two or more cooperative automated vehicles in a platoon drive in a corridor. The leader receives the request to change the behaviour (e.g. change lane, change speed) of the platoon from the road side. The platoon leader negotiates this with the followers and decides to accept the proposed change. Therefore, a new trajectory is planned and sent consequently to the followers.

Scenario 3 (based on situation 2): Two or more cooperative automated vehicles in a platoon drive in a corridor. The leader receives the request to change the behaviour (e.g. change lane, change speed) of the platoon from the road side. The platoon leader negotiates this with the followers and neglects to accept the proposed change. The R-ITS-S is informed about this action.

Link to other use cases

As in this use case an existing platoon is used, all other platooning use cases are linked and relevant to this use case directly such as UC1, UC2, UC4, UC5 and UC6. Furthermore, speed advices (UC7) and lane changes (UC8) are relevant for platoon movement. Emergency situations (UC9) cannot be excluded. Platoons may have a special priority for cooperative intersections. Therefore, platoon information as position and destination data may be relevant to the signal optimisation use cases, also linking this use case to UC10, UC11, UC12, UC13 and UC14. The detection of non-cooperative road users (UC16) may change the platoon movement.

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10.4 UC4: Leaving a platoon

10.4.1 Use case introduction

Background

A platooning vehicle is triggered to leave a platoon or decides to leave the platoon.

Objective (function)

A platooning vehicle is triggered by the R-ITS-S or by the platoon leader to leave the platoon, or decides internally to leave the platoon, e.g. due to driver commands, route changes or technical needs.

Desired behaviour

A vehicle will leave the platoon at a certain moment.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

10.4.2 Use case descriptions

Situation(s)

Situation 1: a cooperative automated vehicle wants to leave a platoon of more than two vehicles on a single lane road.

Situation 2: a cooperative automated vehicle is commanded to leave a platoon of more than two vehicles on a single lane road.

Situation 3: a cooperative vehicle wants to leave a platoon of more than two vehicles on a dual lane road.

Situation 4: a cooperative vehicle is commanded to leave a platoon of more than two vehicles on a dual lane road.

Situation 5: a cooperative vehicle wants to leave a platoon of two vehicles.

Situation 6: a cooperative vehicle is commanded to leave a platoon of two vehicles.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react except in the case that driver decides to take the control manually and therefore requests to leave the platoon. Nevertheless, there should be an optional announcement that the vehicle will leave the platoon.
- **Vulnerable road user**: presence of vulnerable road user(s) may obstruct the leaving of a platoon. No dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct leaving of a platoon.
- **Non-cooperative vehicle driver**: Optional signalling by cooperative vehicles that they are currently in platooning mode or leaving it.

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- **Cooperative non-automated vehicle:** Non-automated cooperative vehicles are informed about the actions and may forward it as information to the driver, e.g. to make way. Non-automated cooperative vehicles can also forward the messages to other vehicles if needed.
- **Cooperative non-automated vehicle driver:** The driver may optionally be informed about the platoon actions.
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): If the vehicle itself is deciding to leave the platoon it is informing the platoon leader about this. When the leaving is triggered by the R-ITS-S or by the leader, the vehicle is informed by the platoon leader.
- **Cooperative intersection** (sys): has the ability to trigger platoon leaving subject to intersection control optimisation criteria.

Scenario(s)

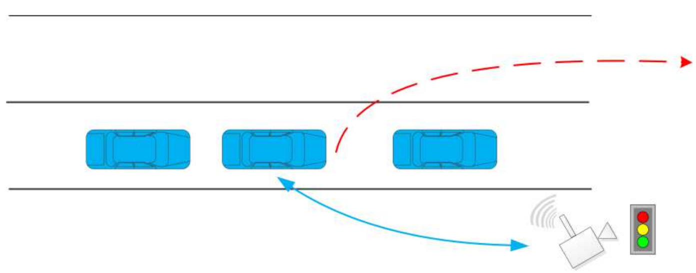

Figure 15 UC4 (Leaving a platoon)

Scenario 1 (based on situation 1 or 3): The platoon leading vehicle is deciding to leave the platoon. The leadership is transferred to the next vehicle in the platoon. The R-ITS-S is informed about this action if in range.

Scenario 2 (based on situation 1 or 3): A platoon trailing vehicle is deciding to leave the platoon. The platoon leader is informed by this action. The vehicle leaves the platoon. The R-ITS-S is informed about this action if in range.

Scenario 3 (based on situation 1): A vehicle being a follower (but not the last) in a platoon is deciding to leave the platoon on a single lane road. The platoon leader is informed by this action. The platoon is split into two platoons, one ahead of the leaving vehicle and one behind. One of the members of the behind platoon is made platoon leader of this platoon according to UC1 and UC5. The R-ITS-S is informed about this action if in range.

Scenario 4 (based on situation 2 or 4): The platoon leading vehicle is triggered by the R-ITS-S to leave the platoon. The leadership is transferred to the next vehicle in the platoon. The R-ITS-S is informed about this action.

Scenario 5 (based on situation 2 or 4): A platoon trailing vehicle is triggered by R-ITS-S or by the platoon leader to leave the platoon. The vehicle leaves the platoon. The R-ITS-S is informed about this action by the platoon leader.
Scenario 6 (based on situation 2): A vehicle being a follower (but not the last) in a platoon is triggered by the R-ITS-S or by the platoon leader to leave the platoon on a single lane road. The platoon is split into two platoons, one ahead of the leaving vehicle and one behind. One of the members of the

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behind platoon is made platoon leader of this platoon according to UC1 and UC5. The R-ITS-S is informed about this action by the platoon leader.

Scenario 7 (based on situation 3): A vehicle being a follower (but not the last) in a platoon is deciding to leave the platoon on a dual lane road. The platoon leader is informed by this action. The vehicle leaves the platoon by changing lanes. The left followers close the gap and remain in the platoon. The R-ITS-S is informed about this action if in range.

Scenario 8 (based on situation 4): A vehicle being a follower (but not the last) in a platoon is triggered by R-ITS-S or by the platoon leader to leave the platoon on a dual lane road. The vehicle leaves the platoon by changing lanes. The left followers close the gap and remain in the platoon. The R-ITS-S is informed about this action by the platoon leader if in range.

Scenario 9 (based on situation 5): A vehicle in a platoon of two vehicles wants to leave the platoon. In this case the platoon is terminated. The R-ITS-S is informed about this action by the platoon leader if in range.

Scenario 10 (based on situation 6): A vehicle in a platoon of two vehicles is commanded to leave the platoon. In this case the platoon is terminated. The R-ITS-S is informed about this action by the platoon leader if in range.

Link to other use cases

As in this use case an existing platoon is left, all other platooning use cases are linked and relevant to this use case directly such as UC1, UC2, UC3, UC5 and UC6. Furthermore, speed advices (UC7) and lane changes (UC8) might be needed for leaving a platoon. Emergency situations (UC9) cannot be excluded. Platoon leaving may be triggered by the cooperative intersection due to the results of the signal optimisation, also linking this use case to UC10, UC11, UC12, UC13 and UC14. The detection of non-cooperative road users (UC16) may change the platoon movement.

10.5 UC5: Platoon break-up

10.5.1 Use case introduction

Background

A non-cooperative or a cooperative but non-automated vehicle is trying to change lane while a platoon is on the other lane.

Objective (function)

Platooning vehicles will react to the non-cooperative/non-automated vehicle by splitting up the platoon and allowing the lane change.

Desired behaviour

Platooning vehicles will react to the non-cooperative/non-automated vehicle by splitting up the platoon and allowing the lane change.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

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10.5.2 Use case descriptions

Situation(s)

Situation 1: one vehicle on one lane, one platoon on the other on a dual lane road

Situation 2: platoon driving on a lane. Platoon leader commands to split the platoon at a specified position.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react. Nevertheless, there should be an optional announcement that the platoon is broken.
- **Vulnerable road user**: presence of vulnerable road user(s) may obstruct the breaking up of a platoon. No dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct the breaking up of a platoon.
- **Non-cooperative vehicle driver**: Using the indicator to show the intention of changing lanes. Optional signalling by cooperative vehicles that they are currently in platooning mode.
- **Cooperative non-automated vehicle:** When non-cooperative vehicle breaks up the platoon, non-automated cooperative vehicles are informed about the actions and may forward it as information to the driver, e.g. to make way. Non-automated cooperative vehicles can also forward the messages to other vehicles if needed. In case a cooperative but non-automated vehicle breaks up the platoon, the driver optionally gets information on where he is supposed to break up.
- **Cooperative non-automated vehicle driver:** The driver may optionally be informed about the platoon actions and the supposed break up position.
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): Negotiating with each other about the correct position in the platoon for breaking up or direct splitting at specified position, due to e.g. a platoon leaving vehicle in the middle of the platoon (see UC4). Negotiation of new platoon leadership in the part behind the non-cooperative vehicle.
- **Cooperative intersection** (sys): has the ability to inform the cooperative vehicles about a non-cooperative vehicle trying to change lane.

Scenario(s)

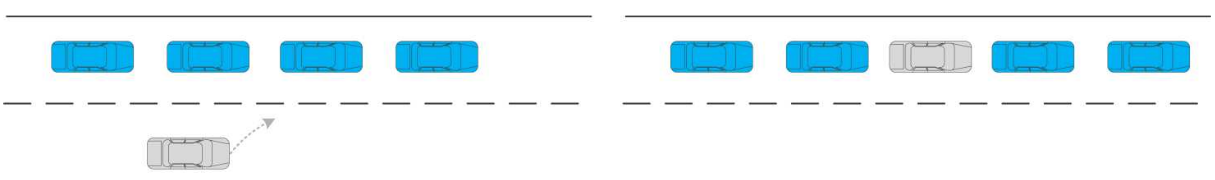

Figure 16 UC5 (Platoon break-up)

Scenario 1 (based on situation 1): The non-cooperative vehicle is indicating to change its lane. This indication is recognized by a following vehicle inside the platoon. This vehicle informs the platoon

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leader about the indication and the position and moving direction of the non-cooperative vehicle. The platoon leader negotiates the optimal behaviour with the followers, finally deciding on the best position of the gap to be opened, where the platoon will be split. One of the members of the behind platoon is elected as new platoon leader of the second platoon, responsible for opening the gap and coordinating its followers. The R-ITS-S is informed about this action if in range.

Scenario 2 (based on situation 1): The non-cooperative vehicle is indicating to change its lane. This indication is recognized by the R-ITS-S. The R-ITS-S informs the platoon leader about the indication and the position and moving direction of the non-cooperative vehicle. The platoon leader negotiates the optimal behaviour with the followers, finally deciding on the best position of the gap to be opened, where the platoon will be split. The platoon member behind this gap is elected as new platoon leader of the second platoon, responsible for opening the gap and coordinating its followers. The R-ITS-S is informed about this action.

Scenario 3 (based on situation 1): Similar to Scenario 1, but the platoon neglects to open a gap (e.g. due to the detected situation). In this case, the non-cooperative vehicle is recognized as a normal surrounding vehicle. The R-ITS-S is informed about this action if in range. The R-ITS-S may suggest other measures to cope with the situation.

Scenario 4 (based on situation 1): Similar to Scenario 2, but the platoon neglects to open a gap (e.g. due to the detected situation). In this case, the non-cooperative vehicle is recognized as a normal surrounding vehicle. The R-ITS-S is informed about this action and may suggest other measures to cope with the situation.

Scenario 5 (based on situation 2): The R-ITS-S informs the platoon leader to split the platoon at a given position, e.g. based on current traffic situations or traffic light phase guarantees. The platoon leader responds by informing the vehicles behind the splitting position to start the negotiation of building a new platoon.

Scenario 6 (based on situation 2): A vehicle in the middle of the platoon wants to leave and informs the platoon leader about this. The platoon leader informs the vehicles behind the leaving vehicle to start the negotiation of building a new platoon.
Scenario 7 (based on situation 2): The platoon leader decides to split the platoon at a given position, e.g. due to lack of computational power for leading the current number of vehicles in the ahead situations. The platoon leader responds by informing the vehicles behind the desired splitting position to start the negotiation of building a new platoon.

Link to other use cases

- UC1, UC2, UC3, UC4, UC6 and UC15

As in this use case an existing platoon is broken up, all other platooning use cases are linked and relevant to this use case directly such as UC1, UC2, UC3, UC4 and UC6. Emergency situations (UC9) cannot be excluded. The detection of non-cooperative road users (UC16) is one possible candidate for detecting the vehicle trying to break up the platoon.

10.6 UC6: Platoon termination

10.6.1 Use case introduction

Background

A travelling platoon is requested by the road side to terminate the platooning.

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Objective (function)

Platooning vehicles will react to this request and drive individually.

Desired behaviour

Safe and reliable transition from platoon mode to individual mode.

Expected impact

Platooning in urban environments will in general impact the traffic flow and emissions of urban traffic.

10.6.2 Use case descriptions

Situation(s)

Situation 1: Travelling platoon of more than two vehicles.

Situation 2: Travelling platoon of two vehicles.

Actors and relations

- **Cooperative automated vehicle driver**: As we are driving highly automated, the driver does not need to react. Nevertheless, there should be an optional announcement that the platoon will be terminated with enough transition time, allowing the driver to take the control of vehicle if needed.
- **Vulnerable road user**: presence of vulnerable road user(s) may obstruct the planned termination of a platoon
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct the planned termination of a platoon.
- **Non-cooperative vehicle driver**: Optional signalling by cooperative vehicles that they are currently in platooning mode or leaving it.
- **Cooperative non-automated vehicle:** n/a
- **Cooperative non-automated vehicle driver:** n/a
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): Negotiating with each other about the correct position and time for termination.
- **Cooperative intersection** (sys): Informs the platoon about termination request and gets informed if platoon is terminated.

Scenario(s)

Use case flow (incl. pre-, interim-, post- and termination conditions)
Use case illustration

Scenario 1: (based on situation 1): A platoon of more than two vehicles is traveling. The leader requests/triggers to terminate the platoon. The leader analyses the situation and it sends termination messages to the followers. Terminating a platoon while lane changes or any other situations which make the transition from platooning to individual mode critical is not possible.

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Scenario 2: (based on situation 1): A platoon of more than two vehicles is traveling. The leader receives message from R-ITS-S to terminate the platoon. The leader analyses the situation and it sends termination messages to the followers. Terminating a platoon while lane changes or any other situations which make the transition from platooning to individual mode critical is not possible.

Scenario 3 (based on situation 2): A vehicle in a platoon of two vehicles wants to leave the platoon. In this case the platoon is terminated. The R-ITS-S is informed about this action by the platoon leader if in range.

Scenario 4 (based on situation 2): A vehicle in a platoon of two vehicles is commanded to leave the platoon. In this case the platoon is terminated. The R-ITS-S is informed about this action by the platoon leader if in range.

Link to other use cases

As in this use case an existing platoon is terminated, all other platooning use cases are linked and relevant to this use case directly such as UC1, UC2, UC3, UC4 and UC5. Furthermore, speed advices (UC7) and lane changes (UC8) might be relevant for platoon termination as well. Emergency situations (UC9) cannot be excluded. Platoon termination may be triggered by the cooperative intersection due to the results of the signal optimisation, also linking this use case to UC10, UC11, UC12, UC13 and UC14. The detection of non-cooperative road users (UC16) may also affect the platoon termination.

10.7 UC7: Speed change advisory (GLOSA)

10.7.1 Use case introduction

Background

Based on information on the phases and timing of traffic lights, speed change advisory can be offered to vehicle drivers or vehicle controls on the approach of and departure from a signalised intersection.

Objective (function)

To calculate a speed advice based on signal phase and timing information, to enable a vehicle or platoon to pass a signalised intersection in the most efficient manner.

Desired behaviour

The vehicle controls comply to the speed change advice, maintaining that speed while passing the signalised intersection.

Expected impact

The primary expected impact is a smoother vehicle trajectory while passing a signalised intersection, which reduces stops and emissions. In case of a stop the start delay is expected to decrease as the start of the green phase is known in advance.

The secondary expected impact results from interaction with UC14 – Signal Optimisation and UC15 – Negotiation. As the driving speeds and the signal phases and timing will be optimized synchronously, the delay times at the signalised intersection are expected to decrease.

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10.7.2 Use case descriptions

Situation

One or more cooperative automated vehicles, possibly driving as a platoon, are approaching a signalised intersection.

Actors and relations

- **Cooperative automated vehicle driver**: no manual action is required.
- **Vulnerable road user**: presence of vulnerable road user(s) may affect the validity of the speed advice (to be) given. Detection of vulnerable road users is considered by the signal optimisation algorithm (UC14). There is no dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct the feasibility of a speed advice, e.g. to increase driving speed.
- **Non-cooperative vehicle driver**: the non-cooperative vehicle driver may perceive the driving behaviour of a cooperative automated vehicle which complies to a speed advice as unnatural, e.g. in case of a decrease of the driving speed.
- **Cooperative non-automated vehicle:** presence of non-cooperative vehicle(s) may obstruct the feasibility of a speed change advice. Using (dedicated) V2V communication the speed change intentions of the cooperative automated vehicle can be indicated.
- **Cooperative non-automated vehicle driver: u**sing vehicle-to-vehicle communication the cooperative non-automated vehicle driver may be informed accordingly.
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): receives speed advice and activates the vehicle controls accordingly.
- **Cooperative intersection** (sys): the communication unit transmits speed advice to cooperative automated vehicles, whereas the CPU computes the speed advice based on signal optimisation and scheduled desired arrival pattern of vehicles at the signalised intersection.

Scenario

While approaching the signalised intersection, the cooperative automated vehicles receive speed advice which is transmitted by the cooperative intersection. There are four possible scenarios:

1. As indicated by the speed advice a vehicle maintains the current speed and arrives at the intersection during a green phase.
2. As indicated by the speed advice a vehicle increases the current speed (never beyond the legal speed limit) and arrives at the intersection before the end of a green phase.
3. As indicated by the speed advice a vehicle decreases the current speed and arrives at the intersection at the start of a green phase.
4. As indicated by the speed advice a vehicle gradually decreases speed and stops to wait for the next green phase. The vehicle receives a speed (acceleration) advice as soon as the light switches to green in order to minimize the start delay.

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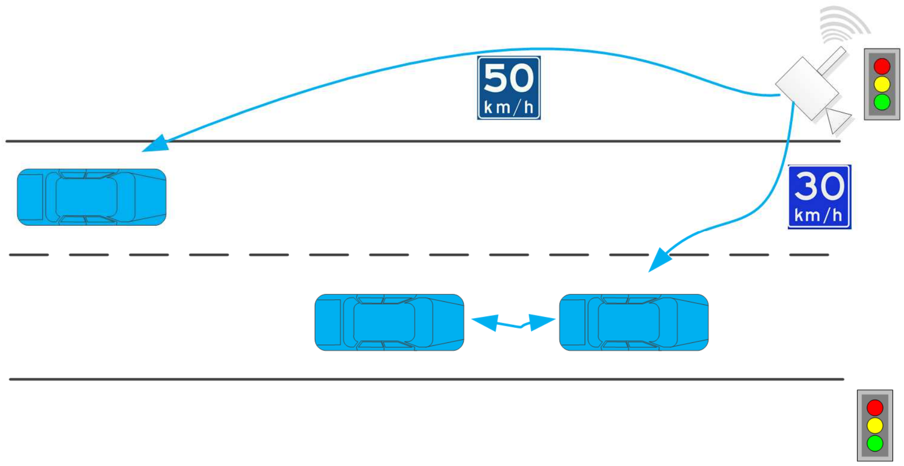

Figure 17 UC7 (Speed change advisory)

Link to other use cases

Only use cases with a direct link are considered here.

- **UC3**: in a platoon, the platoon leader interacts with the cooperative intersection and sets the driving speed for the entire platoon.
- **UC8**: speed change advisory has a lane-level precision and is subject to lane changes.
- **UC14**: to impose speed changes on approaching vehicles is a control variable which is part of the signal optimisation algorithm.
  UC15: rather than top-down speed advice, the speed changes can be negotiated, e.g. if the imposed speed changes is very inefficient from a vehicle's perspective.

10.8 UC8: Lane change advisory

10.8.1 Use case introduction

Background

Due to, for example, queuing vehicles or parked vehicles the traffic flow on a lane may be impeded. In case of a multi-lane road, cooperative automated vehicles can be advised to move to the adjacent lane. In addition, from the perspective of signal optimisation it can be beneficial to evenly balance traffic over the available approach lanes, hence triggering lane change advice.

Objective (function)

To distributed vehicles over the available lanes to making optimal use of the road capacity.

Desired behaviour

The or vehicle controls comply to the lane change advice and make the lane change manoeuvre.

Expected impact

The primary expected impact is a smoother vehicle trajectory and improve traffic flow, which reduces stops, emissions and delay.

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10.8.2 Use case descriptions

Situation(s)

Situation 1: unprotected right turn at a (signalised) intersection causes a queue on the right lane as vehicles have to give way to vulnerable road users. Cooperative automated vehicles (or platoon) are approaching and have the possibility to pass the queue using the left lane.

Situation 2: cooperative automated vehicles (or platoon) are approaching a signalised intersection where traffic is queuing at the traffic light, with a longer queue on the right lane than on the left lane.

Actors and relations

- **Cooperative automated vehicle driver**: vehicle no manual action is required.
- **Vulnerable road user**: presence of vulnerable road user(s) may, indirectly, be the triggering conditions for lane change advisory. Detection of vulnerable road users is considered by the signal optimisation algorithm (UC14). There is no dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may obstruct the feasibility of a lane change advice, e.g. when it is driving in the adjacent lane.
- **Non-cooperative vehicle driver**: there is no dedicated signalling to non-cooperative vehicle drivers.
- **Cooperative non-automated vehicle:** presence of non-cooperative vehicle(s) may obstruct the feasibility of a lane change advice, e.g. when it is driving in the adjacent lane. Using (dedicated) V2V communication the lane change intentions of the cooperative automated vehicle can be indicated.
- **Cooperative non-automated vehicle driver:** using vehicle-to-vehicle communication the cooperative non-automated vehicle driver may be informed accordingly.
- **Road authority** (policy maker / road operator): n/a
- **Cooperative automated vehicle** (sys): receives lane change advice and activates the vehicle control accordingly.
- **Cooperative intersection** (sys): the communication unit transmits lane change advice to cooperative automated vehicles, whereas the CPU computes relevant lane change advice based on queuing vehicles and detected obstacles.

Scenario(s)

Scenario 1 (based on situation 1): the cooperative intersection detects the presence of vulnerable road users and the necessity of right turning vehicles to give way and therefore halt. To make best use of the available road capacity the cooperative intersection advises approaching cooperative automated vehicles (or platoons) to move to the left driving lane.

Scenario 2 (based on situation 2): the cooperative intersection monitors the queue length for every lane. Aiming to evenly balance traffic volumes over available lane, the cooperative intersection advises relevant approaching cooperative automated vehicles to change to the adjacent lane.

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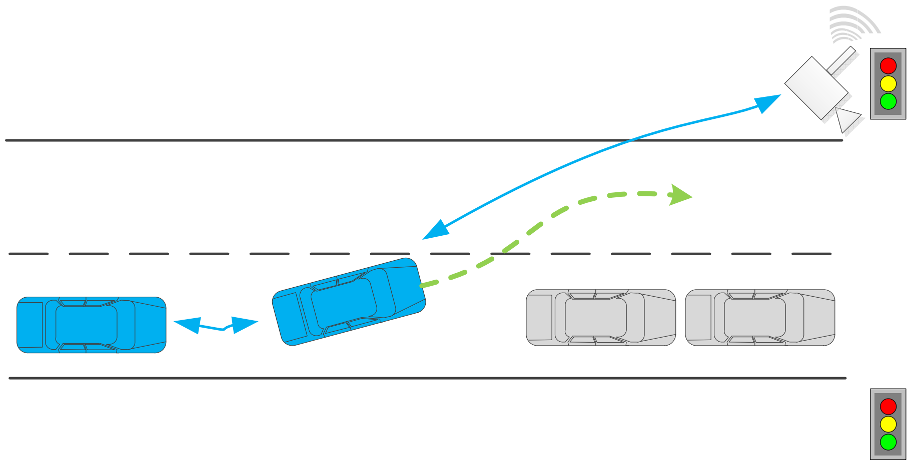

Figure 18 UC8 (Lane change advisory)

Link to other use cases

- **UC2**: a lane change may lead to the situation that a cooperative automated vehicle can join a platoon.
- **UC3**: a lane change may apply to all cooperative automated vehicles travelling in a platoon.
- **UC4**: lane changes in general may cause a cooperative automated vehicle to leave a platoon.
- **UC5**: lane change advisory may cause break-up of a platoon.
- **UC6**: if, due to lane changes, too many vehicle leave a platoon it may imply platoon termination.
- **UC7**: lane change advisory and speed change advisory are closely related and affect each other, together defining the trajectory of cooperative automated vehicles.
- **UC11**: queue length estimation is a main input to lane change decision-making.
- **UC12**: local level routing most likely requires changes lanes to prepare for a turn.
- **UC14**: to optimise traffic flow, emissions and delays, signal optimisation may use lane change advisory as a control variable.
- **UC15**: cooperative automated vehicles or platoons may reject the lane change advise and interact with the intersection controller to explore alternatives.

10.9 UC9: Emergency situations

10.9.1 Use case introduction

Background

Unexpected events may have a considerable impact on the operational scenarios described in the other use cases descriptions. These events can range from system failure to unexpected presence of vulnerable road users to emergency vehicles. Unexpected events may lead to emergency situations and the MAVEN system must be able to handle them, e.g. to trigger use cases, to terminate others or to activate ADAS.

Objective (function)

To mitigate the risks of unexpected events and to ensure traffic safety.

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Desired behaviour

Depending on the situation , the desired behaviour may range from an emergency stop to termination active use cases (e.g. platooning) to triggering other use cases to realise an alternative trajectory and/or manoeuvre.

Expected impact

Improved anticipation to unexpected events, which improves the quality level of traffic safety.

10.9.2 Use case descriptions

Situation(s)

Situation 1: a cooperative automated vehicle is travelling in the middle of a platoon.

Situation 2: a vulnerable road user, which is obstructed by an object, suddenly enters the road in front of an approaching cooperative automated vehicle (or platoon).

Situation 3: an emergency vehicle suddenly approaches and its trajectory will intersect with the trajectory of a cooperative automated vehicle (or platoon).

Actors and relations

- **Cooperative automated vehicle driver**: the driver shall be informed about an emergency situation and related response.
- **Vulnerable road user**: a vulnerable road user which cannot be directly detected by a cooperative automated vehicle may cause an emergency situation.
- **Non-cooperative vehicle**: unexpected manoeuvres by non-cooperative vehicles may cause an emergency situation.
- **Non-cooperative vehicle driver**: the emergency response of a cooperative automated vehicle may be unexpected for drivers of other vehicles. There is no dedicated signalling to non-cooperative vehicle drivers.
- **Cooperative non-automated vehicle:** unexpected manoeuvres by cooperative non-automated vehicles may cause an emergency situation.
- **Cooperative non-automated vehicle driver:** the emergency response of a cooperative automated vehicle may be unexpected drivers of other vehicles. Using vehicle-to-vehicle communication the cooperative non-automated vehicle driver may be warned accordingly.
- **Road authority** (policy maker / road operator): n/a
- **Cooperative automated vehicle** (sys): activates or deactivates use cases and/or ADAS in case an emergency situation is detected or when notified.
- **Cooperative intersection**: has the ability to trigger an emergency response of a cooperative automated vehicle, through provision of sensory information and/or transmission of notification messages.

Scenario(s)

Scenario 1 (based on situation 1): a cooperative automated vehicle is travelling in the middle of a platoon. Due to a system failure the cooperative automated vehicle transfers the control of the vehicle to the driver. Immediately, the other vehicles in the platoon terminate the platoon and to the extent possible increase headways (e.g. by means of lane change or acceleration) to increase safety margins.

Scenario 2 (based on situation 2): a vulnerable road user, which is obstructed by an object, suddenly enters the road in front of an approaching cooperative automated vehicle (or platoon). Using roadside sensors a cooperative intersection detected the vulnerable road users and informed the cooperative automated vehicle before the vulnerable road user entered the road. The cooperative automated vehicle brakes or makes a lane change.

Scenario 3 (based on situation 3): an emergency vehicle suddenly approaches and its trajectory will intersect with the trajectory of a cooperative automated vehicle (or platoon). Using V2X communication, either directly (V2V) or indirectly (message by infrastructure) the cooperative automated vehicle (or lead vehicle of the platoon) is informed about the approaching emergency vehicle and overwrites active use cases.

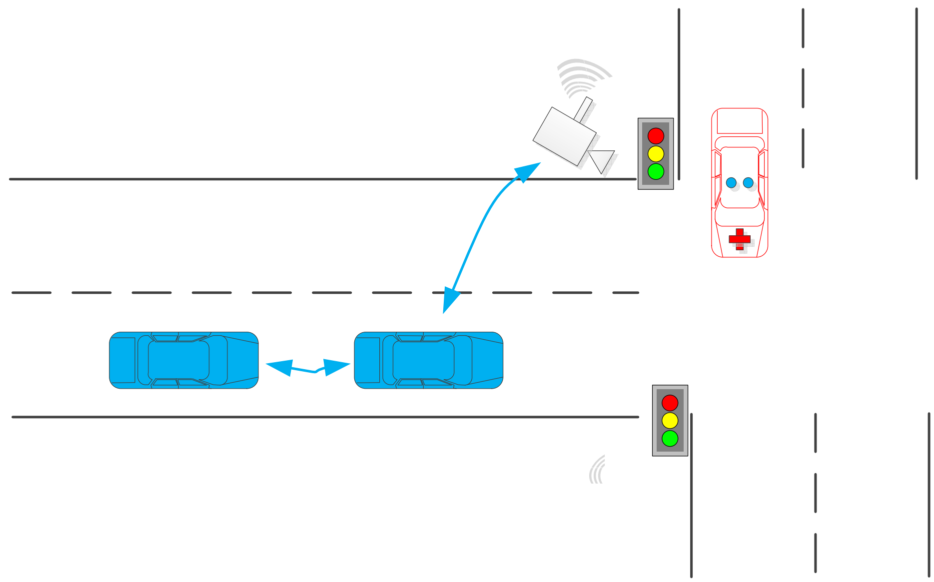

Figure 19 UC9 (Emergency situations)

Link to other use cases

- **UC1**: an emergency situation may abort platoon initialisation.
- **UC2**: an emergency situation may abort or call for joining a platoon.
- **UC3**: an emergency situation may abort travelling in a platoon.
- **UC4**: an emergency situation may call for leaving a platoon.
- **UC5**: an emergency situation may call for platoon break-up.
- **UC6**: an emergency situation may call for platoon termination
- **UC7**: an emergency situation may abort, interfere with or call for speed change advisory.
- **UC8**: an emergency situation may abort, interfere with or call for lane change advisory.
- **UC10**: an emergency situation may reorder priorities.
- **UC14**: an emergency situation may interfere with signal optimisation.
- **UC16**: an emergency situation may be based on detection of road users.

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10.10 UC10: Priority management

10.10.1 Use case introduction

Background

This use case balances different stakeholders requesting priority at an intersection. This can be emergency vehicles, public transport, heavy goods vehicles, automated vehicle (platoons) or a specific modality or route prioritized by the road authority.

Objective (function)

The objective of this use case is to balance the priorities according to the policies set by the road operator.

Desired behaviour

The MAVEN system should ensure the priorities are balanced correctly. This means the stakeholders with the highest priority according to the policy should always get a more favourable control strategy than others. Volume is an important factor here, a large traffic volume with a medium priority can still get a better outcome than a single vehicle belonging to a higher priority class.

Expected impact

With this use case it is expected that stakeholders with the highest priority according to the policy should always get a more favourable control strategy than others.

10.10.2 Use case descriptions

Situation(s)

A traffic light controller is in normal operation with regular traffic arriving from different directions. At the same time multiple priority vehicles are approaching from different directions.

Actors and relations

The traffic management centre can set the policy parameters of the traffic light controller. However, it is not directly in the loop of this use case, the parameters are more like a pre-condition to the use case. The traffic light controller is responsible for the control strategy and takes requests from approaching priority traffic participants into account. It should be noted that this only applies to cooperative vehicles or vehicles requesting priority through dedicated priority technology like KAR [15] and VECOM [16]. Other traffic including VRUs is detected by sensors but will not receive priority unless they are part of a green wave route with priority.
Prioritized traffic participants request priority by checking in and out for a specific signal group. In case of an entire modality or specific route receiving priority, this is done implicitly through the traditional detection.

- **Cooperative automated vehicle driver**: in case priority is received according to policy, the trip will have less travel time.
- **Vulnerable road user**: No role
- **Non-cooperative vehicle**: No role
- **Non-cooperative vehicle driver**: No role
- **Road authority** (policy maker / road operator): Supplies priority policies.

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- **Cooperative automated vehicle** (sys): in case priority is received according to policy, the trip will have less travel time.
- **Cooperative intersection** (sys): Responsible for communication for the priority requests feedback. Will implement the policies and react to requests received.

Scenario(s)

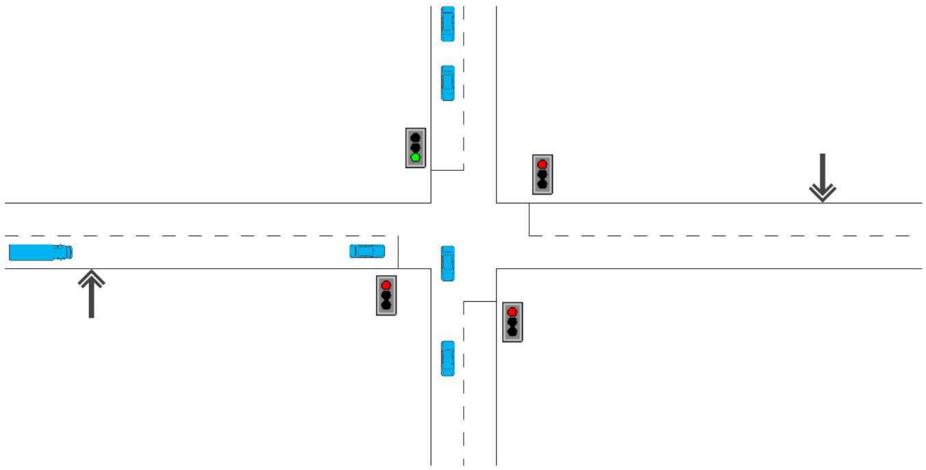

Figure 20 UC10 (Priority management) – a) initial situation

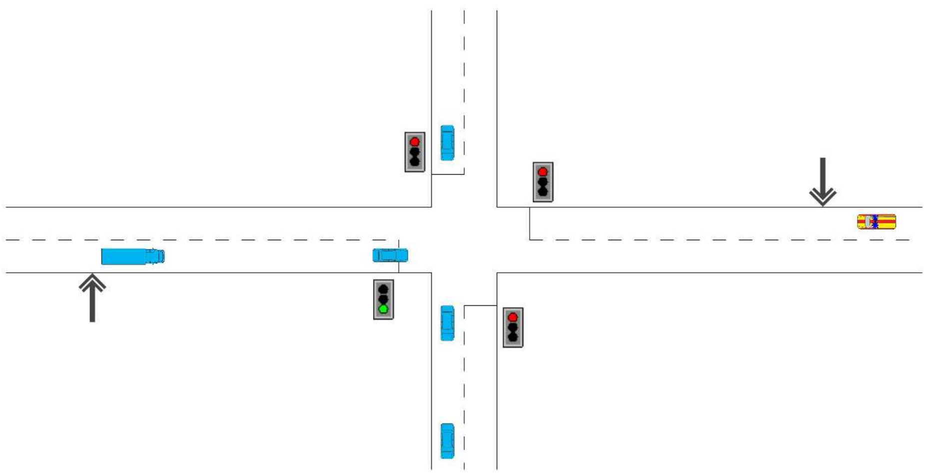

Figure 21 UC10 (Priority management) – b) heavy goods vehicle has signed

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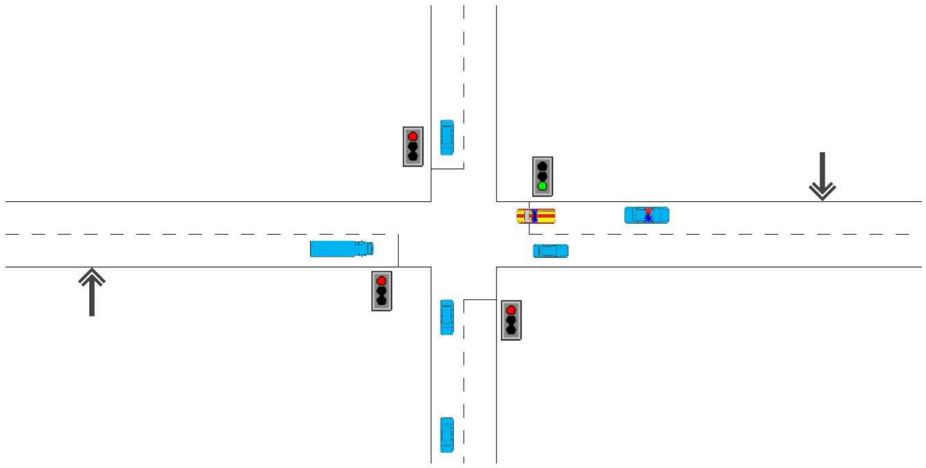

Figure 22 UC10 (Priority management) – c) the emergency vehicle has also signed

The triggering condition for this scenario is a check-in from a priority vehicle. The situation in 1 is the initial situation, a heavy goods vehicle (HGV) with priority is arriving from the left towards a red light. From the right an emergency vehicle is also arriving, but it is still out of range of the picture. Neither vehicle has signed in yet for priority. In 2 the HGV has signed in and the traffic light controller switched the light to green. At situation 3, the emergency vehicle has also signed in and the traffic light controller concluded the priority of the emergency vehicle is higher than for the HGV. Therefore, the final outcome is that the light on the right is green and the emergency vehicle can first pass the intersection.

Link to other use cases

- UC11 Queue length estimation gives data input for this use case, through UC14.
- UC14 is a generic use case for signal optimization and relates to this, although a different aspect of signal optimization is considered in UC14.
- The resulting plan changes are output that can be used for UC7 speed change advisory and
- UC15 negotiation.
- Both UC7 and UC15 have a link with the infrastructure and again the effects of this use case pass through UC14 to reach the others.

10.11 UC11: Queue length estimation

10.11.1 Use case introduction

Background

Traditional queue measurement takes place with point detections. Vehicles are counted both at the entrance of a road section and at the exit (usually the stop line of an intersection). Based on counts, historical turning percentages, a propagation model of the vehicles approach and fault correction logic, an estimate on how many vehicles are approaching each signal group. Due to the detection taking place only at specific points and no guarantee about 100% reliability, there is still a chance for errors. Especially the turning percentages are prone to cause large errors. This use case estimates queue length based on new data sources available thanks to cooperative and automated vehicles.

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Objective (function)

With this improved queue length estimation a better control strategy should be possible and more accurate speed advice for GLOSA.

Desired behaviour

The systems involved in this use case should improve the queue estimation.

Expected impact

An improved queue estimation is the expected impact, which in its turn will improve traffic flow and reduce emissions through UC14.

10.11.2 Use case descriptions

Situation(s)

A traffic light controller is in normal operation with some vehicles queued up on different signal groups. The queue algorithm based on traditional detection has made some errors in the past and therefore the amount of waiting vehicles per signal group does not match what is in the traditional queuing model. This is caused by rapidly changing demand ratios between the different turning directions.

Actors and relations

The traffic light controller is responsible for delivering data about the traffic light state, the traditional detector data and the traditional queue model state. It should also accept external data on queue measurement to improve its queue model state.
Cooperative vehicles come in various kinds, connected through a back office giving trajectory information on approximately every minute scale. Cooperative vehicles continuously transmit CAM messages every 100-1000ms and can be followed precisely. Lastly, automated vehicles also have sensory information about their surroundings to share, which can be interesting for the queue estimation.
The cooperative queue estimation software runs in the cooperative Road Side Unit (RSU) and receives the previously described information. Whenever it notices a deviation from the traditional queue estimate it will share this with the traffic light controller.

- **Cooperative automated vehicle driver**: no direct role, will enjoy benefits of the system
- **Vulnerable road user**: will trigger conventional sensors to feed the traditional queue model
- **Non-cooperative vehicle**: will trigger conventional sensors to feed the traditional queue model
- **Non-cooperative vehicle driver**: has no direct role, will enjoy benefits of the system
- **Road authority** (policy maker / road operator): has no direct role, will enjoy benefits of the system
- **Cooperative automated vehicle** (sys): will trigger conventional sensors to feed the traditional queue model and transmits CAM messages to feed the enhanced queue model of this use case
- **Cooperative intersection** (sys): Enables the infrastructure to receive the CAM. Receives updates of the enhanced queue model.

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Scenario(s)

This scenario has no triggering conditions, as the queue length estimation is always switched on. The reception of a CAM message can be seen as triggering condition, as this is data the algorithm will be able to process and create improved queue estimates. Many different scenarios are part of this use case and it's part of the research to determine which scenarios can be useful to include in the logic. An example is illustrated by the figure below:

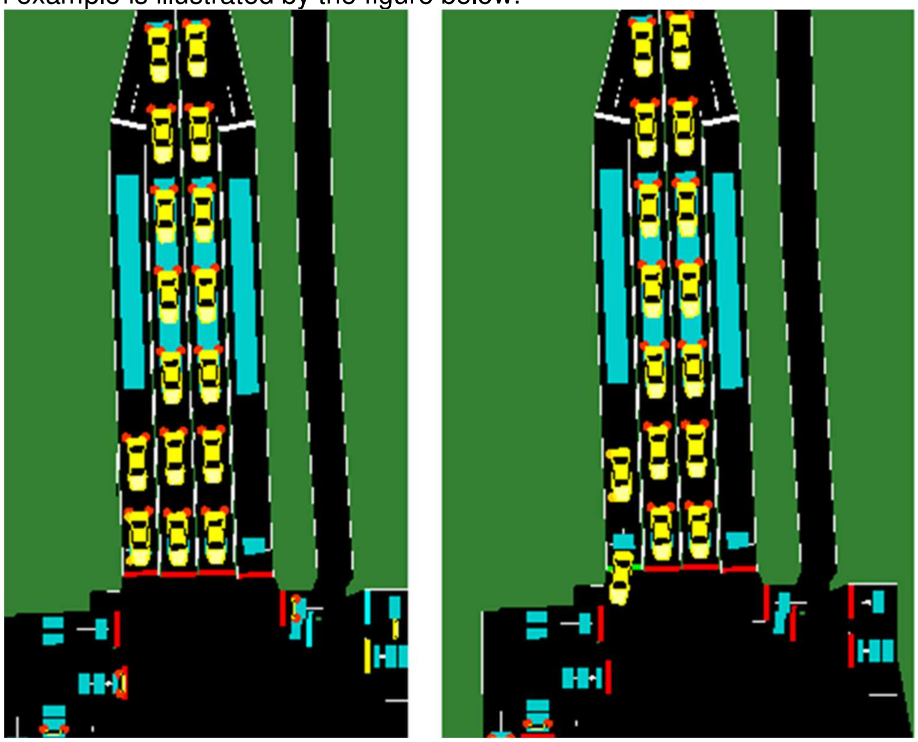

Figure 23 UC11 (Queue length estimation)

On the left side of the figure 2 vehicles are waiting for a right turn and 14 for the through movement spread over 2 lanes. At the right side of the figure the two vehicles started moving due to the start of the green phase. In case all vehicles are cooperative, the queue estimation algorithm can already conclude at this point there are only 2 vehicles in the queue for the right turn. This is because no third vehicle started moving and the traditional detection field (the blue rectangles indicate inductive loops) concluded there is no vehicle waiting for the left turn.

Scenarios can be different on many factors including (but not limited to):

- Amount of signal groups and lanes
- Amount of vehicles waiting in each lane (depending on the demand)
- The traffic control strategy (i.e. which signal groups are red/green)
- Percentage of vehicles with cooperative technology
- The kind of cooperative technology present in vehicles
- The status of the queues when a cooperative vehicle arrives
- The status of the queues when a cooperative vehicle starts moving (or doesn't start moving after a light on a parallel lane switching to green)

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Link to other use cases

UC10 priority management and UC14 signal optimization use the output of this use case for more efficient traffic light control. UC7 and UC15 use it for more accurate speed advice.

10.12 UC12: Local level routing

10.12.1 Use case introduction

Background

Knowing the traffic light plans in advance can be beneficial for routing when two routing alternatives are very similar on a macro-level (e.g. distance, average travel time). This can result in knowing whether it's likely to get a green wave on one route alternative or if a queue is about to grow beyond the capacity of one cycle.

Objective (function)

The objective is to give vehicles an advice on a small horizon of <5 minutes which route to take.

Desired behaviour

Giving a local routing advice.

Expected impact

This use case should result in better network load balancing, reduced travel times and reduced emissions.

10.12.2 Use case descriptions

Situation(s)

A vehicle arrives at a decision point where 2 or more route alternatives are possible, either to its end destination or to a waypoint towards its end destination. The latter is not relevant for the use case.

Actors and relations

Vehicle receives route advice from the route advice subsystem.
Route advice subsystem gets data from green wave component and local traffic light controller
Green wave component and traffic light controller deliver data.

- **Cooperative automated vehicle driver**: Receives advice and decides whether to follow it or not.
- **Vulnerable road user**: No role.
- **Non-cooperative vehicle**: No direct role, will benefit from improved load balancing
- **Non-cooperative vehicle driver**: No direct role, will benefit from improved load balancing
- **Road authority** (policy maker / road operator): No direct role, will benefit from improved load balancing
- **Cooperative automated vehicle** (sys): Receives advice
- **Cooperative intersection** (sys): Communication towards vehicles Supply data on which advice can be based.

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Scenario(s)

The triggering condition is when a cooperative vehicle arrives at the route decision point. The use case flow is rather simple here. The route advice subsystem continuously collects data from green wave component and traffic light controllers. Based on the data received over time the route advice subsystem has a model of the network and can send route advice to the vehicle. Once the vehicle arrives at the decision point, the latest status of the network model is used to calculate an advice for that individual vehicle. This advice is sent using 802.11p communication and the driver (or automated system in the car) can decide whether to follow the advice or not. The vehicle follows this advice and saves time and fuel. The figure below shows an example of a network with two route alternatives.

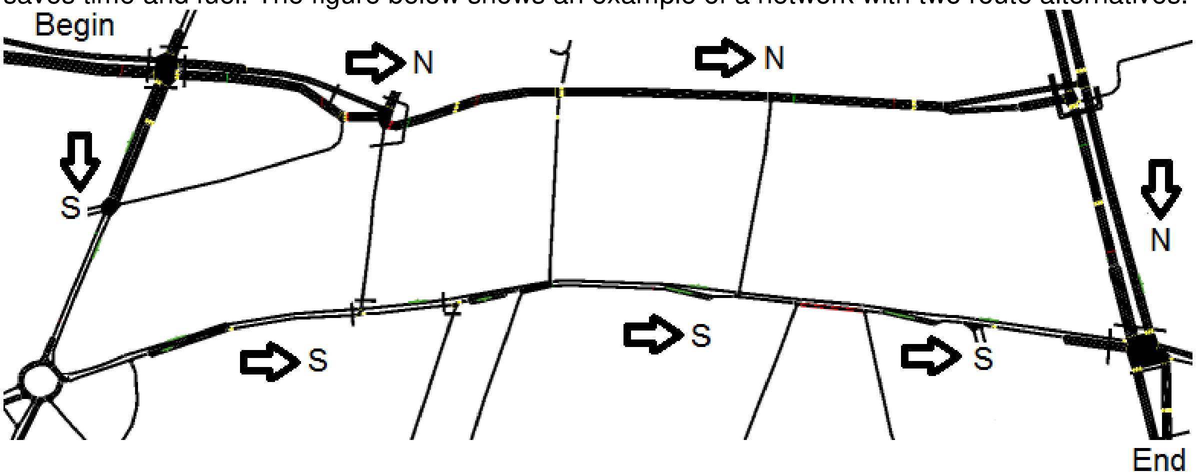

Figure 24 UC12: Local level routing

Link to other use cases

This use case links to UC13 network coordination, UC14 signal optimization and UC10 priority management as they can all result in factors influencing the route advice.

10.13 UC13: Network coordination – green wave

10.13.1 Use case introduction

Background

Green waves have been around for a long time, most often done with a static control plan with fixed offset to guarantee a green wave. With adaptive control this can be realized by putting a high priority on a certain route, but this never guarantees a green wave. However, both solutions are at the cost of increased delay for traffic not in the green wave. With cooperative and automated vehicles there are more possibilities for green wave as the speed of the vehicles can be adjusted.

Objective (function)

The objective of this use case is to create a dynamic green wave for automated and cooperative vehicles in close cooperation with GLOSA speed advice with less impact on other traffic than traditional green wave systems have.

Desired behaviour

The desired behaviour of this use case is that a dynamic green wave for automated and cooperative vehicles is created in close cooperation with GLOSA speed advice, which causes less impact on other traffic than traditional green wave systems.

Expected impact

This scenario should create a dynamic green wave, which results in less travel time and pollutant emissions.

10.13.2 Use case descriptions

Situation(s)

A network is filled with traffic close to saturation at some intersections, but not so close on others. At the same time, the intersections are not equally spaced, so cycle time synchronization based on the travel time between intersections is not efficient. The network is a corridor shape network (like in Helmond) and platoons arrive at random intervals in both directions on the corridor.

Actors and relations

Traffic light controllers have an overview of their current status, the green wave system coordinates between them and tells the traffic light controllers what to do. GLOSA system reads the resulting plans and advices vehicles which speed to follow. The vehicles follow this speed.

- **Cooperative automated vehicle driver**: Actively participated in the cooperative green wave following speed advice of UC7 when applicable.
- **Vulnerable road user**: no role
- **Non-cooperative vehicle**: no direct role, will still enjoy benefits of the green wave
- **Non-cooperative vehicle driver**: no direct role, will still enjoy benefits of the green wave
- **Road authority** (policy maker / road operator): sets policies for the green wave
- **Cooperative automated vehicle** (sys): receives messages related to signal timing for the green wave through UC7
- **Cooperative intersection** (sys): enables communication with the vehicle through UC7implements the green wave strategy

Scenario(s)

This scenario is always on, a triggering condition can be the moment the traffic lights are switched on. The figure below is a standard time-distance diagram for a bi-directional green wave. It is enhanced for asymmetrical intersections with different distances between the intersection in different directions.

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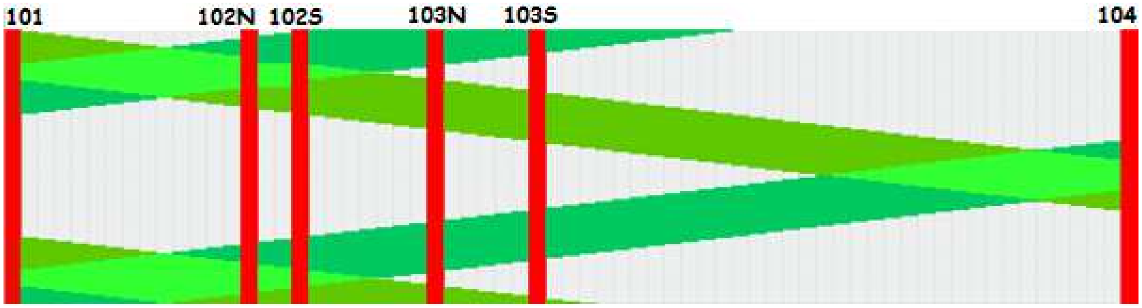

Figure 25 UC13 (Network coordination – green wave)

Use As can be seen in the figure the greens don’t perfectly match at each intersection, especially 103 has a large offset. This was planned here due to a much lower saturation at this intersection. The green wave system will take this data about the topology into account and dynamically design an optimal time-distance diagram based on current saturation ratio’s and the size of the platoons requiring a green wave. It will result in vehicles having to change their speed on certain subsections to create better synchronization.

Link to other use cases

UC7 speed advice should take the signal plans coming out of this into account. Additionally, the presence of platoons will increase the saturation flow, enabling more efficient green wave windows. Therefore, a link to UC1-6 is required to acquire information about platoons.

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10.14 UC14: Signal optimisation

10.14.1 Use case introduction

Background

The introduction of automated and cooperative vehicles enable further signal optimization possibilities. One of the major challenges for a traffic light controller is to estimate the size of the queues and their distribution over the different lanes. The functionality of UC11 will provide more detailed data about the queue distribution. Additionally, the introduction of GLOSA can pose challenges to the control algorithm as it assumes vehicles approach the stop line with the maximum speed limit (or a running average of the approach speed). Thanks to cooperative data and information coming from the GLOSA negotiation (UC15), this can be anticipated. Additionally, it is important the supplied speed advice will be accurate. This depends directly on the supplied signal phase predictions and therefore the controller has to stabilize this.

Objective (function)

Improve controller performance (reduced average delay and stops for all traffic) by using the new data. Stabilize the signal plan for approaching vehicles with speed advice.

Desired behaviour

Improved controller performance (reduced average delay and stops for all traffic) by using the new data and new actuators. Stabilized signal plan for approaching vehicles with speed and lane change advice. Managing dynamic priorities of different types of vehicles in order to improve the overall performance.

Expected impact

This use case should result in more optimal signal plans and proper management of automated vehicles, which results in less travel time and pollutant emissions.

10.14.2 Use case descriptions

Situation(s)

1. A traffic light controller is in normal operation with some vehicles queued up on different signal groups. The queue algorithm based on traditional detection has made some errors in the past and therefore the amount of waiting vehicles per signal group does not match what is in the traditional queuing model. This is caused by rapidly changing demand ratios between the different turning directions.
2. A traffic light controller is in normal operation with some vehicles queued up on different signal groups. An automated vehicle is approaching and initiates GLOSA negotiation.

Actors and relations

At the cooperative intersection, the traffic light controller receives information from the GLOSA negotiation system and the enhanced queue algorithm and uses it to improve the control strategy. Vehicles take part in the negotiation and share data through the negotiation. They also benefit from the improved control strategy.

- **Cooperative automated vehicle driver**: no direct role, benefits from better control
- **Vulnerable road user**: no direct role, benefits from better control

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- **Non-cooperative vehicle**: no direct role, benefits from better control
- **Non-cooperative vehicle driver**: no direct role, benefits from better control
- **Road authority** (policy maker / road operator): sets control policies
- **Cooperative automated vehicle** (sys): no direct role, benefits from better control
- **Cooperative intersection** (sys): only participates through other UCs implements improved control.

Scenario(s)

The scenarios are basically continuously active, switching on the traffic light controller can be seen as triggering condition. Reception of data from UC11 or UC15 will activate improved performance.

1. UC11 completes (see 3.12) and delivers data to the traffic light controller. This data is used to recalculate the optimal signal control strategy. This new strategy is followed and all traffic incurs a smaller average delay and amount of stops.
2. UC15 completes (see 3.15) and delivers data about approach speed of vehicles. This data is used by the traffic light controller to anticipate a later arrival at the stop line and the control strategy takes measures to increase the chances the speed advice was accurate. GLOSA vehicles then keep following a stable advice speed and pass the light without stopping.

Link to other use cases

- UC11 Queue length estimation, delivers enhanced data about the queue states.
- UC15 Negotiation, delivers data about the speed of vehicles approaching with an advice.
- Additionally, the presence of platoons will increase the saturation flow, enabling more efficient control plans. Therefore, a link to UC1-6 is required to acquire information about platoons.
- UC7 Speed change advisory, is a mean of imposing the optimized control onto the traffic flow (particularly automated vehicles).
- UC8 Lane change advisory, is a mean of imposing the optimized control onto the traffic flow (particularly automated vehicles).

10.15 UC15: Negotiation

10.15.1 Use case introduction

Background

C-ITS can enable negotiation strategies according to which cooperative automated vehicles and cooperative intersections exchange information about intentions and possibilities in a way to provide optimal traffic flows at intersections

Objective (function)

Performing a bidirectional exchange of information for negotiations using communications from Infrastructure and vehicles and back.

Desired behaviour

The cooperative intersection can correctly collect V2I messages representing vehicle dynamic information (e.g. time of arrival at the intersection stop line, size of an approaching platoon), intentions about routes (driving patterns through the intersection area), and information about perceived environment (presence of non-cooperative vehicles, obstacles or other traffic

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participants). The intersection analyses the received data, performs calculations and possibly influences the vehicles driving behaviour suggesting or imposing corrective measures by using I2V communications and dedicated information.

Expected impact

Create the basis to optimize traffic management in the context of connected automated traffic at road intersections

10.15.2 Use case descriptions

Situation(s)

Situation 1: A single cooperative vehicle approaching an intersection with a cooperative traffic light
Situation 2: Individual cooperative vehicles (not organized in a platoon) approaching an intersection with a cooperative traffic light
Situation 3: A small platoon of cooperative vehicles approaching an intersection with a cooperative traffic light

Actors and relations

- **Cooperative automated vehicle driver**: interaction or announcement that the vehicle is going to act in a given way according to the outcome of the negotiation algorithms.
- **Vulnerable road user**: presence of vulnerable road user(s) may influence the calculations of the negotiation algorithms. No dedicated signalling to vulnerable road users.
- **Non-cooperative vehicle**: presence of non-cooperative vehicle(s) may influence the calculations of the negotiation algorithms.
- **Non-cooperative vehicle driver**: signalling data from traffic light as reaction to negotiation algorithms.
- **Cooperative non-automated vehicle:** Receives I2V messages as result of negotiation algorithms that anyhow do not have an impact in terms of automated driving functions, but only in terms of improved V2X information
- **Cooperative non-automated vehicle driver:** receive information resulting from V2X signalling data from traffic light as reaction to negotiation algorithms
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): communicates different type of information depending on its role of platoon leader (Situation 2) or single vehicle (situation 1). Receives I2V messages as result of negotiation algorithms that have an impact on automated driving functions
- **Cooperative intersection** (sys): receives V2I messages, performs negotiation algorithms and in turn replies with I2V messages displays possible changes in signalling according to the results of the negotiation algorithms.

Scenario(s)

Scenario 1 (based on situation 1): one cooperative automated vehicle is approaching an intersection with a cooperative traffic light. As soon as cooperative messages are received from the traffic light (possibly containing speed advices), it calculates the time of arrival at the intersection. As a consequence, it communicates this information to the traffic light, possibly along with the intended

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trajectory at the intersection area (e.g. inbound/outbound lane). The traffic light receives, this information, and by considering the other intersection data, may decide to apply changes to the intended vehicle behaviour. If this is the case, the traffic light will use I2V messages to suggest/impose to it a platoon joining, alternative trajectory, speed, or a change in the signalled traffic light phases and times (which are of course reflected by the visible traffic light signals).

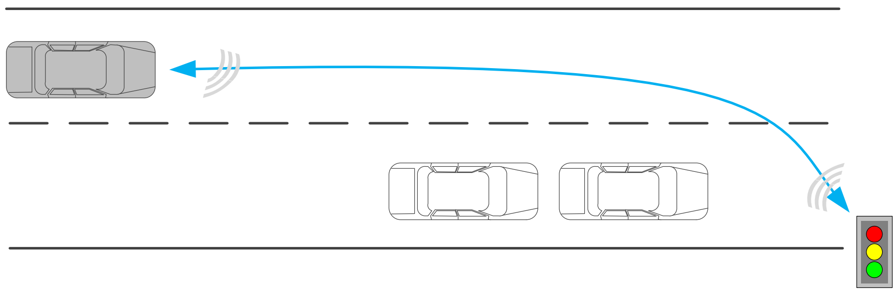

Figure 26 UC15 (Negotiation) – single vehicle

Triggering condition for this scenario is the vehicle getting in the communication range of the cooperative intersection (i.e. vehicle and intersection are in conditions to reliably exchange wireless messages), or alternatively the vehicle passing a threshold distance from the intersection center inside the above mentioned communication range.

Scenario 2 (based on situation 2): individual cooperative automated vehicles are approaching an intersection with a cooperative traffic light without being organized in a platoon. Each vehicle communicates information about estimated time of arrival at the stop line, possibly along with the intended trajectory at the intersection area (e.g. inbound/outbound lane), and information regarding environmental perception (non-cooperative vehicles, obstacles, VRUs). The traffic light receives, this information, and by considering the other intersection data, may decide to apply changes to the vehicles behaviour. If this is the case, the traffic light will use I2V messages to suggest/impose platoon formation, platoon joining, individual alternative trajectories, speeds, or a change in the signalled traffic light phases and times (which are of course reflected by the visible traffic light signals)

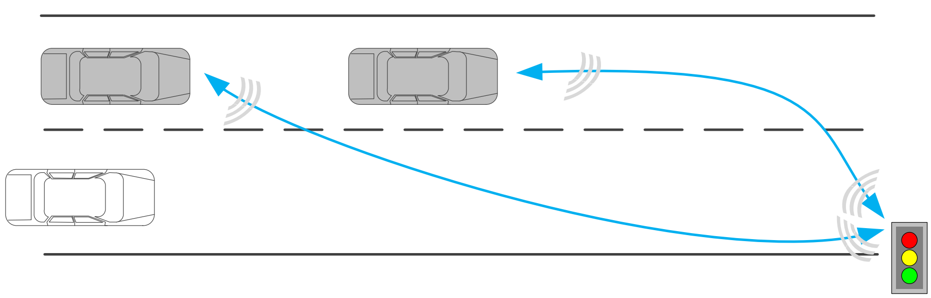

Figure 27 UC15 (Negotiation) – multiple vehicles

Triggering condition for this scenario is individual cooperative automated vehicles getting in the communication range of the cooperative intersection (i.e. vehicle and intersection are in conditions to reliably exchange wireless messages), or alternatively the vehicles passing a threshold distance from the intersection centre inside the above mentioned communication range.

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Scenario 3 (based on situation 3): a small platoon of cooperative vehicles is approaching an intersection with a cooperative traffic light. As soon as cooperative messages are received from the traffic light (possibly containing speed advices), the platoon calculates the time of arrival at the intersection. As a consequence, it communicates this information to the traffic light, possibly along with platoon information like the platoon size (number of vehicles composing it) and/or the intended trajectory of every platoon vehicle at the intersection area (e.g. inbound/outbound lanes). The traffic light receives, this information, and by considering the other intersection data, may decide to apply changes to the intended platoon behaviour. If this is the case, the traffic light will use I2V messages to suggest/impose to the platoon vehicles an alternative trajectory, speed, trigger a platoon leaving, break-up, or simply a change in the signalled traffic light phases and times (which are of course reflected by the visible traffic light signals)

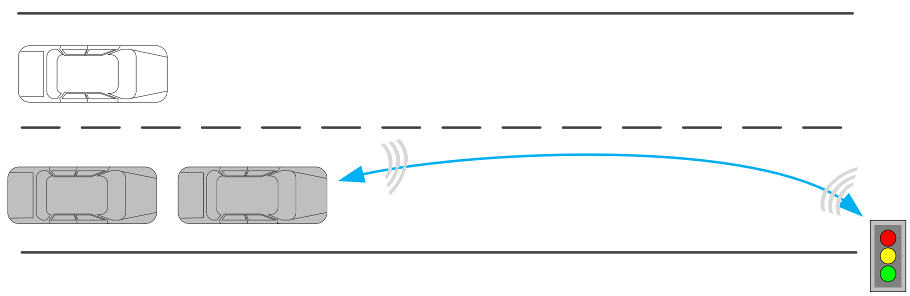

Figure 28 UC15 (Negotiation) – platoon of vehicles

Triggering condition for this scenario is individual cooperative automated vehicles getting in the communication range of the cooperative intersection (i.e. vehicle and intersection are in conditions to reliably exchange wireless messages), or alternatively the vehicles passing a threshold distance from the intersection centre inside the above mentioned communication range.

Link to other use cases

- This use case precedes UC1 as it provides the means to enable infrastructure platoon initialization decisions and their implementation
- This use case precedes UC2 as it provides the means to enable infrastructure platoon joining decisions and their implementation
- This use case precedes UC4 as it provides the means to enable infrastructure platoon leaving decisions and their implementation
- This use case precedes UC6 as it provides the means to enable infrastructure platoon termination decisions and their implementation
- This use case precedes UC7 as it provides the means to enable infrastructure-based GLOSA decisions and their implementation
- This use case precedes UC8 as it provides the means to enable infrastructure-based lane change advisory decisions and their implementation
- This use case precedes UC10 as it provides the means to enable infrastructure-based priority management decisions and their implementation
- This use case precedes UC10 as it provides the means to enable signal optimization decisions and their implementation.

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10.16 UC16: Detect non-cooperative road users

10.16.1 Use case introduction

Background

Many of the MAVEN use cases can be influenced from the presence of traffic participants that cannot cooperatively participate to the functions envisioned by the MAVEN framework. As those users have to be carefully taken into account for ensuring safety and traffic efficiency, the MAVEN subsystems have to be capable to detect them.

Objective (function)

Detection and characterization of MAVEN complementing non-cooperative road users(VRUs, non-cooperative vehicles) for their inclusion in relevant MAVEN use cases.

Desired behaviour

VRUs and non-cooperative vehicles are correctly detected and their information is available to the MAVEN algorithms and functions that need to make use of them.

Expected impact

Ensuring continuity in the generation of safety and traffic efficiency, by providing the basis to react to situations in which the presence of non-cooperative road users could disrupt the implementation of the MAVEN functionalities.

10.16.2 Use case descriptions

Situation(s)

Situation 1: Cooperative automated vehicles (individual or in a platoon) are approaching, from different approaches, an intersection with a cooperative traffic light but no detection capabilities. A pedestrian is currently in a dangerous position (e.g. crossing when forbidden). The VRU is visible only by some of the vehicles approaching. The other vehicles cannot detect the VRU (e.g. behind the corner) and could hit him if not warned

Situation 2: Cooperative automated vehicles (individual or in a platoon) are approaching an intersection with a cooperative traffic light but no detection capabilities. A non-cooperative vehicle is currently trying to interfere the platoon dynamics (e.g. trying to change on the lane where the platoon is driving). The non-cooperative vehicle is visible only by some of the platoon vehicles. The other vehicles and the cooperative intersection cannot detect it.
Situation 3: Cooperative automated vehicles (individual or in a platoon) are approaching an intersection with a cooperative traffic light and detection systems (e.g. a hemispheric camera). A VRU is currently in a dangerous position (e.g. crossing when forbidden). The vehicles cannot detect the VRU (e.g. behind the corner) and could hit him if not warned

Actors and relations

- **Cooperative automated vehicle driver**: interaction or announcement that the vehicle is going to act in a given way according to the outcome of the VRU detection and consequent reaction.
- **Vulnerable road user**: presence of vulnerable road user(s) is necessary for this use case as they are the actors to be detected.

- **Non-cooperative vehicle and cooperative non-automated vehicle**: presence of non-cooperative vehicle(s) and cooperative non-automated vehicle(s) may influence the ability of detecting actors. Moreover, these vehicles have to be detected and their presence shared when this information is needed by other use cases
- **Non-cooperative vehicle driver**: n/a
- **Road authority** (policy maker / road operator): n/a.
- **Cooperative automated vehicle** (sys): communicates information regarding detected road users to other cooperative vehicles or cooperative traffic lights
- **Cooperative intersection** (sys): communicates information regarding detected VRUs to cooperative vehicles

Scenario(s)

Scenario 1 (based on situation 1): the vehicles that can detect the VRU use V2X communications for cooperative sensing to broadcast information (position, characteristics, location with respect to the intersection topology, etc.) about the VRU. The other vehicles that initially cannot detect the VRU (e.g. because behind the corner), as well as the cooperative traffic light get informed in advance about the presence of the VRU in a dangerous situation. This information can be used by vehicles to drive ADAS functions (e.g. automated braking) or influence automated driving algorithms (e.g. stopping a platoon). At the same time, cooperative traffic lights can use the received information to automatically apply reactions like traffic light status changes (turn on the red light) to mitigate the situation.

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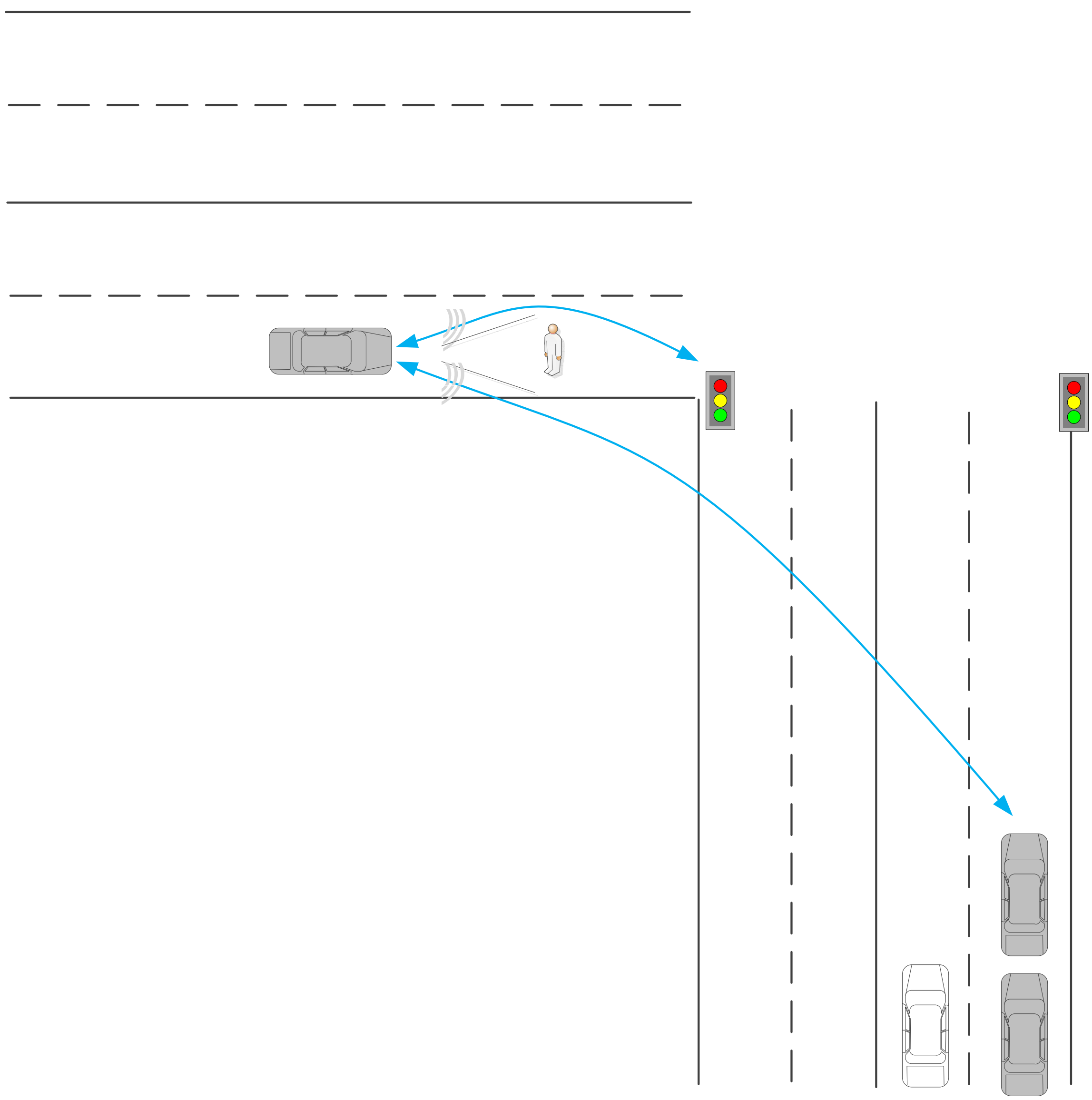

Figure 29 UC16 (Detect non-cooperative road users) - pedestrian

There are no specific triggering conditions for this scenario as the detection functionality and the consequent information sharing is always active.

Scenario 2 (based on situation 2): the vehicles that can detect the interfering non cooperative vehicle use V2X communications for cooperative sensing to broadcast information (position, characteristics, location with respect to the intersection topology, etc.) about this vehicle. The other vehicles that initially cannot detect the interfering vehicle (e.g. because ahead in the platoon), as well as the cooperative traffic light get informed in advance about the presence of the interfering vehicle. This information can be used by vehicles to drive ADAS functions (e.g. automated braking) or influence automated driving algorithms (e.g. stopping and/or braking a platoon). At the same time, cooperative traffic lights can use the received information to automatically apply reactions like traffic light status changes (turn on the red light) to mitigate the situation.

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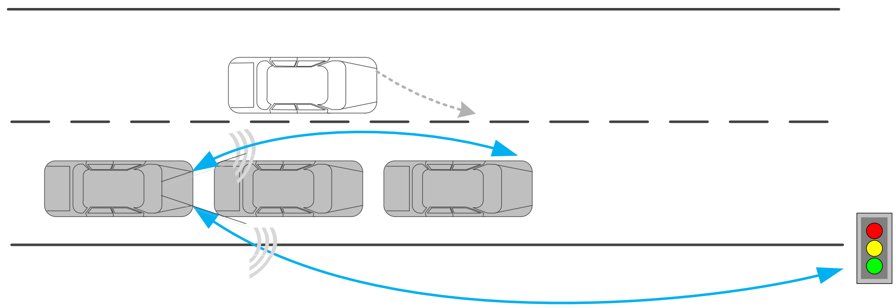

Figure 30 UC16 (Detect non-cooperative road users) - vehicle

There are no specific triggering conditions for this scenario as the detection functionality and the consequent information sharing is always active.

Scenario 3 (based on situation 3): the traffic light that can detect the VRU use I2V communications for cooperative sensing to broadcast information (position, characteristics, location with respect to the intersection topology, etc.) about the VRU. The receiving vehicles that initially cannot detect the VRU (e.g. because behind the corner), get informed in advance about the presence of the VRU in a dangerous situation. This information can be used by vehicles to drive ADAS functions (e.g. automated braking) or influence automated driving algorithms (e.g. stopping a platoon).

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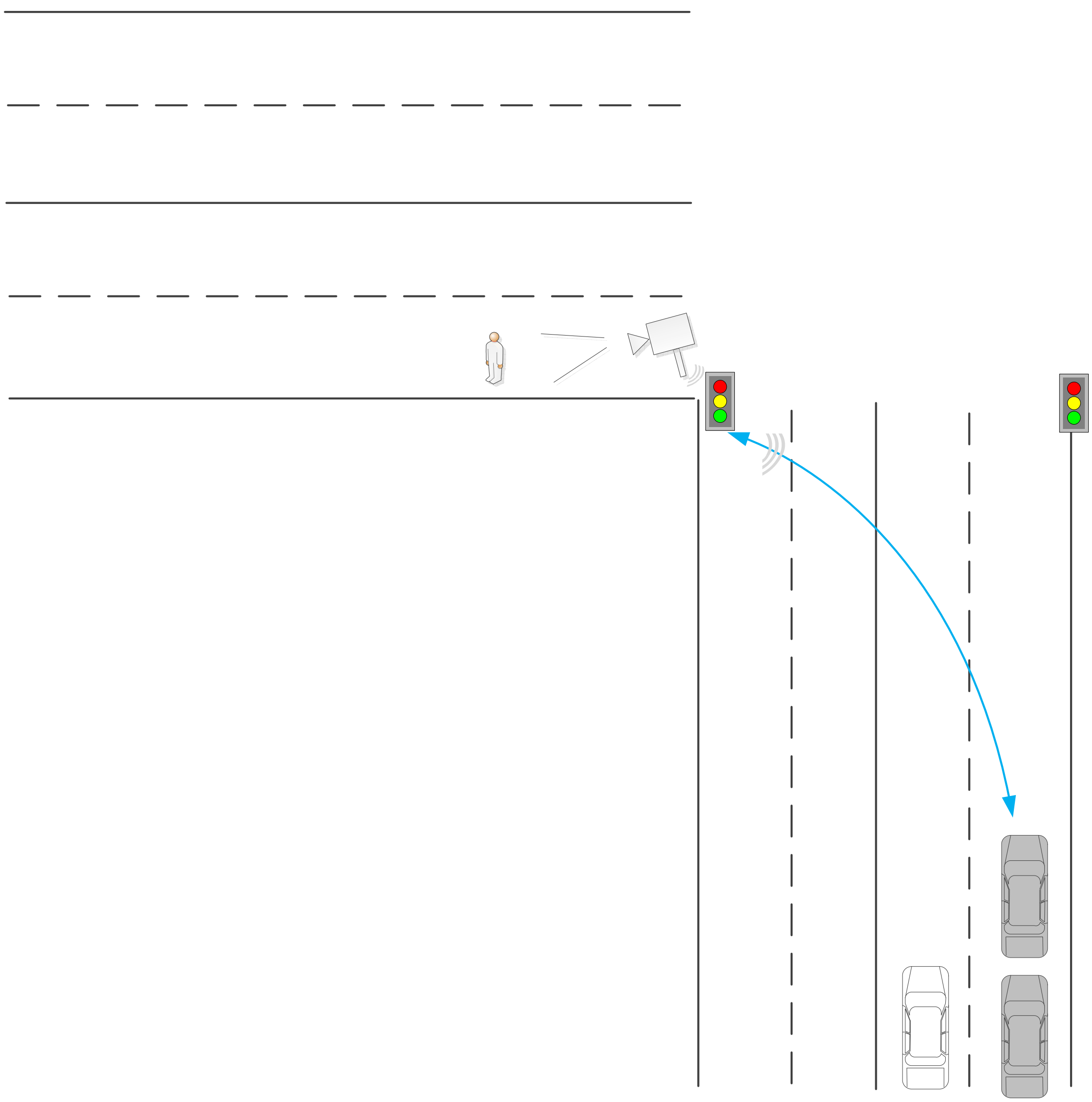

Figure 31 UC16 (Detect non-cooperative road users) – intersection sensing

There are no specific triggering conditions for this scenario as the detection functionality and the consequent information sharing is always active.

Link to other use cases

- This use case precedes UC5 as it provides the means to enable platoon breaking decisions and their implementation
- This use case precedes UC9 as it provides the means to enable emergency situation decisions and their implementation
- This use case precedes UC7 as it provides the means to enable infrastructure-based GLOSA decisions and their implementation
- This use case precedes UC8 as it provides the means to enable infrastructure-based lane change advisory decisions and their implementation

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- This use case precedes UC10 as it provides the means to enable priority management decisions and their implementation
- This use case precedes UC14 as it provides the means to enable signal optimization decisions and their implementation.

11 Appendix C – Traceability of Use Cases and Requirements

This appendix depicts the link among the particular Use Cases and the Requirements. We distinguish two different types of relationship:

- **R** denotes the realisation of a use case through a requirement. In order to fulfil the needs of the use case, the requirement must be fulfilled.
- **D** denotes the dependency of a use case on a requirement, so basically an indirect influence.

	UC1: Platoon initialization	UC2: Joining a platoon	UC3: Traveling in a platoon	UC4: Leaving a platoon	UC5:Platoon break-up	UC6: Platoon termination	UC7: Speed change advisory	UC8: Lane change advisory	UC9: Emergency situations	UC10: Priority management	UC11: Queue length estimation	UC12: Local level routing	UC13: Network coordination - green	UC14: Signal optimization	UC15: Negotiation	UC16: Signaling other road users	UC17: Detect road users
3.1.1: Global digital map available	R	R	R	R	D	D	D	D	D						D		D
3.1.2: Global digital map accessible	R	R	R	R	D	D	D	D	D						D		D
3.1.3: Use global digital map for routing	R	R	R	R	D	D									D		
3.1.4: Topological high accurate map available	R	R	R	R	R	R	R	R	R						D		D
3.1.5: Topological high accurate map accessible	R	R	R	R	R	R	R	R	R						D		D
3.1.6: Update topological high accurate map with vehicle sensor data	R	R	R	R	R	R			R								
3.1.7: Link topological high accurate map ID's	R	R	R	R	R	R									D		D
3.1.8: Environment model	R	R	R	R	R	R	R	R	R								
3.2.1: High precision positioning data available	R	R	R	R	R	R	R	R	R			D			D		
3.2.6: High precision positioning data	R	R	R	R	R	R	R	R	R			D			D		
3.2.2: Obstacle detection and classification	R	R	R	R	R	R	D	D	R								R
3.2.3: Obstacle position and heading available	R	R	R	R	R	R	D	D	R								R
3.2.3: Obstacle position and heading	R	R	R	R	R	R	D	D	R								R
3.2.4: Obstacle velocity and acceleration available	R	R	R	R	R	R	D	D	R								R

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3.2.8: Obstacle velocity and acceleration	R	R	R	R	R	R	D	D	R								R
3.2.5: Indicator lights detection	D	D	D	D	R	D											R
3.3.1: Platoon brake-up due to merging	D	D	D	D	R	D											
3.4.1: Access to vehicle CAN data	R	R	R	R	R	R	D	D							D		
3.5.1: Local Dynamic Map	R	R	R	R	R	R	D	D	R								R
3.5.10: Manual override	R	R	R	R	R	R	D	D	D								
3.5.2: LDM: state of dynamic objects	R	R	R	R	R	R	D	D	R								R
3.5.3: LDM: state of static objects	R	R	R	R	R	R	D	D	R								R
3.5.4: LDM: state of traffic lights	R	R	R	R	R	D									D		
3.5.5: LDM: probabilities	R	R	R	R	D	D											
3.5.6: LDM: data fusion		R	R	R	R	D	R	R	R								
3.5.7: Path matches reference trajectory			R						R			R					
3.5.8: Actuator reference value			R									R					
3.5.9.: Traffic flow sensors														R			
3.6.1: Trajectory prediction of dynamic objects	R	R	R	R	R	R											R

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3.6.10: Calculation of info needed for negotiation by intersection	D	D	D	D	D	D	R	R							R		
3.6.2: Minimum Risk Maneuver	R	R	R	R	R	R			R								
3.6.3: V2X communication about planned trajectories	R	R	R	R	R	R	D	D									
3.6.5: V2X communication for planned actions	R	R	R	R	R	R	D	D									
3.6.6: Platoon leader as coordinator	R	R	R	R	R												
3.6.7: Platoon leader as negotiator	R	R	R	R	R		R	R									
3.6.8: Platoon leader as decision maker	R	R	R	R	R												
3.6.9: Calculation of info needed for negotiation by vehicle	R	R	R	R	D	D	R	R									
3.8.1: V2R standards compatibility	R	R	R	R	D	D	R	R							R		D
3.8.2: Planned route of ego vehicle	R	R	R	R	D	D	R	R				R			D		
3.9.1: Trajectory planning based on obstacles	R	R	R	R	R	R	R	R	R								
3.9.2: Trajectory planning based on tasks and roles	R	R	R	R	D	R	R	R	R						R		
3.9.3.: Adaptation to speed change advice			D				R	R	D						C		

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3.9.4.: Adaptation to lane change advice								R							V		
4.1.1: Common unit							D	D		R				D	D		
4.1.2: Stakeholders for policies	D	D	D	D	D	D	D	D		R							
4.1.3: Improving a policy parameter							D	D		R							
4.1.4: Clear policy resolution							D	D		R							
4.2.1: Using eRternal queue measurements							D	D			R			D	D		
4.2.10: Communication with other TLC							R				R	D	R	R			
4.2.11: GLOSA							R							R			
4.2.12: GLOSA							D							R			
4.2.13: GLOSA negotiation							D							R	R		
4.2.14: SPAT data for test side							D							R			
4.2.2: Using queue model							D	D			R	D		D	D		
4.2.3: Using spillback detection											R			D			
4.2.4: Spillback detection	D	D	D	D		D					R						
4.2.5: Permissive green							D	D									
4.2.6: Green wave Negotiation													R	D	R		

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4.2.7: Negotiation	D	D	D	D			D	D					R	D	R		
4.2.8: Negotiation - conflicts	D	D	D	D		D	D	D			R						
4.2.9: Negotiation - conflicts	D	D	R	D		D	D	D			R			D	R		
4.3.1: Detecting waiting vehicles	D	D	D	D		D	D	R			R						
4.3.2: Detecting obstructung vehicles	D	D	D	D		D	D	R			R						
4.3.3: Calculating partial conflicts							D	R			R						
4.4.1: Detecting spillback														R	D		
4.5.1: Dynamic Green wave	D	D	R	D		D	R				R		R		D		
4.5.2: Green wave - criteria	D	D	D	D		D	R				R		R				
4.5.3: Green wave - policies													R				
4.5.4: Green wave - recalculation							R						R	D			
4.6.1: Queue estimates - Lane level accuracy							D	D			R						
4.6.2: Queue estimates - GPS inaccuracy											R						
4.6.3: Queue estimates - penetration rate							D				R						
4.6.4: Queue estimates - C-ITS											R						
4.6.5: Queue estimates - automated vehicles	D	D	D	D	D	D					R						

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4.7.1: GLOSA - optimal speed							D				D			D	R		
4.7.2: Special road users - recognition							D				D			D	R		
4.8.1: Synchronization										D			R	R			
4.9.1: Routing data												R		D			
4.9.2: Routing communications												R					
4.9.3.: Local routing												R		D			
5.1.1: Access to positioning data	R	R	R	R	R	R	R	R	R						D		R
5.1.10: Message transmission triggering - event based	R	R	R	R	R	R									R		
5.1.11: Message transmission triggering - periodic	R	R	R	R	R	R	D	D							R		R
5.1.12: Message coding & decoding - standards	R	R	R	R	R	R									R		
5.1.13: Message coding & decoding - MAVEN standards	R	R	R	R	R	R	D	D	D						R		R
5.1.14: V2X communication for vehicle dynamics information	R	R	R	R	R	R	D	D	D						R		
5.1.15: V2X communication for hazard warning	R	R	R	R	R	R			R								

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	UC1: Platoon initialization	UC2: Joining a platoon	UC3: Traveling in a platoon	UC4: Leaving a platoon	UC5:Platoon break-up	UC6: Platoon termination	UC7: Speed change advisory	UC8: Lane change advisory	UC9: Emergency situations	UC10: Priority management	UC11: Queue length estimation	UC12: Local level routing	UC13: Network coordination - green	UC14: Signal optimization	UC15: Negotiation	UC16: Signaling other road users	UC17: Detect road users
5.1.16: V2X communication for platoon formation	R	R					D	D							R		
5.1.17: V2X communication for platoon management	R	R	R	R	R	R									R		
5.1.18: V2X communication for platoon merging/leaving		R	R	R	R	R									R		
5.1.19: V2X communication for cooperative sensing	R	R	R	R	R	R			R								R
5.1.2: Access to map database	R	R	R	R	R	R	R	R	R						D		D
5.1.20: V2X communication for negotiations	R	R	R	R	R	R	D	D							R		
5.1.22: Messages for traffic light phasing and road topology	R	R	R	R	R	R	D	D							R		
5.1.23: V2X communication for road info	R	R	R	R	R	R	D	D							R		
5.1.24: V2X communication for speed advisory							R										
5.1.25: V2X communication for lane advisory								R									
5.1.3: Access to traffic light information							R	R							D		

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5.1.4: Access to traffic management center information							R	R							D		
5.1.5: Access to vehicle dynamic information	R	R	R	R	R	R	D	D							D		
5.1.6: Access to information from on-board sensors	R	R	R	R	R	R			R								R
5.1.7: LDM database management	R	R	R	R	R	R	D	D	D								R
5.1.9: Message transmission triggering	R	R	R	R	R	R	D	D	D								R
5.2.1: Maps availability for relevant testing locations	R	R	R	R	R	R											
5.2.2: Maps availability with different granularity	D	D	R	D	D	D											
5.2.3: Management of maps with different granularity	D	D	R	D	D	D											
5.3.1: Risky situation detection with own sensing capabilities	R	R	R	R	R	R			R								
5.3.2: Risky situation detection with cooperative sensing capabilities	R	R	R	R	R	R			R								

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5.3.3: ADAS reactions on own system controllers	R	R	R	R	R	R			R								
5.3.4: ADAS reactions to influence other systems' controllers	R	R	R	R	R	R			R								

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