Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

interACT D1.1 Definition of interACT use cases and scenarios

Work package	WP1: Scenarios, Requirements and interACT System Architecture
Task	Task 1.1: Scenario definition
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Table of content

Glossary of terms **5**

List of abbreviations and acronyms **6**

Executive Summary **7**

1. Introduction **9**

1.1 Purpose and scope 9

1.2 Intended readership 10

1.3 Relationship with other interACT deliverables 10

2. Development path for automated passenger vehicles **11**

3. Terminology definition for interACT **14**

3.1 Scene 14

3.2 Scenario 14

3.3 Use case 15

3.4 Use case cluster 15

4. Selection process for use cases and selection criteria **17**

4.1 Use case workshop 17

4.2 Use case cluster 18

4.3 Use case rating template 21

4.4 Selected use cases in interACT 21

4.4.1 Must-have use cases 21

4.4.2 Optional use cases 22

5. Methodology for describing use cases and scenarios **23**

5.1 Use case description template 23

5.2 Scenario description template 25

6. Description of selected interACT use cases **30**

6.1 Must-have use cases 30

6.1.1 React to crossing non-motorised TP at crossings without traffic lights 30

Draft

6.1.2 React to an ambiguous situation at an unsignalised intersection 32
6.1.3 React to non-motorised TP at a parking space 34
6.1.4 React to vehicles at a parking space 36
6.2 Optional use cases 37
6.2.1 React to vehicles on the road in turning situation (AV wants to turn) 37
6.2.2 React to crossing non-motorised TP at a signalised crossing 39
6.3 Scenario examples 41
6.3.1 Scenario: React to a single pedestrian crossing at a distance from 3m-10m from right to left at a crossing without traffic lights 41
6.3.2 Scenario: React to an ambiguous situation at an unsignalised 4-way intersection while all 4-ways are blocked 45
6.3.3 Scenario: React to multiple non-motorised TP (two from left one from right) at a parking space 49
6.3.4 Scenario: React to an out parking vehicle at a parking space 53
6.3.5 Scenario: React to a vehicle while turning- Other vehicle yields 57
6.3.6 Scenario: React to a crossing pedestrian at a zebra crossing 61
7. Summary and conclusion 65
8. References 67
Annex 1: Use case template 69
Annex 2: Scenario template 70

Draft

Index of figures

Figure 1: Challenge of the interACT project – from human-human interaction toward human-machine interaction with AVs in mixed traffic environments 9
Figure 2: ERTRAC roadmap - development path of road automation 12
Figure 3: ERTRAC roadmap - Overview of automated driving technology 13
Figure 4: Graphical representation of a scene with actors, relationships and dynamics 14
Figure 5: Several scenes forming a scenario 15
Figure 6: Relations between use case, scenario and scene (adapted from Ulbrich et al.) 16
Figure 7: Brainstorming results of possible use cases at the interACT use case workshop 17
Figure 8: Brainstorming of possible selection criteria for use cases at the interACT use case workshop 18
Figure 9: Use case cluster with must-have and optional use cases for interACT 20
Figure 10: Use case description template 24
Figure 11: Use case diagram for a signalised crossing use case 24
Figure 12: Sequence diagram for a zebra crossing scenario 27
Figure 13: Scenario description template 29

Index of tables

Table 1: Used criteria for rating the interACT use cases 21
Table 2: Must-have use cases in interACT 22
Table 3: Optional use cases in interACT 22
Table 4: Relevant attributes for describing a use case 23
Table 5: Relevant attributes for describing a scenario 25

Draft

Glossary of terms

Term	Description
Automated vehicle (AV)	Vehicle that provides automation of longitudinal and lateral vehicle control and can free the driver from the driving task - at least in some driving situations
Coordination and Communication Planning Unit	interACT central software unit that plans AV behaviour and explicit HMI control in an integrated, timely, and synchronised manner
Interaction	Within interACT interaction is understood as the complex process where multiple traffic participants perceive one another and react towards the continuously changing conditions of the situation resulting from actions of the other TP, to achieve a cooperative solution. These actions and reactions involve various means of communication
Mixed traffic environment	Traffic environment in which AVs are mixed with other non-equipped traffic participants such as pedestrians, cyclists, powered two-wheelers, and other manually driven vehicles
Non-motorised TP	Pedestrians or cyclists (not on the road)
On-board user	Human on-board of the AV who acts as a driver in all cases the AV cannot handle (SAE level 3) or is a passenger for all SAE 4 and 5 applications
Other road user	All possible road users from the perspective of the ego vehicle (the AV) i.e. pedestrians, bicyclists, motorcyclists, vehicles, automated vehicles
Scenario	Description regarding the sequences of actions and events performed by different actors over a certain amount of time (see 3.2)
Scene	Snapshot of the environment. All dynamic elements, as well as all actors and the scenery are included in this snapshot (see 3.1)
Use Case	Functional description of the behaviour of the AV in a traffic situation (see 3.3)
Vehicles	Passenger cars, busses, trucks, motorcycles and bicycles driving on the road

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List of abbreviations and acronyms

Abbreviation	Meaning
ADAS	Advanced driver assistance systems
AV	Automated vehicle
CCPU	Coordination and communication planning unit
ERTRAC	The European road transport research advisory council
interACT	EU-Project designing cooperative interaction of automated vehicles with other road users in mixed traffic environments
Lidar	Light detection and ranging sensor. Used for the detection of distances and velocities of objects
MAIS	Maximum abbreviated injury scale
OEM	Original Equipment Manufacturer
Radar	Radio detection and ranging sensor
SAE	Society of Automotive Engineers
TP	Traffic participant
UML	Unified Modelling Language
USS	Ultrasonic sensor. Used for measuring distances to objects by using sound waves
WP	Work package

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Executive Summary

interACT studies current human-machine interactions in mixed traffic and will increase the chances of safe deployment of AVs by developing novel software and HMI hardware components for reliable and user-centric communication among an AV, its on-board user and other road users. It is expected that by reaching its goals, this project will facilitate the gradual integration of AVs in future transport networks.

The present document is the D1.1 "Definition of interACT *scenarios*" which is prepared as the first document within WP1 of the interACT project. The document presents the selection process for scenarios, a framework for the *use case* description and the selected interACT *use cases* and example *scenarios*.

Use cases are a functional description of the behaviour of the AV in a traffic situation (see 3.3). *Scenarios* are a description of sequences of actions and events performed by different actors over a certain amount of time (see 3.2).

As the natural traffic environment consists of a manifold variety of traffic scenes, it is essential for the interACT technical project work to reduce the complexity of the traffic environment to a manageable number of relevant *use cases* and *scenarios* that an AV could be confronted with. Therefore, WP1 started with an agreement on and definition of relevant interACT *use cases* and *scenarios* among all industrial and academic consortium members. The interACT *use cases* and *scenarios* have been selected using a step-wise process of intensive discussions within the consortium. Starting with some open brain-storming discussions the *use cases* were aggregated and rated by the partners against several criteria (such as relevance for safety, need for interaction behavior etc.) to agree on the most relevant ones.

The present document illustrates the selection process of the addressed *use cases*, including the results of a workshop and the consortium ratings. Moreover, a method for describing and documenting of *use cases* is presented in the deliverable. This method is meant to structure the discussion within the consortium but is also a very promising tool for fostering the exchange of knowledge with stakeholders of the interACT consortium, such as academic and industrial partners (Chapter 5). In the main part of the document the selected *use cases* and example *scenarios* are described. The consortium defined four "must-have" *use cases* that are of highest relevance. These *use cases* are to be covered by research and technical developments in all technical WPs and evaluated and demonstrated in the interACT demonstrator vehicles and simulators at the end of the project. These are the following "must-have" *use cases*:

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- React to crossing non-motorised traffic participants (TP) at crossings without traffic light
- React to an ambiguous situation at an unsignalised intersection
- React to non-motorised TP at a parking space
- React to vehicles at a parking space

In addition, two "optional" *use cases* were selected:

- React to vehicles in turning situations
- React to crossing non-motorised TP at signalised crossings

The "optional" *use cases* aim to inspire further research within the project and the exchange of knowledge with international research partners to foster for example cross-cultural comparisons.

This deliverable sets the basis for all further work in WP1 and all other technical WPs of the interACT project.

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1. Introduction

1.1 Purpose and scope

Road traffic will never be fully automated – think, for example, of cyclists, pedestrians or other non-equipped vehicles. An inherent challenge in mixed traffic of both automated vehicles (AVs) and non-automated road users is that there are many ambiguous *scenarios*. Such *scenarios* cannot only be solved by traffic rules, and typically need cooperation among all road users, so that they may reach an agreement about safe future motion plans. In mixed traffic, such interactions among road users are frequent, and it is important for all road users to have a good understanding of the intentions of AVs, in order to achieve safe, smooth and cooperative flow of traffic. Understanding how to develop the right cooperation strategy between all road users (including AVs) is of high priority, in order to ensure successful deployment and acceptance of such AVs by all road users. Thus, the vision of the interACT project is to develop novel and holistic interaction concepts for AVs, that will enable the integration of AVs into mixed traffic environments, in a safe and intuitive way (Figure 1).

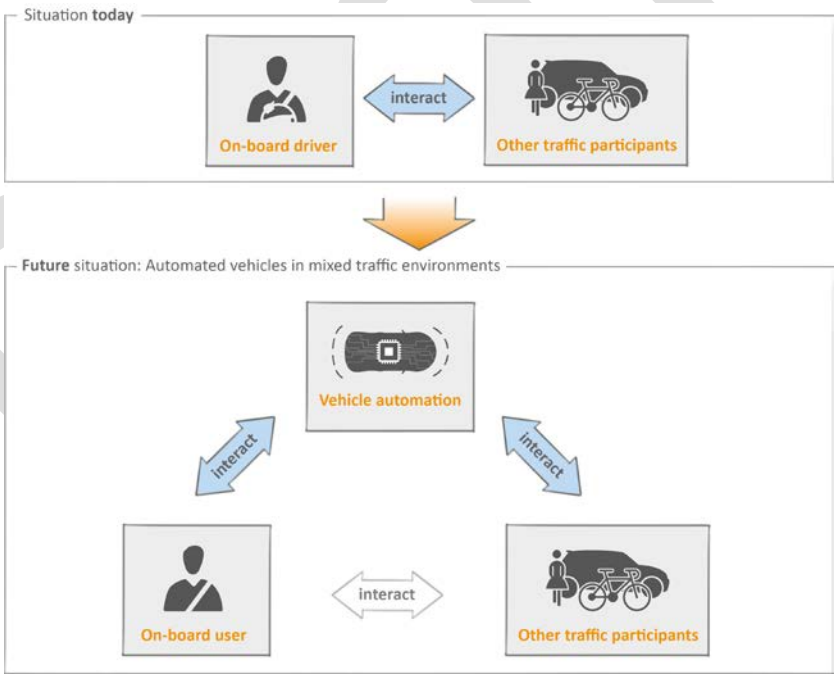

Figure 1: Challenge of the interACT project – from human-human interaction toward human-machine interaction with AVs in mixed traffic environments

As one can easily imagine the amount of traffic *scenarios* which will require interaction between AVs and other traffic participants is nearly countless. Considerable work was required to reduce the wide range of real-world *scenarios* to a manageable number of *use cases* and *scenarios* for the technical

development of the interACT solutions. In order to align the understanding of the relevant *use cases* and *scenarios* within the interACT consortium, the following work was conducted in the first four project months:

- Definition of a common terminology.
- Agreement on a common framework for the description of *use cases* and *scenarios.*
- Discussion and selection of relevant interACT *use cases* and description of example *scenarios*.

The outcome of this work is documented in this deliverable.

1.2 Intended readership

This deliverable focuses on two different readerships: First, it serves as main document for the technical work within the interACT project for all consortium partners. The *use case*s and *scenarios* described in this deliverable are the basis for the technical discussion of the project.

Secondly, the deliverable is available to the public and is written to foster the exchange of knowledge and research strategies among experts in the field of automated driving. Thus, the intended readership comprises all interested researchers in academia and automotive industry. The document is expected to support the discussion of and agreement on similar *scenarios* for cross-cultural data collection and analysis between different research teams; for example within the twinning team of the NHTSA project AVIntent and the EU project interACT.

1.3 Relationship with other interACT deliverables

This deliverable is part of the work in Work Package (WP) 1: "*Scenarios*, *Requirements and interACT System Architecture*". As the first deliverable of WP1 it will directly influence the technical deliverable D1.2 "Requirements, system architecture and interfaces for software modules", as the technical requirements of the interACT solutions are directly dependent on the selected *use cases* within the project. In addition, the included information is the basis for all technical developments and research activities in all technical WPs of the project. The real-world observations and modelling, and intention recognition elements of WP2 will all focus on the selected *use cases*. This is also true for the technical development within WP3 "Cooperation and Communication Planning Unit" and WP4 "Suitable HMI for successful human-vehicle interaction", where solutions for the intuitive and safe integration of the AV in mixed traffic environments are developed for the interACT *use cases*. In WP5 "Integration, Testing and Demonstration" the demonstrators are addressing the *use cases* described in this deliverable to provide the final, integrated interACT solutions for the evaluation work in WP 6, and to present the interACT achievements to the public in the interACT demonstrator vehicles and simulators.

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2. Development path for automated passenger vehicles

interACT focus on the safe and efficient integration of AVs in mixed traffic environments. The project builds up several technical solutions and evaluates and demonstrates them in demonstrator vehicles and simulators. The main focus of interACT is on passenger vehicles with the clear expectation that the interACT solutions can be adapted also for freight vehicles and ADS-dedicated vehicles (SAE-Society of Automotive Engineers, 2016) driving on dedicated areas or in mixed traffic without any human operator on board. The interACT project team will also take the solutions developed for the selected *use cases* described in this deliverable, as the basis for generalisation to other application *scenarios*.

The selection process of relevant interACT *use cases* and *scenarios* is based on the most likely development paths that we see for automated passenger vehicles for the future. The European Road Transport Research Advisory Council (ERTRAC, 2017) roadmap was considered as main document to guide this process. While support, warning, and advanced driver assistance systems (ADAS) are already on the market, along with early automated driving applications such as a traffic jam chauffeur, the ERTRAC roadmap forecasts a further, progressive step-wise increase of automation levels in passenger vehicles during the upcoming decade. As described in Figure 2 the predicted development path covers all levels of automation ranging from 0 to 5 (SAE), with an incremental increase of automation levels from today until 2030, which is expected to continue into the following decades. Consequently, the interACT consortium assumes that the original equipment manufacturer (OEM) industry will gradually extend the automation of conventional vehicles (i.e. the evolutionary scenario described by ERTRAC). However, the interACT solutions are also applicable in a more progressive scenario in which ADS-dedicated vehicles with no driver on-board are brought to market by the OEMs or other players such as Google or Apple (revolutionary scenario). As the interACT technologies are focussing on the integration of AVs into mixed traffic environments, they are easily adaptable to other forms of automated driving and vehicle types (trucks, driver-less vehicles, and shuttles).

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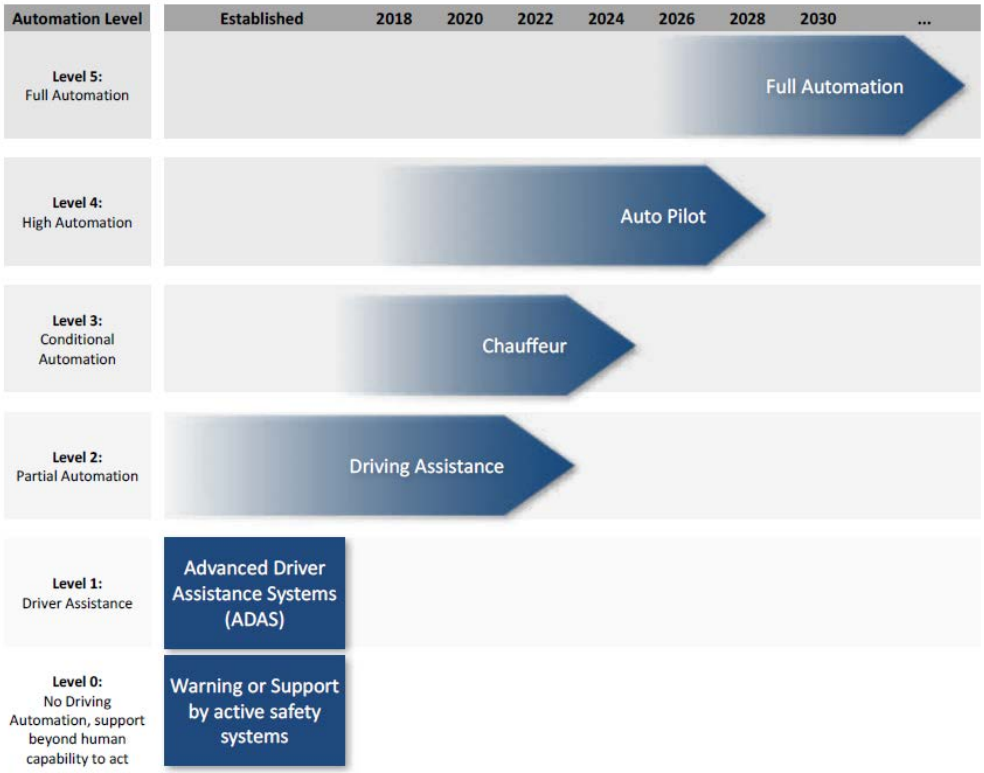

Figure 2: ERTRAC roadmap - development path of road automation

Most interesting for the interACT project are applications of automated driving technology in mixed traffic environments that come with the need for interactions of different types of traffic participants such as pedestrians, cyclists and other manually driven vehicles. These interactions are very likely to occur in automated parking and urban applications (marked in orange in the roadmap in Figure 3). For interACT, both application domains are highly relevant for the understanding and development of solutions for safe and efficient interaction of AVs with other human road users.

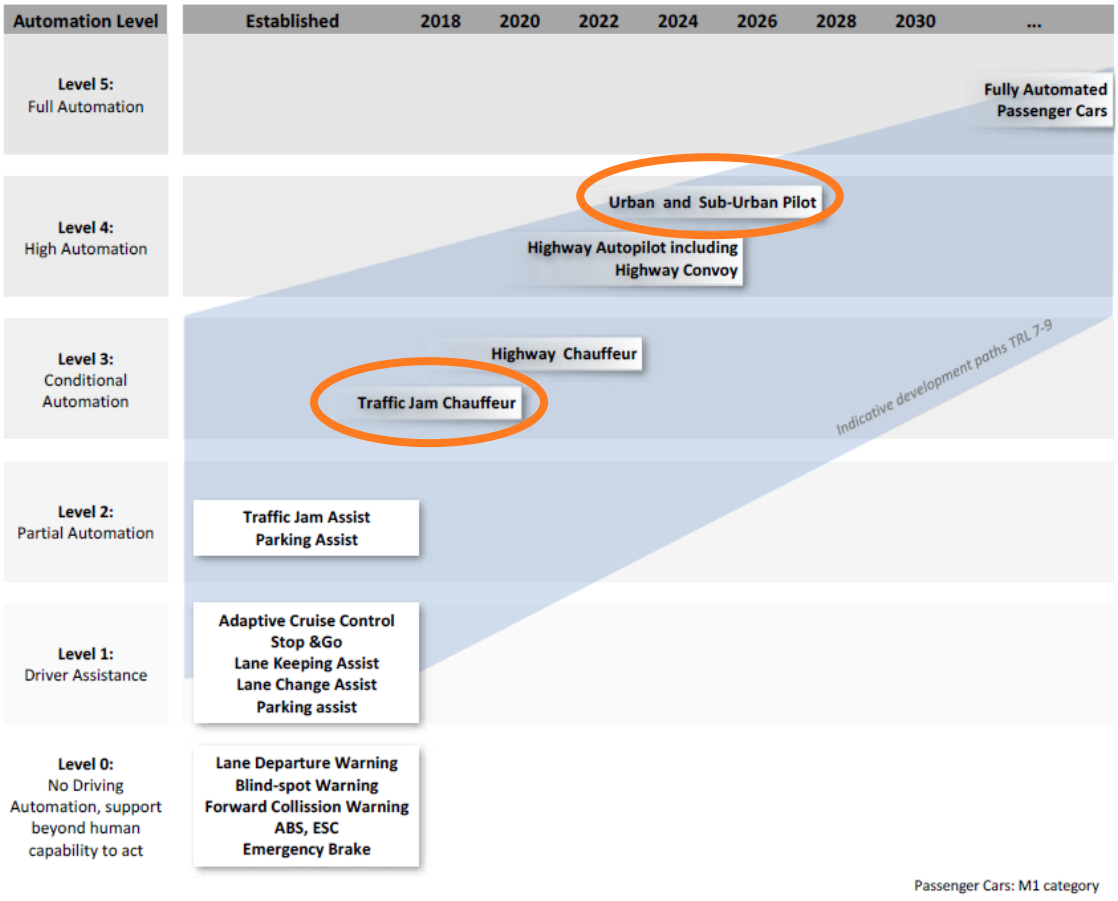

Figure 3: ERTRAC roadmap - Overview of automated driving technology

3. Terminology definition for interACT

The definition of terminology is a key aspect for achieving a common understanding and successful communication in the interACT project and to set the ground for the discussion with other research teams and interACT stakeholders. Therefore, all project partners of interACT agreed on the following taxonomy for the definition of the terms *scene, scenario, use case* and *use case cluster,* based on the taxonomy created by Ulbrich et al. (2015).

3.1 Scene

A *scene* represents a snapshot of the environment. All dynamic elements, as well as all actors and the scenery are included in this snapshot. Further the relationships among those entities are represented in the *scene*. Figure 4 illustrates a graphical representation of a *scene* including scenery (urban road with zebra crossing), actors (AV and pedestrian), dynamics (speed of the AV) and relationship (10m distance). A sequence of *scenes* represents a *scenario*.

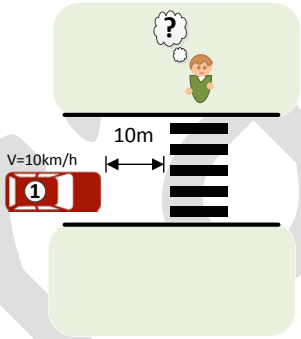

Figure 4: Graphical representation of a scene with actors, relationships and dynamics

3.2 Scenario

In line with Go and Carroll (2004) and Ulbrich et al. (2015) the interACT project defines a *scenario* as a description of the sequences of actions and events performed by different actors over a certain amount of time. Further, the *scenario* specifies goals, objectives and information about the environment related to the different actors. A *scenario* is typically described by several *scenes*, starting with an initial *scene*. An example for a scenario is illustrated in Figure 5. The *scenario* describes the actions performed by two actors: the AV (vehicle no.1 in red) and a pedestrian (green). The pedestrian intents to cross the road via zebra crossing. The AV is driving on the street with a speed of 10km/h and a distance of 10m to the zebra crossing. The pedestrian crosses the road via the zebra crossing while the AV is at a distance of 5m. After the pedestrian has past the road the AV crosses the zebra crossing.

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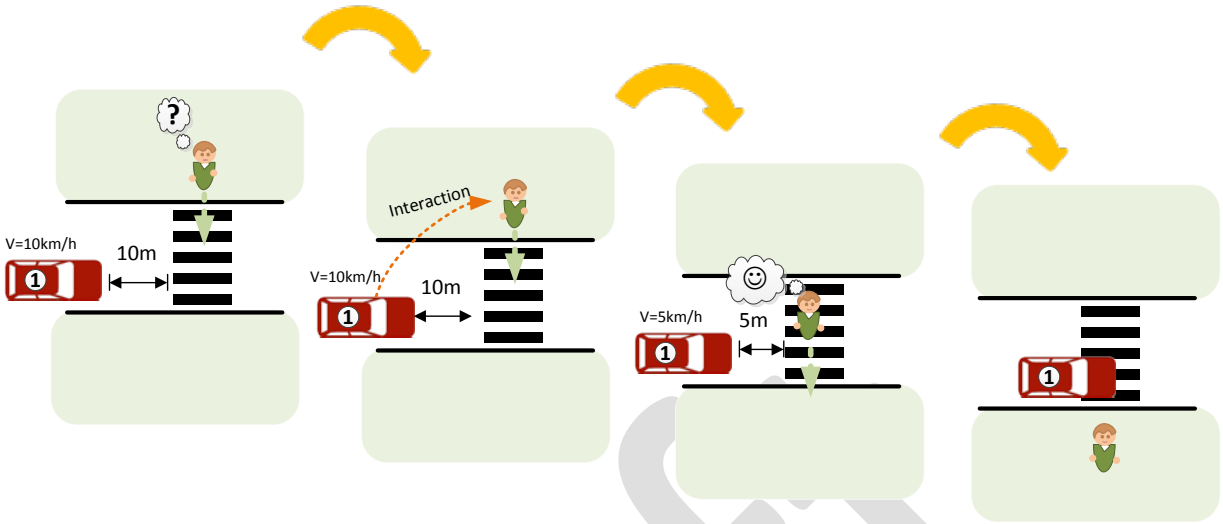

Figure 5: Several scenes forming a scenario

3.3 Use case

A *use case* is a functional description for a technical system (AV) and its behaviour for a specific usage e.g. the AV has to pass a zebra crossing safely. A *use case* entails a description of the desired behaviour of the AV. *Use cases* are defined in the early phases of the design and are not as specific in the description of actors, scenery and dynamic objects as a *scenario* or *scene*. The interACT *use cases* are always described from the AV perspective. This means that a *use case* is always formulated in a way that an AV needs to react to a certain traffic situation. The *use case* for the example given in Figure 5 would be that the AV has to pass the zebra crossing safely, while obeying the traffic rules and reacting to pedestrians.

3.4 Use case cluster

The *use case cluster* is the top element in the interACT taxonomy. The *use case cluster* covers *use cases, scenarios* and *scenes*. The main feature of a *use case cluster* is that similar *use cases* can be grouped into one common *use case cluster* to provide an overview of all possible *use cases,* and highlight the similarities between different *use cases*. Figure 6 illustrates that a *use case cluster* can include numerous *use cases*. These *use cases* can have numerous different *scenarios,* but a *scenario* can only have a set number of *scenes* that are ordered in a specific sequence (starting with an initial *scene*), depending on the natural flow of an event. An example how *use case clusters* might be used is the separation of *use cases* referring to an interaction between the AV and non-motorised traffic participants (use cases cluster: interaction with non-motorised TP), and *use cases* where an AV has to interact with other vehicles (use case cluster: interaction with vehicles).

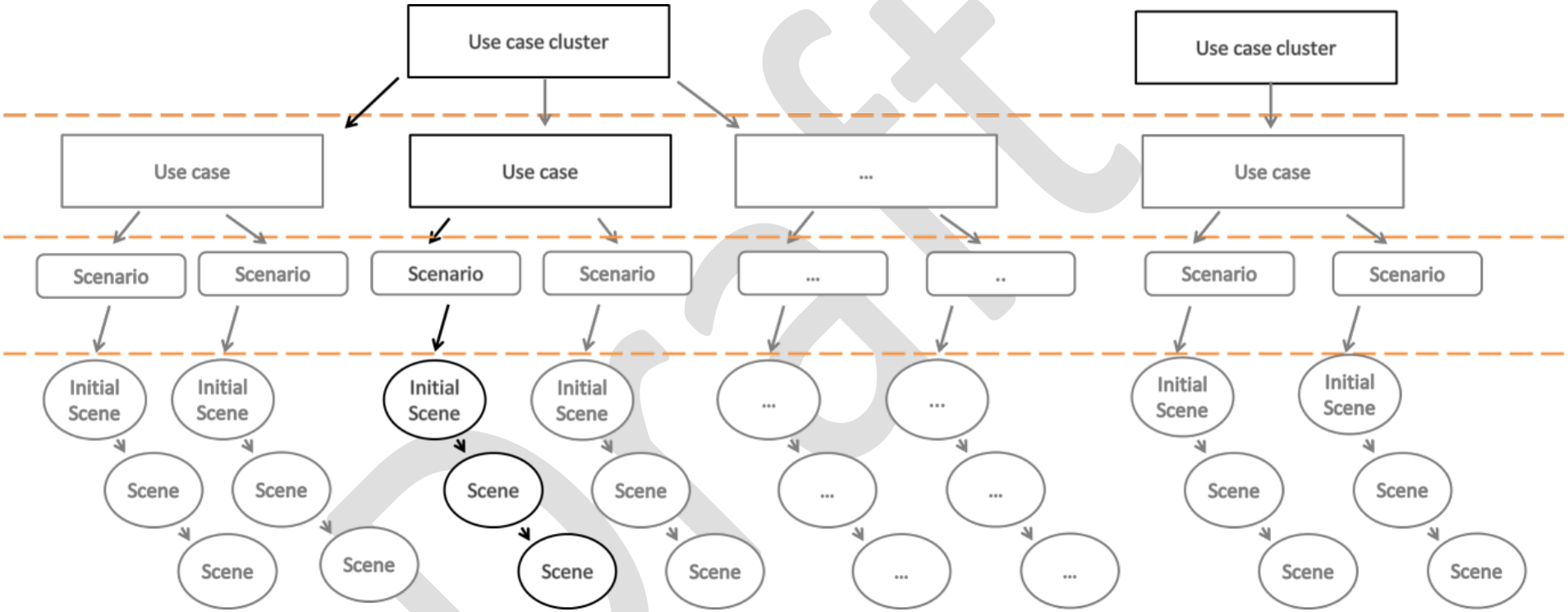

Figure 6: Relations between use case, scenario and scene (adapted from Ulbrich et al.)

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4. Selection process for use cases and selection criteria

The selection of relevant *use cases* was an essential task in the interACT project. As all future work in the technical WPs of interACT is based on a proper *use case* description, this task was started right from the beginning of the interACT project. The selection of the *use cases* was a participative process in which all consortium partners were involved. The following sections provide a breakdown of the steps involved.

4.1 Use case workshop

The initial step towards the selection of the *use cases* was a workshop with all project partners in Braunschweig. All consortium partners participated in this initial *use case* workshop. First of all, the definition of the terms *use case*, *scenario* and *scene* were discussed and agreed. Thereafter, a brainstorming session started. All partners were asked to independently write down what they considered to be the most important *use cases* for interACT. The results were collected and mapped into main clusters. From this brainstorming session a first set of *use cases* and *scenarios* were identified (Figure 7): zebra crossings, intersections, roundabouts, the access ramp to estates, jaywalking, parking garage/ area, pedestrian zones/ shared spaces, roadworks, roads with multiple lanes, highways.

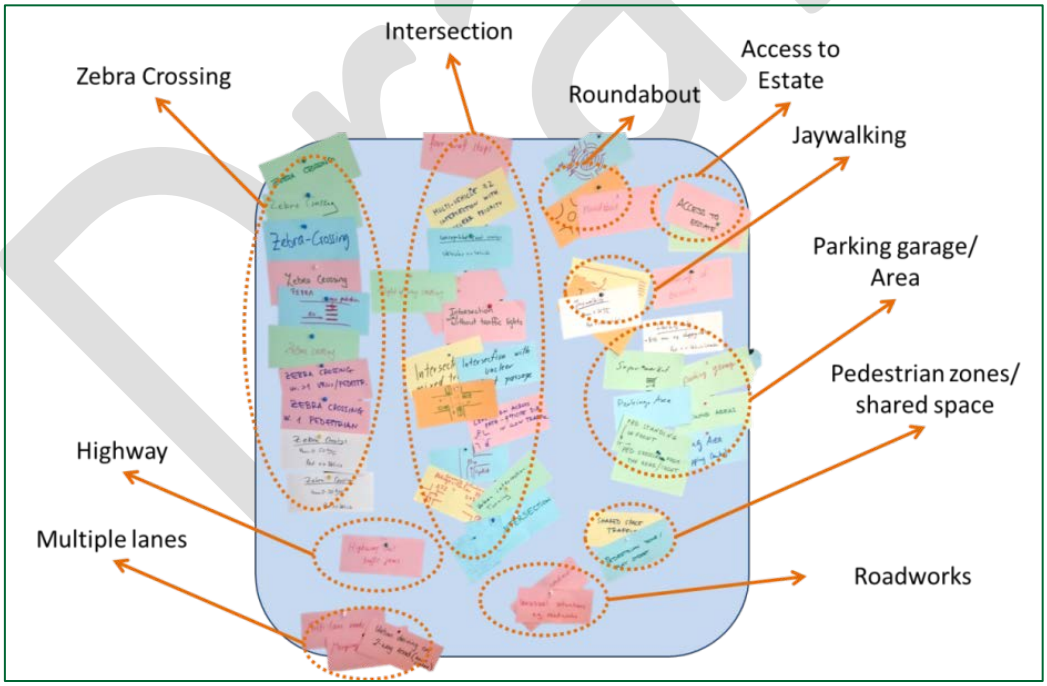

Figure 7: Brainstorming results of possible use cases at the interACT use case workshop

Further, a second brainstorming session was run to define most important criteria for the selection of relevant *use case*s within the interACT project. Within the brainstorming session, the following criteria were identified: safety/ accident data, frequency of occurrence, expected acceptance of the AV, need for new HMI, influence on traffic flow, influence of season and lightning conditions, necessity of

interaction, the likelihood of realisation in the test vehicles, and potential cross-cultural differences (Figure 8). In addition, partners mentioned some sources for the collection of the required information ("information from literature/ observation data" and "expert and stakeholder input"). The results of the *use case* workshop were used to cluster all possible *use cases* for the interACT project.

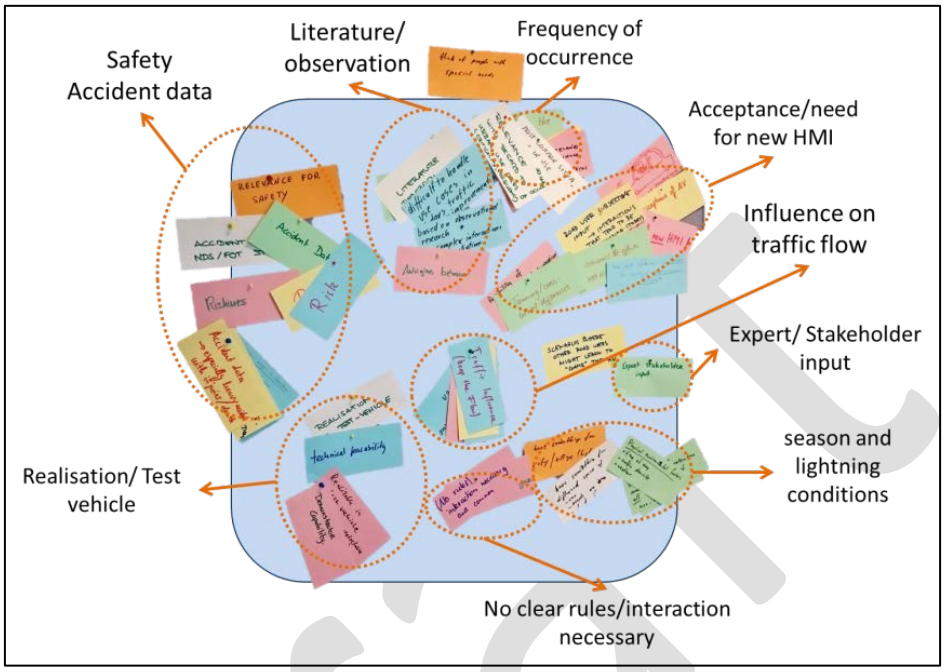

Figure 8: Brainstorming of possible selection criteria for use cases at the interACT use case workshop

4.2 Use case cluster

The input of the *use case* workshop was considered as input for the selection of relevant *use cases* for the interACT project. The main objective of introducing *use case clusters* was to identify similar *use cases,* and to create an overview of all possible *use cases*. Two main *use case clusters* were identified: *interaction with non-motorised TP (pedestrians and bicyclists),* and *interaction with vehicles (incl. bicyclists) on the road* (Figure 9). The first *use case cluster* addresses all *use cases* where the AV interacts with other road users that spend most of their time on specific zones such as a pedestrian walkway or bike path, and cross the road only at specific points in time; while the second *use case cluster* includes all interaction with other vehicles in the same, shared environment – usually the road itself. Under these *use case cluster*s, further subheadings were identified. These subheadings include *use cases* relating to an AV *reacting to the crossing of a non-motorised TP*, an AV *reacting to a non-motorised TP in specific zones,* an *AV reacting to an ambiguous situation on the road* (when the rules are not clear), and *an AV reacting to vehicles on the road.* The *use case cluster* should give an overview about possible *use cases* that could be addressed in interACT, and also show the potential for how the number of *use cases* could be reduced by identifying *use cases* that might need similar interaction strategies of the AV. The selected *use cases* (described in Chapter 4.4) are highlighted in orange (must have use case) and grey (optional use case).

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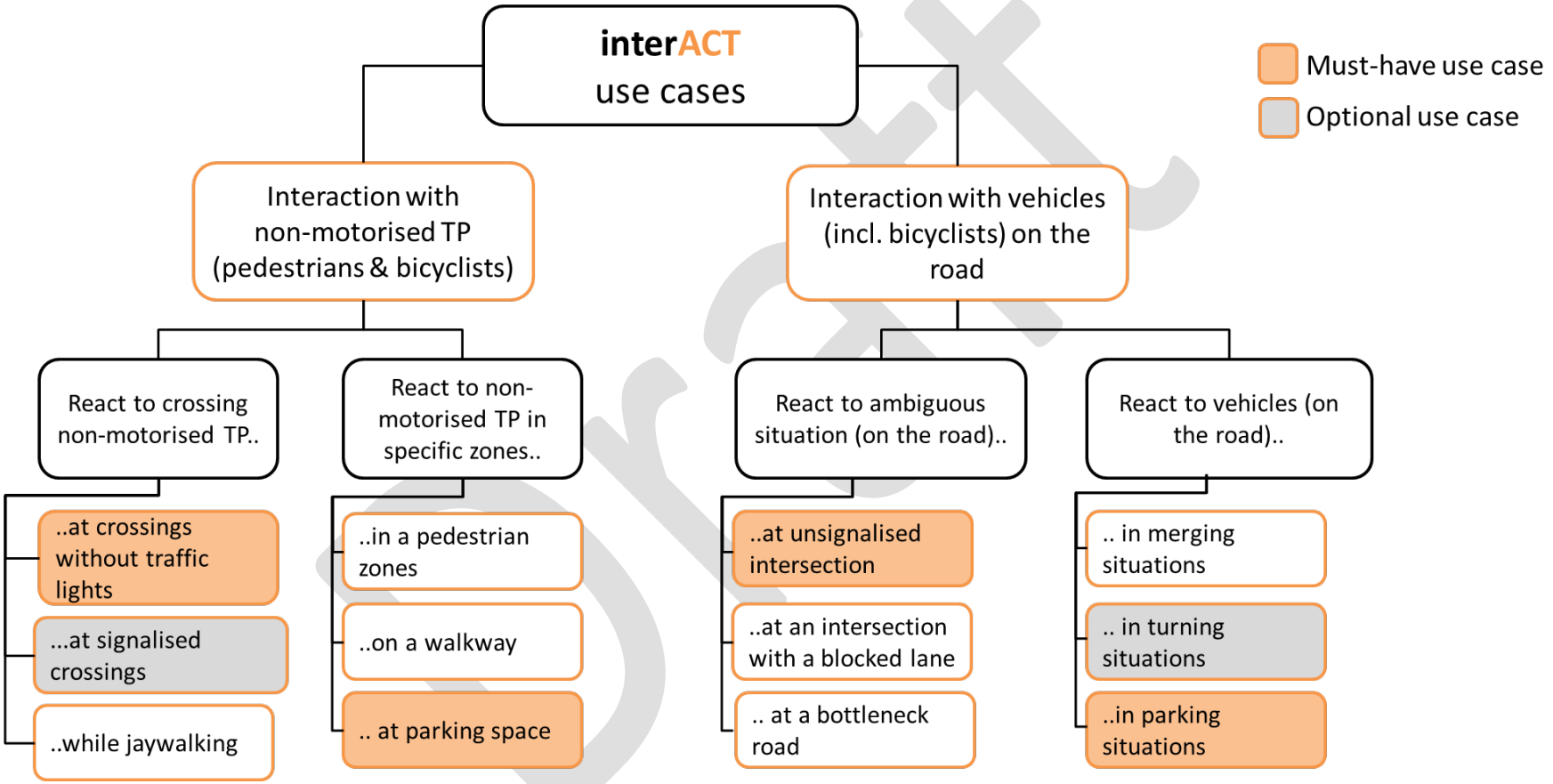

Figure 9: Use case cluster with must-have and optional use cases for interACT

4.3 Use case rating template

The next step for the selection of *use cases* was to rate the collected and clustered *use cases* against different criteria. By using the same criteria for all *use cases,* a fair comparison between the *use cases* should be possible. Furthermore, the criteria should help to understand why one *use case* is more important than another. The criteria applied for the *use cases* rating is shown in Table 1.

Table 1: Used criteria for rating the interACT use cases

Category	Criteria
Scientific	Relevance for safety (e.g. accident frequency, severity of accidents)
	Frequency of occurrence (is this a situation that occurs often or seldom)
	Relevance for traffic flow
	Need for interaction with human road users (e.g. no interaction needed, interaction helpful, interaction essential)
	Expected effects on user acceptance (e.g. for non-motorised TP / Human traffic participant / On-board user)
Project related	Realisation in demo vehicles (possible/not possible)
	Realisation in driving simulators (possible/not possible)

All project partners worked in tandem-teams (always two partners together; one from academia, one from industry). Every tandem-team provided ratings against each of the criteria for one of the *use case cluster*s. The tandem teams provided results from a literature review and their expert opinion on all selection criteria. The criterion *realisation in demo vehicles as well as realisation in driving simulators* was identified as critical criterion for the evaluation and demonstration of interACT results, and was considered carefully by the vehicle and simulator owners.

The input from all partners was combined in one document which includes the results of the literature review and the expert opinions for all *use case cluster*s. This document was used by all partners to rate each of the *use case*s based on the collected information. For the rating the following categories were used: "+" = must-have *use case*, "o" = optional *use case,* and "–" = *use case* not interesting for interACT. The results of the rating were discussed within several conference calls, and four "must-have" and two "optional *use case*s" were finally selected.

4.4 Selected use cases in interACT

In the interACT project we distinguish between two kinds of *use case*s: Must-have *use case*s and optional *use case*s.

4.4.1 Must-have use cases

The must-have *use case*s are the main *use case*s that guide all research activities and the technical development within interACT. The must-have *use case*s are the target *use case*s for which the

technical solutions are to be implemented in the demo vehicles and simulators for the evaluation and dissemination of the project results. Thus, these *use case*s will be addressed and focused in WP2-4 in the project, implemented in WP5, and evaluated in WP6. The selected must-have *use case*s for the interACT project are:

Table 2: Must-have use cases in interACT

Must have use cases
React to crossing non-motorised TP at crossings without traffic lights
React to an ambiguous situation at an unsignalised intersection
React to non-motorised TP at a parking space
React to vehicles at a parking space

4.4.2 Optional use cases

In addition, to the must have *use case*s some other *use case*s were identified that are of interest for the research activities within interACT. Each work package can make a decision on whether to include these *use cases.* The purpose of these optional use cases is to inspire the discussion within the consortium and with stakeholders and other research teams.

Table 3: Optional use cases in interACT

Optional use cases
React to vehicles in turning situations
React to crossing non-motorised TP at signalised crossings

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5. Methodology for describing use cases and scenarios

In the project interACT it is important to outline and define the future work. While countless possible traffic situations exist, to begin with we need to focus on the most important ones for AV interactions. For this it is important to develop a methodology for describing *use case*s and *scenarios* clearly. While the description of a *use case* will only define a functional behaviour of the AV, the description of a scenario needs to be more specific. The main idea of creating a methodology for defining *use case*s and *scenarios* is to create a taxonomy for identifying situation specific attributes to create repeatable and comparable *scenarios* across different partners in the project.

The description of the *use case*s and *scenarios* is based on the approach of Fuest et al. (2017). An adapted version was used to develop taxonomies for describing *use case*s and *scenarios* within the interACT project.

5.1 Use case description template

The *use case* template includes information about the name of the described *use case*, information on whether the *use case* is a must-have *use case* or an optional one, along with a description of the *use case* environment (intersection or parking). Furthermore, a *use case* diagram with a functional description of the AVs behaviour, a verbal description of the *use case,* and information about the importance of the *use case* are provided in the *use case* template. Additionally, the adapted taxonomy for describing a *use case* defines relevant attributes which influence explicit (indicator, hooter, etc.) and implicit (hand and head gestures, etc.) communication among the traffic participants (Fuest et al., 2017). Relevant attributes for describing a *use case* are shown in Table 4. Further the *use case* template is illustrated in Figure 10.

Table 4: Relevant attributes for describing a use case

Attributes	Values
Addressed interaction partner(s)	Driver of other vehicle Cyclist Pedestrian
Driving direction AV	Driving forward Reverse

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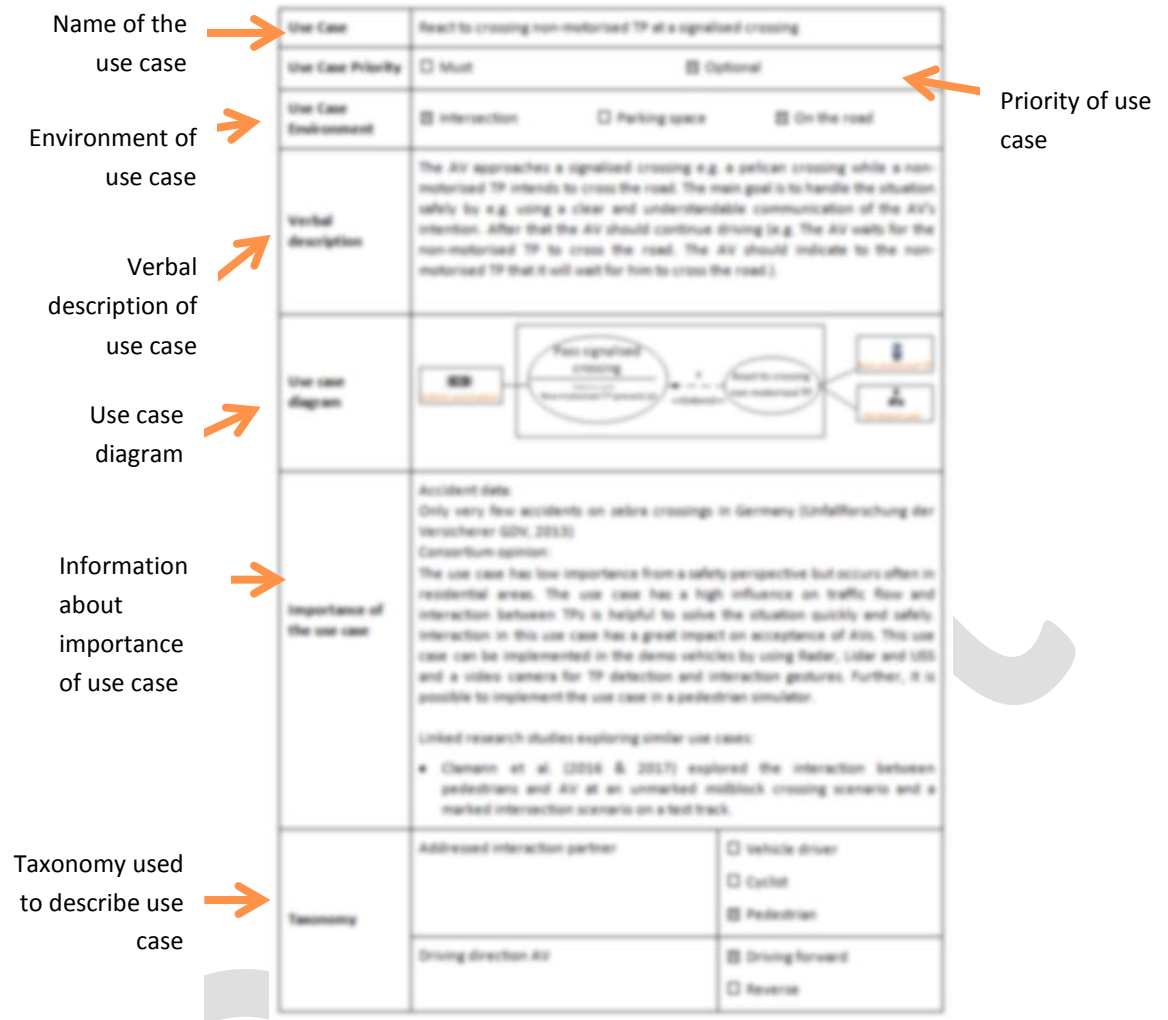

Figure 10: Use case description template

The *use case* diagram in UML shows the relationship between different actors regarding the interaction with a specific system. Figure 11 shows a *use case* diagram for the *use case* "React to crossing non-motorised TP at a signalised crossing". Different actors are involved in this *use case* (AV, non-motorised TP and on-board user). The desired behaviour of the AV is to pass the signalised crossing. When non-motorised TP are present (extension point a) this behaviour will be extended by reacting to crossing non-motorised TP. In this case the AV needs to interact with the non-motorised TP and the on-board user.

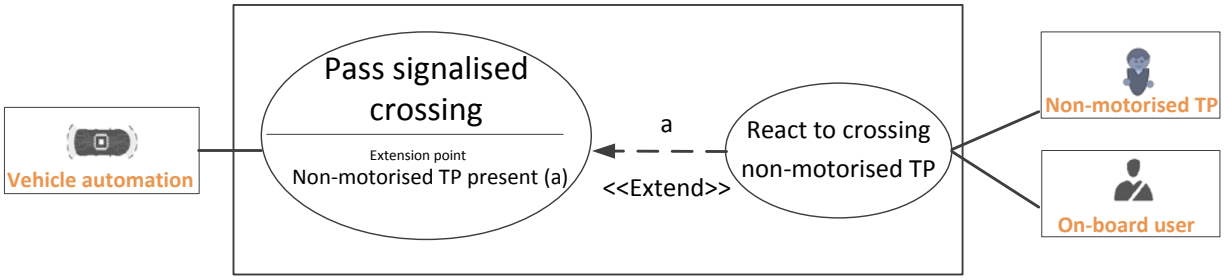

Figure 11: Use case diagram for a signalised crossing use case

5.2 Scenario description template

The first part of the scenario description template is similar to that of the use case description, and contains information about the related *use case*, the author, the priority of the *use case* and the *use case* environment, along with detailed verbal and graphical descriptions of the scenario. After that the scenario specific attributes and dynamic characteristics are described. The information is clustered into attributes related to the traffic and environment, AV related attributes and TP related attributes (shown in Table 5).

Table 5: Relevant attributes for describing a scenario

Attribute Cluster	Attributes	
Traffic & Environment	Right of way	☐ AV ☐ other TP ☐ Undefined
	Longitudinal distance (headway)	☐ < 3m ☐ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☐ > 3m
	Speed AV	☐ 0 km/h ☐ 10 km/h ☐ 30 km/h ☐ 50 km/h
	Speed other TP	☐ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☐ Day ☐ Night
	Lighting conditions	☐ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☐ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☐ Ahead ☐ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☐ Let other TP go first ☐ Go first

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	Attention on-board user towards traffic situation	☐ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☐ Driver of other vehicles ☐ Cyclist ☐ Pedestrian
	Number of traffic participants	__ AV __ Non-motorised TP __ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☐ Go first
	Age of TP	☐ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☐ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP towards AV	☐ Yes ☐ No

Furthermore a diagram describing the sequence of interaction is presented at the end of the scenario description template. The sequence diagram is a central element in the scenario description which describes the flow of information over time between relevant entities in a specific scenario. All relevant entities are presented on the left side of the sequence diagram (Figure 12). The time elapse from left to right and the flow of information is illustrated by arrows from the source of information to the receiver of the information. A short description of the information is placed next to the arrow. Information regarding human-machine-interaction is highlighted by an orange colour. Decisions regarding the Interaction strategy are displayed with a grey rectangle. Figure 13 provides an illustration of the scenario template.

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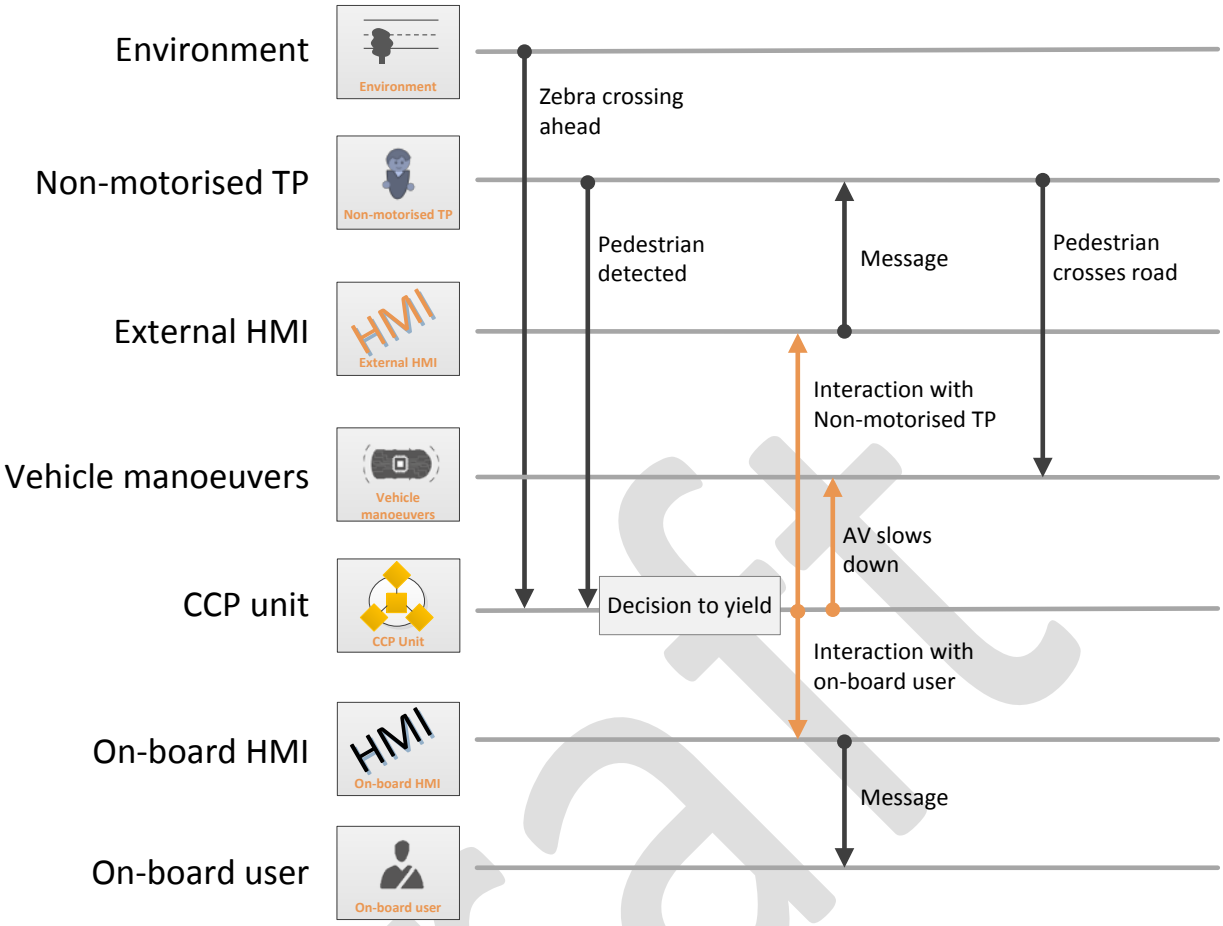

Figure 12: Sequence diagram for a zebra crossing scenario

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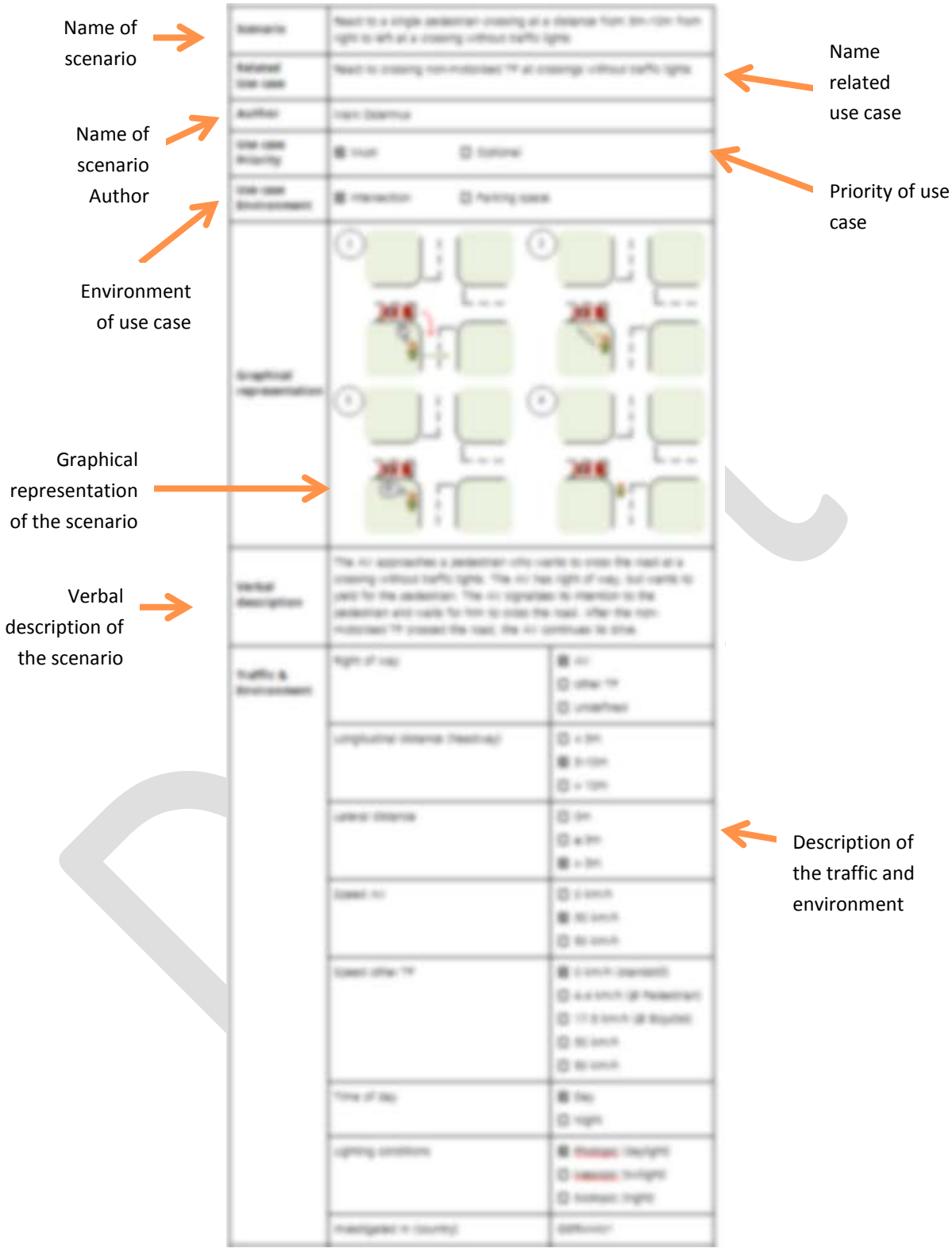

Name of scenario
Name of scenario Author
Environment of use case
Graphical representation of the scenario
Verbal description of the scenario
Name related use case
Priority of use case
Description of the traffic and environment

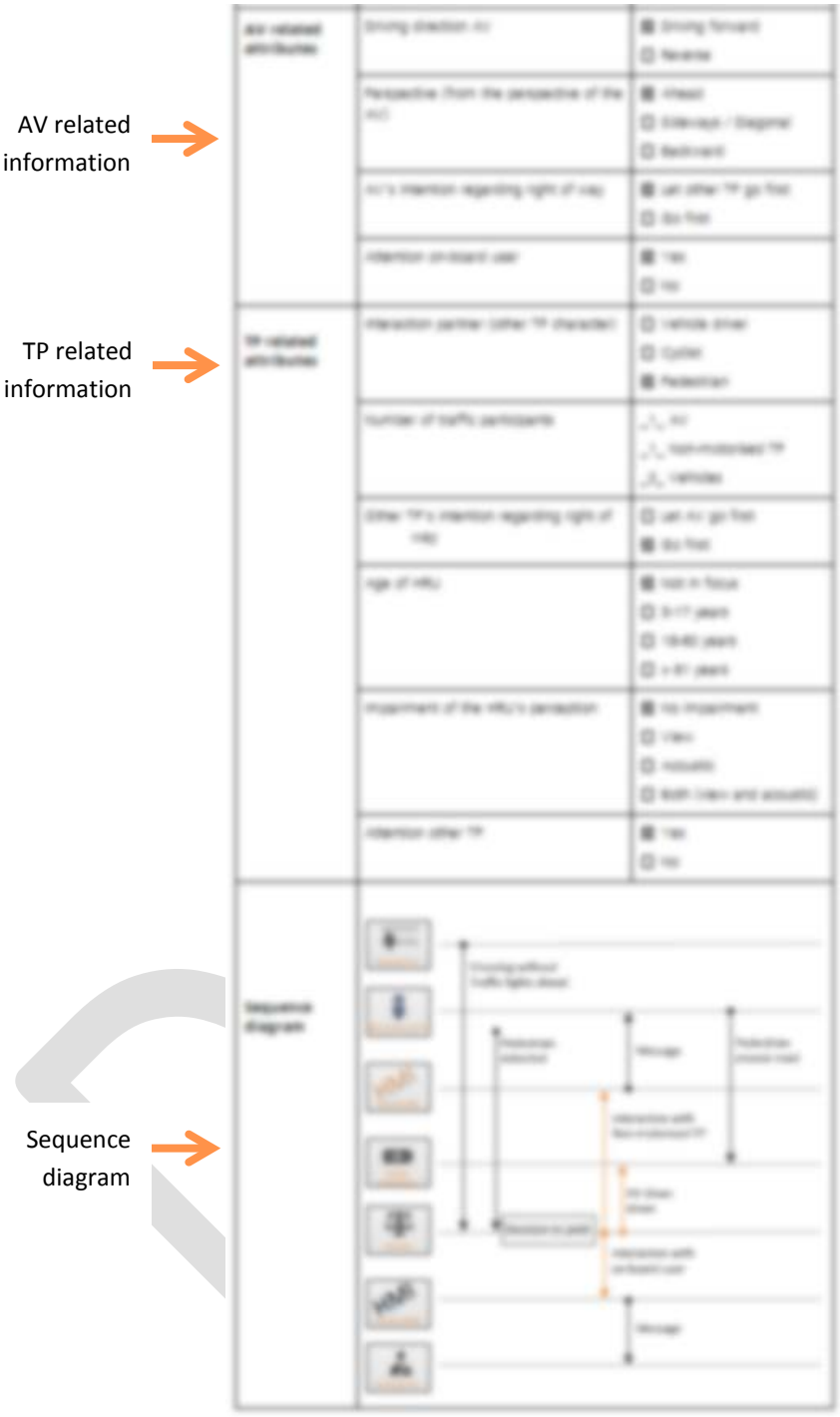


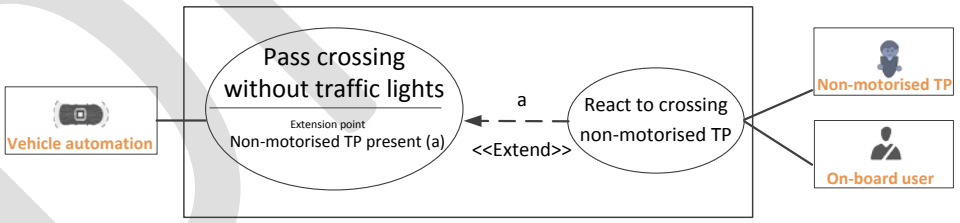
Figure 13: Scenario description template

6. Description of selected interACT use cases

In this chapter the selected must-have and optional *use cases* for interACT are described. The description is provided using the developed *use case* template. Over the course of the interACT project these *use cases* will be further defined using scenario descriptions similar to that displayed in subchapter 5.3.

6.1 Must-have use cases

6.1.1 React to crossing non-motorised TP at crossings without traffic lights

Use Case	React to crossing non-motorised TP at crossings without traffic lights
Use Case Priority	☒ Must ☐ Optional
Use Case Environment	☒ Intersection ☐ Parking space ☒ On the road
Verbal description	The AV approaches a non-motorised TP who wants to cross the road at a crossing without traffic lights. Main goal is to handle the situation safely by using a clear and understandable communication of the AV's intention. After that the AV should continue driving (see section 6.3.1 for an example scenario of this use case).
Use case diagram	
Importance of the use case	Accident data: 5621 pedestrians killed on road accidents in the EU in 2014. 22 % of all killed on EU roads are pedestrians. Highest risk in urban areas (69%). Children and elderly are particularly at risk (European Commission, 2016). Accident statistics in Sweden show that 36 percent of all the police reported accidents, which involve an injury between pedestrians and drivers, occur at pedestrian crossings (OECD, 2009). A naturalistic driving study conducted between 2015 and 2017 reveals large cross-cultural effects in this use case (UDrive, 2017). Consortium opinion: The use case is important from a safety perspective and occurs often in residential areas. The use case has strong influence on traffic flow and

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<table>
<tr><td></td><td colspan="2">interaction between TPs is needed and has a great impact on acceptance for AVs. Further it is possible to realise the use case in the demo vehicles (using Lidar, USS, Radar and video camera for TP detection) and in a pedestrian simulator.

Linked research studies exploring similar use cases:
• Rothenbücher et al. (2016) studied the interaction of pedestrians with AVs on intersections in a field experiment in the US.
• Clamann et al. (2016) explored the interaction between pedestrians and AV at an unmarked midblock crossing scenario and a marked intersection scenario on a test track.
• Lagström and Malmsten Lundgren (2015) studied the interaction of pedestrians with AVs at an un-signalized crossing on a test track.
• Willrodt and Wallaschek (2016) studied dangerous traffic situations where today's human interaction by eye contact is very important for the non-motorized TP.
• Liu et al. (2017) studied the visibility and perception issues of external HMI for the interaction with pedestrians on a test track.
• Fridman et al. (2017) conducted an online study regarding different HMI designs variants for on external HMI in a pedestrian crossing scenario.</td></tr>
<tr><td rowspan="2">Taxonomy</td><td>Addressed interaction partner</td><td>☐ Driver of other vehicles
☒ Cyclist
☒ Pedestrian</td></tr>
<tr><td>Driving direction AV</td><td>☒ Driving forward
☐ Reverse</td></tr>
</table>

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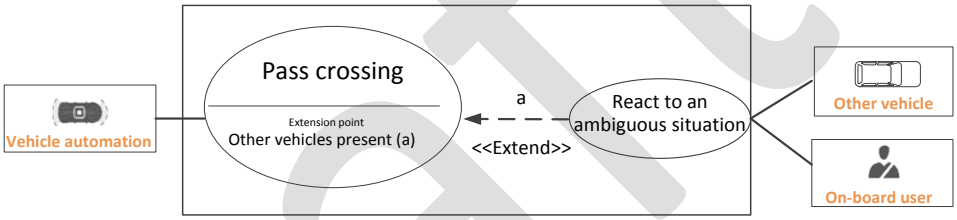
6.1.2 React to an ambiguous situation at an unsignalised intersection

Use Case	React to an ambiguous situation at an unsignalised intersection	
Use Case Priority	☒ Must ☐ Optional	
Use Case Environment	☒ Intersection ☐ Parking space ☐ On the road	
Verbal description	The AV approaches an unsignalised intersection which requires interaction with another/multiple other vehicles. The main goal is to pass the intersection safely by using a clear and understandable communication of the AV's intention. After the situation is solved the AV should continue driving (see section 6.3.2 for an scenario example of this use case).	
Use case diagram		
Importance of the use case	Accident data: 53% of all intersection accidents and 59% of the fatalities and serious injuries at intersection belong to the "cutting scenario" class, where one vehicle drives straight as another vehicle turns left/right (Simon et al, 2009). About 51% of two vehicle rear-end crashes occur at intersections or intersection-related locations (Najm et al, 2003). Consortium opinion: The use case is important from a safety perspective and occurs often in residential areas. The use case has a great influence on traffic flow and interaction between TPs is essential to solve the situation. Interaction in this use case has a great impact on acceptance of AVs. It is possible to realise the use case in the demo vehicles (using Radar and video cameras for TP detection) and in a driving simulator.	
Taxonomy	Addressed interaction partner	☒ Driver of other vehicles ☒ Cyclist ☐ Pedestrian

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	Driving direction AV	☒ Driving forward ☐ Reverse

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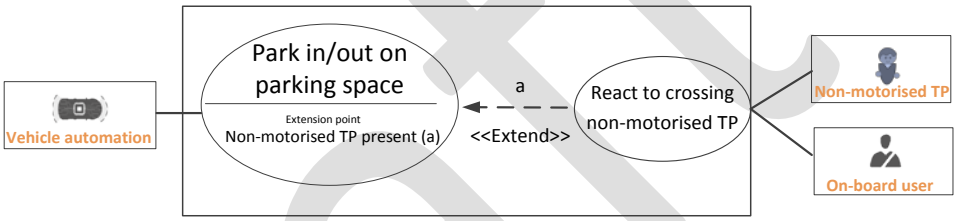
6.1.3 React to non-motorised TP at a parking space

Use Case	React to non-motorised TP at a parking space
Use Case Priority	☒ Must ☐ Optional
Use Case Environment	☐ Intersection ☒ Parking space ☐ On the road
Verbal description	The AV is driving into or out of a parking space and has to react to a non-motorised TP in their path. The main goal is to handle the situation safely by providing clear and understandable communication of the AV's intention so that successful negotiation of priority takes place. (see section 6.3.3 for an scenario example of this use case).
Use case diagram	
Importance of the use case	Accident data: A third of all accidents with injured or killed pedestrians happen with velocities around 10 km/h. Most of these accidents occur while parking manoeuvers on daytime. Reverse parking out manoeuvres are especially critical. Older people (>70 years) are at particularly high risk (86%) (Unfallforschung der Versicherer GDV, 2017). Consortium opinion: This use case is important from a safety perspective and occurs often around parking spaces. The use case has a low influence on traffic flow on the roads but a high influence for the traffic flow in parking lots. Interactions between TPs is essential has a great impact on the acceptance of AVs. This use case can be realised in the demo vehicles by using Radar, Lidar and USS and a video camera for TP detection and interaction gestures. Further, it is possible to implement the use case in a pedestrian simulator. There is also an interesting aspect that an AV might move without user on-board (remote parking), and that this use case might be on the road quite soon. Linked research studies exploring similar use cases: • Within the CityMobil2 project some studies on the interaction of pedestrians with fully automated vehicle (without a driver) on shared spaces were conducted that might have some similarities to the parking use

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	case (Merat et al., submitted for publication)	
Taxonomy	Addressed interaction partner	☐ Driver of other vehicles ☐ Cyclist ☒ Pedestrian
	Driving direction AV	☒ Driving forward ☒ Reverse

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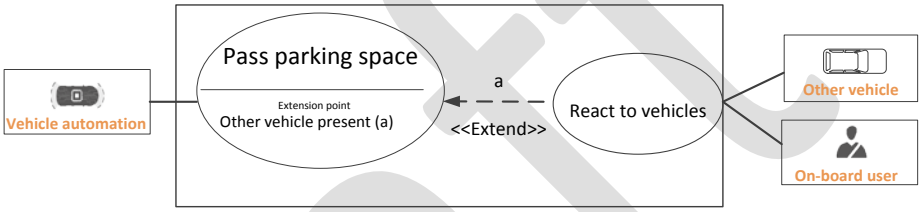
6.1.4 React to vehicles at a parking space

Use Case	React to vehicles at a parking space	
Use Case Priority	☒ Must ☐ Optional	
Use Case Environment	☐ Intersection ☒ Parking space ☐ On the road	
Verbal description	The AV approaches a parking space which another vehicle is leaving. The main goal is to handle the situation safely by providing clear and understandable communication of the AV's intention. (see section 6.3.4 for an example scenario of this use case).	
Use case diagram		
Importance of the use case	Accident data: In 93% of parking crashes a second vehicle is involved. 79% of all parking crashes occurred while driving backwards. (Unfallforschung der Versicherer GDV, 2016). Consortium opinion: The use case is less important for safety but occurs often in parking lots. The use case has a low influence on traffic flow on the roads but a high influence for the traffic flow in the parking lot. Interaction between TPs is essential and has a great impact on the acceptance of AVs. This use case can be implemented in the demo vehicles by using Radar and a video camera for TP detection. Further, it is possible to implement the use case in a driving simulator.	
Taxonomy	Addressed interaction partner	☒ Driver of other vehicle ☐ Cyclist ☐ Pedestrian
	Driving direction AV	☒ Driving forward ☒ Reverse

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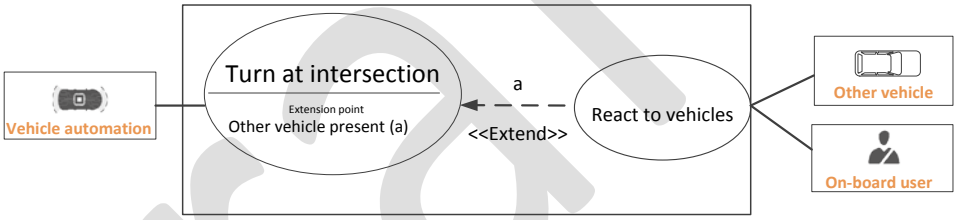
6.2 Optional use cases

6.2.1 React to vehicles on the road in turning situation (AV wants to turn)

Use Case	React to vehicles on the road in turning situation (AV wants to turn)
Use Case Priority	☐ Must ☒ Optional
Use Case Environment	☒ Intersection ☐ Parking space ☐ On the road
Verbal description	The AV approaches an intersection and wants to turn. While turning, the AV has to obey the traffic rules and to react to other vehicles from the opposite or even the same direction (e.g. bicycle). The AV needs to communicate its intention to turn and additional information for other vehicles to handle this turn safely. (see section 6.3.5 for an scenario example of this use case).
Use case diagram	
Importance of the use case	Accident data: 1.24% of all people at non-signalised junction accidents suffered high-level MAIS (Maximum Abbreviated Injury Scale) 3+ injuries. Vehicle(s) Turning at non-signalised junctions was the second most frequent pre-crash scenario of two-vehicle light-vehicle crashes (10.83% of all crashes) (Najm, 2007). Consortium opinion: The use case is important from a safety perspective and occurs often in residential areas. The use case has a high influence on traffic flow, and interaction between TPs is essential to solve the situation fast and safe. Interaction in this use case has a high impact on acceptance of AVs. Further the use case can be implemented in the demo vehicles by using Radar, Lidar and USS and a video camera for TP detection. Further it is possible to implement the use case in a driving simulator. Linked research studies exploring similar use cases: Portouli et al. (2014) analysed the human-human interaction on a ring road and classified different variants of social interaction. The results of this study might be applicable to driver-AV interaction for this use case.

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Taxonomy	Addressed interaction partner	☒ Driver of other vehicle ☒ Cyclist ☐ Pedestrian
	Driving direction AV	☒ Driving forward ☐ Reverse

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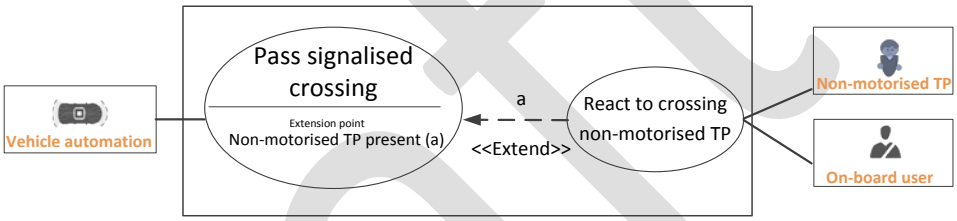
6.2.2 React to crossing non-motorised TP at a signalised crossing

Use Case	React to crossing non-motorised TP at a signalised crossing
Use Case Priority	☐ Must ☒ Optional
Use Case Environment	☒ Intersection ☐ Parking space ☒ On the road
Verbal description	The AV approaches a signalised crossing e.g. a pelican crossing while a non-motorised TP intends to cross the road. The main goal is to handle the situation safely by e.g. using a clear and understandable communication of the AV's intention. After that the AV should continue driving. (see section 6.3.6 for an scenario example of this use case).
Use case diagram	
Importance of the use case	Accident data: Only very few accidents on zebra crossings in Germany (Unfallforschung der Versicherer GDV, 2013). Consortium opinion: The use case has low importance from a safety perspective but occurs often in residential areas. The use case has a high influence on traffic flow and interaction between TPs is helpful to solve the situation quickly and safely. Interaction in this use case has a great impact on acceptance of AVs. This use case can be implemented in the demo vehicles by using Radar, Lidar and USS and a video camera for TP detection and interaction gestures. Further, it is possible to implement the use case in a pedestrian simulator. Linked research studies exploring similar use cases: • Clamann et al. (2016 & 2017) explored the interaction between pedestrians and AV at an unmarked midblock crossing scenario and a marked intersection scenario on a test track.

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Taxonomy	Addressed interaction partner	☐ Driver of other vehicle ☐ Cyclist ☒ Pedestrian
	Driving direction AV	☒ Driving forward ☐ Reverse

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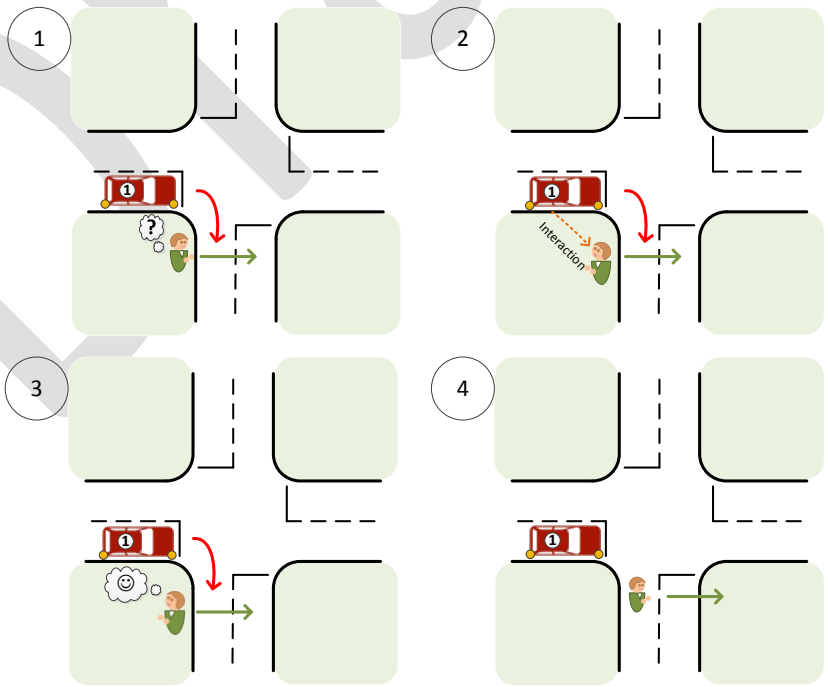
6.3 Scenario examples

The scenario template will set the basis for a standardised scenario description among all project partners in the interACT project. Since WP2 will investigate and deliver real-life data from observations of different traffic situations, results will be used for a further definition of the *scenarios* addressed in interACT. The completed template below provides an example for a scenario description.

6.3.1 Scenario: React to a single pedestrian crossing at a distance from 3m-10m from right to left at a crossing without traffic lights

Scenario	React to a single pedestrian crossing at a distance from 3m-10m from right to left at a crossing without traffic lights
Related Use case	React to crossing non-motorised TP at crossings without traffic lights
Author	Marc Wilbrink
Use case Priority	☒ Must ☐ Optional
Use case Environment	☒ Intersection ☐ Parking space ☐ On the road
Graphical representation	
Verbal description	The AV approaches a pedestrian who wants to cross the road at a crossing without traffic lights. The AV has right of way, but wants to yield for the

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	pedestrian. The AV signalizes its intention to the pedestrian and waits for him to cross the road. After the non-motorised TP crossed the road, the AV continues its drive.	
Traffic & Environment	Right of way	☐ AV ☒ other TP ☐ Undefined
	Longitudinal distance (headway)	☐ < 3m ☒ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☒ ≤ 3m ☐ > 3m
	Speed AV	☐ 0 km/h ☐ 10 km/h ☒ 30 km/h ☐ 50 km/h
	Speed other TP	☒ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☒ Ahead

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		☐ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☒ Let other TP go first ☐ Go first
	Attention of on-board user	☒ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☐ Driver of other vehicle ☐ Cyclist ☒ Pedestrian
	Number of traffic participants	_1_ AV _1_ Non-motorised TP _0_ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☒ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

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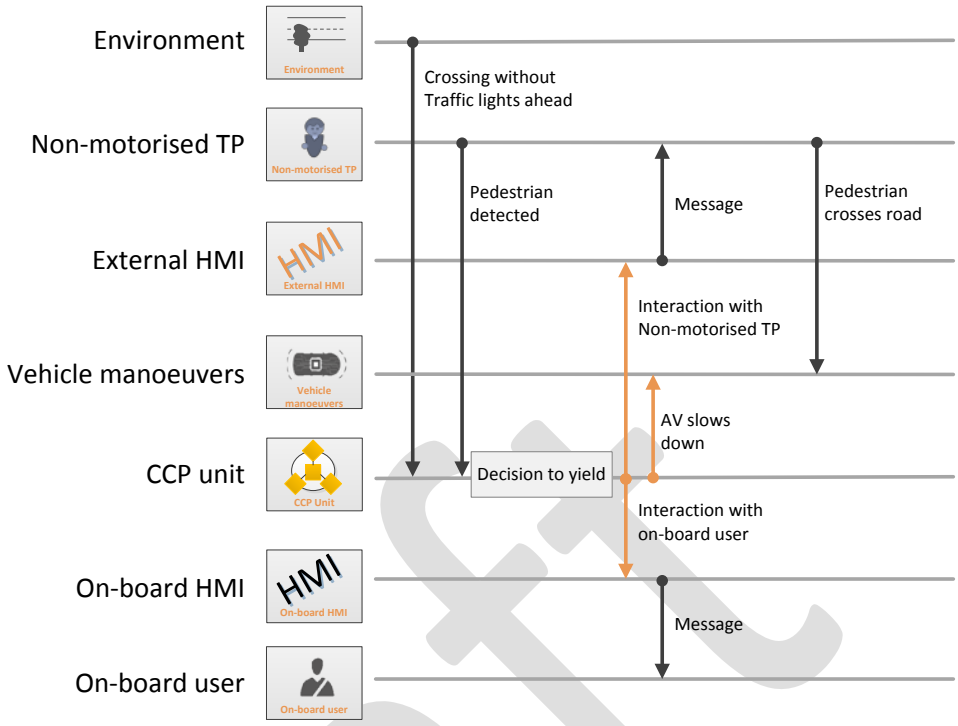
Sequence diagram	

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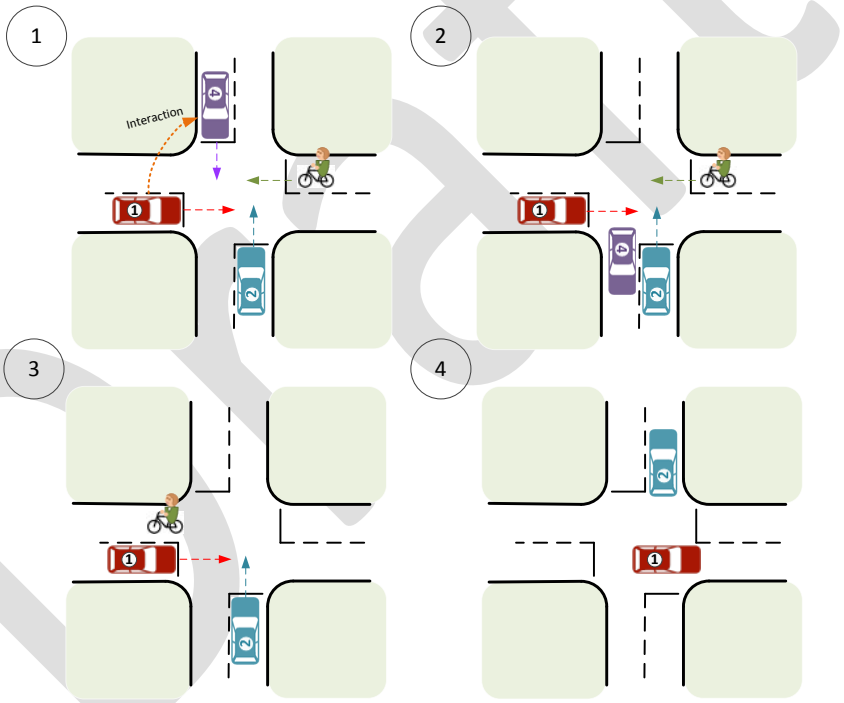
6.3.2 Scenario: React to an ambiguous situation at an unsignalised 4-way intersection while all 4-ways are blocked

Scenario	React to an ambiguous situation at an unsignalised 4-way intersection while all 4-ways are blocked	
Related Use case	React to an ambiguous situation at an unsignalised 4-way intersection	
Author	Marc Wilbrink	
Use case Priority	☒ Must ☐ Optional	
Use case Environment	☒ Intersection ☐ Parking space ☐ On the road	
Graphical representation		
Verbal description	The AV approaches an unsignalised 4-way intersection. All 4 intersection-arms are blocked. All drivers have to give way to the TP on their right side. Since all roads are blocked the situation needs to be solved by an interaction between the TPs. The AV is the first road user who signalises that it gives way to the TP on his left side (Vehicle #4). After Vehicle #4 crosses the intersection all other TPs can cross the intersection by following the traffic rules. The AV crosses the (empty) intersection.	
Traffic & Environment	Right of way	☐ AV ☐ other TP

		☒ Undefined
	Longitudinal distance (headway)	☐ < 3m ☐ 3-10m ☒ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☒ > 3m
	Speed AV	☒ 0 km/h ☐ 10 km/h ☐ 30 km/h ☐ 50 km/h
	Speed other TP	☒ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☐ Ahead ☒ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☒ Let other TP go first

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		☐ Go first
	Attention of on-board user	☒ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☒ Driver of other vehicle ☐ Cyclist ☐ Pedestrian
	Number of traffic participants	_1_ AV _0_ Non-motorised TP _3_ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☒ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

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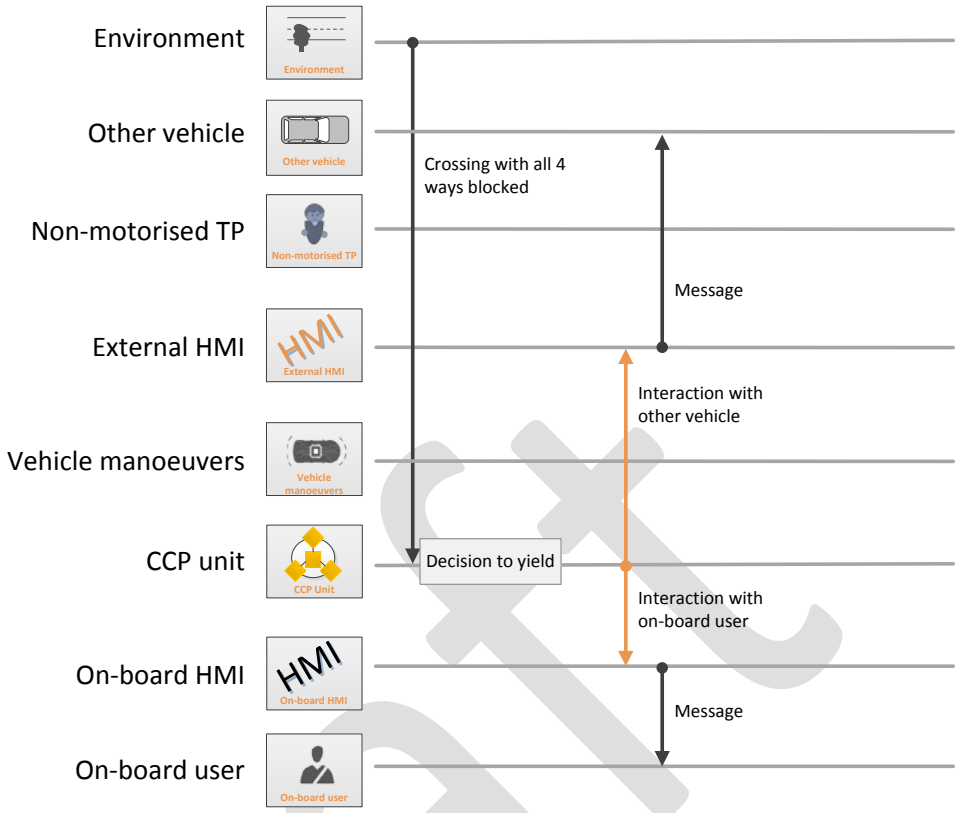
Sequence diagram	

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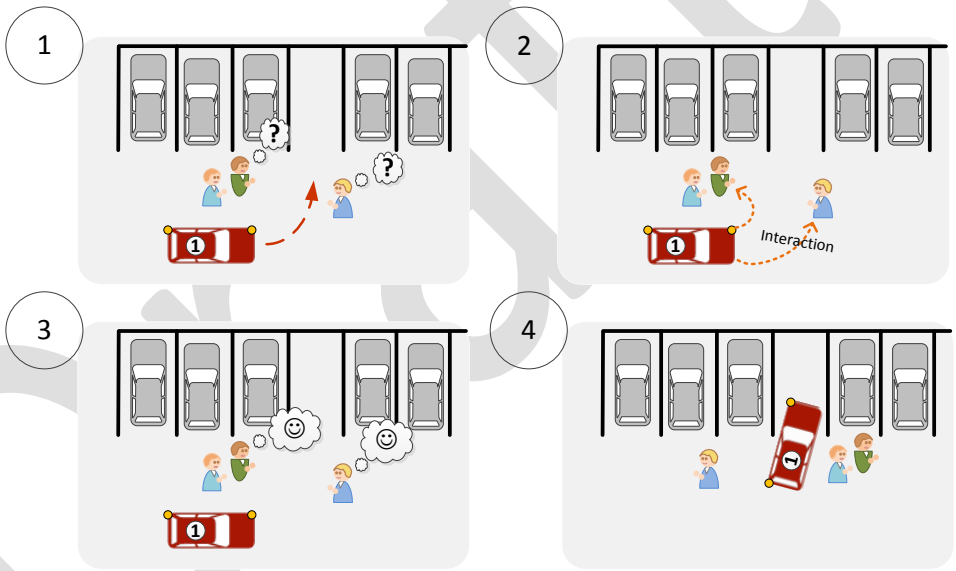
6.3.3 Scenario: React to multiple non-motorised TP (two from left one from right) at a parking space

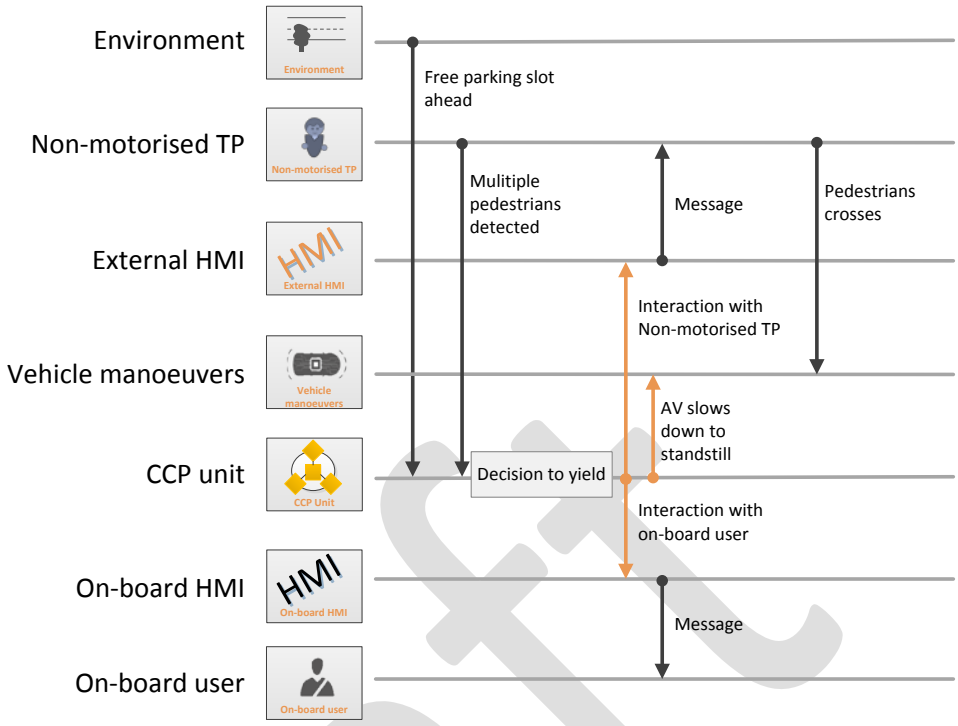
Scenario	React to multiple non-motorised TP (two from left one from right) at a parking space	
Related Use case	React to non-motorised TP at a parking space	
Author	Marc Wilbrink	
Use case Priority	☒ Must ☐ Optional	
Use case Environment	☐ Intersection ☒ Parking space ☐ On the road	
Graphical representation		
Verbal description	The AV is driving towards a parking space. The AV arrives at a free parking slot, but multiple pedestrians block the way. The AV interacts with the pedestrians to its left and right side to communicate that it will wait until the pedestrians have crossed. Once the way into the parking slot is free, the AV enters the parking slot.	
Traffic & Environment	Right of way	☐ AV ☐ other TP ☒ Undefined
	Longitudinal distance (headway)	☒ < 3m ☐ 3-10m ☐ > 10m

	Lateral distance	☐ 0m ☒ ≤ 3m ☐ > 3m
	Speed AV	☐ 0 km/h ☒ 10 km/h ☐ 30 km/h ☐ 50 km/h
	Speed other TP	☐ 0 km/h (standstill) ☒ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☒ Ahead ☒ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☒ Let other TP go first ☐ Go first
	Attention of on-board user	☐ Yes, attentive ☐ No, distracted ☒ No on-board user inside

Draft

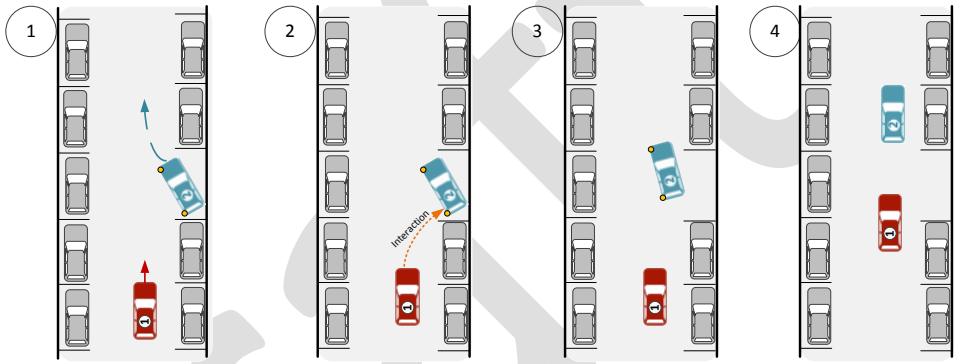
TP related attributes	Interaction partner (other TP character)	☐ Driver of other vehicles ☐ Cyclist ☒ Pedestrian
	Number of traffic participants	_1_ AV _3_ Non-motorised TP _0_ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☒ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

Draft

Sequence diagram	

Draft

6.3.4 Scenario: React to an out parking vehicle at a parking space

Scenario	React to an vehicle moving out of a parking space	
Related Use case	React to other vehicles on the road in parking situations	
Author	Marc Wilbrink	
Use case Priority	☒ Must ☐ Optional	
Use case Environment	☐ Intersection ☒ Parking space ☐ On the road	
Graphical representation		
Verbal description	The AV drives on the parking space and approaches a vehicle which wants to leave a parking spot. The parking spot is in parallel to the driving direction and the vehicle needs some space to successfully move out. The AV communicates that it will wait for the vehicle to move out and keep a gap. The other vehicle moves out and continues driving. The AV continues driving.	
Traffic & Environment	Right of way	☒ AV ☐ other TP ☐ Undefined
	Longitudinal distance (headway)	☐ < 3m ☒ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☒ > 3m
	Speed AV	☐ 0 km/h

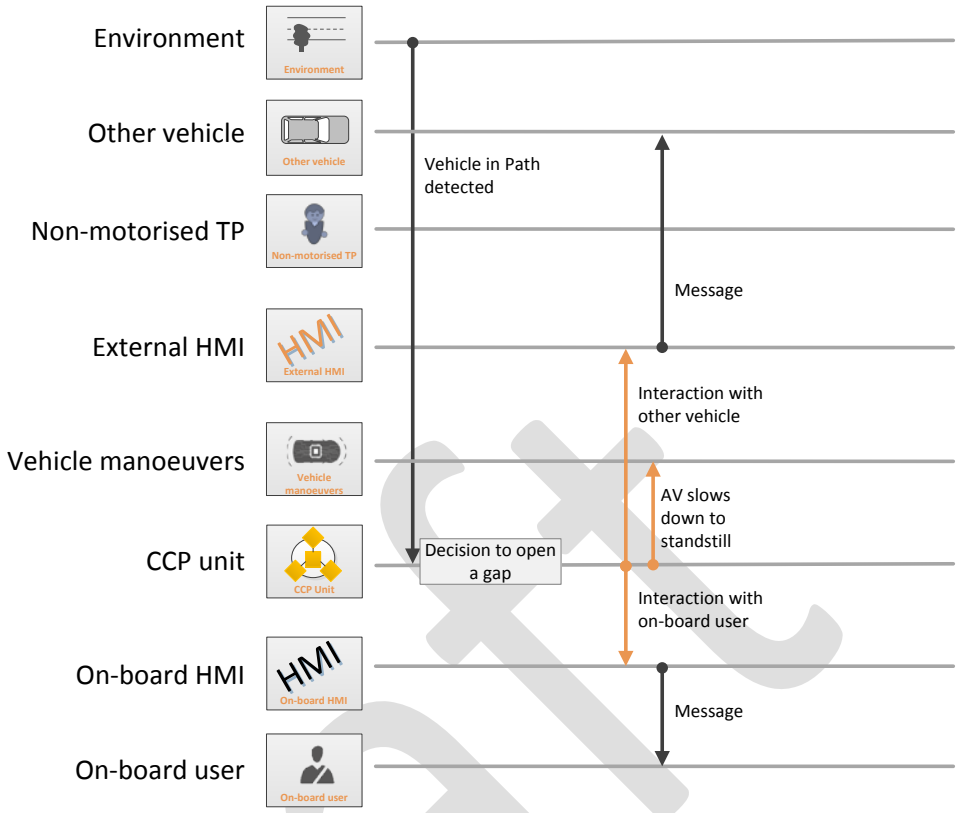
Draft

		☒ 10 km/h ☐ 30 km/h ☐ 50 km/h
	Speed other TP	☐ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☒ 10 km/h (parking) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☐ Ahead ☒ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☒ Let other TP go first ☐ Go first
	Attention of on-board user	☒ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☒ Driver of other vehicles ☐ Cyclist ☐ Pedestrian

Draft

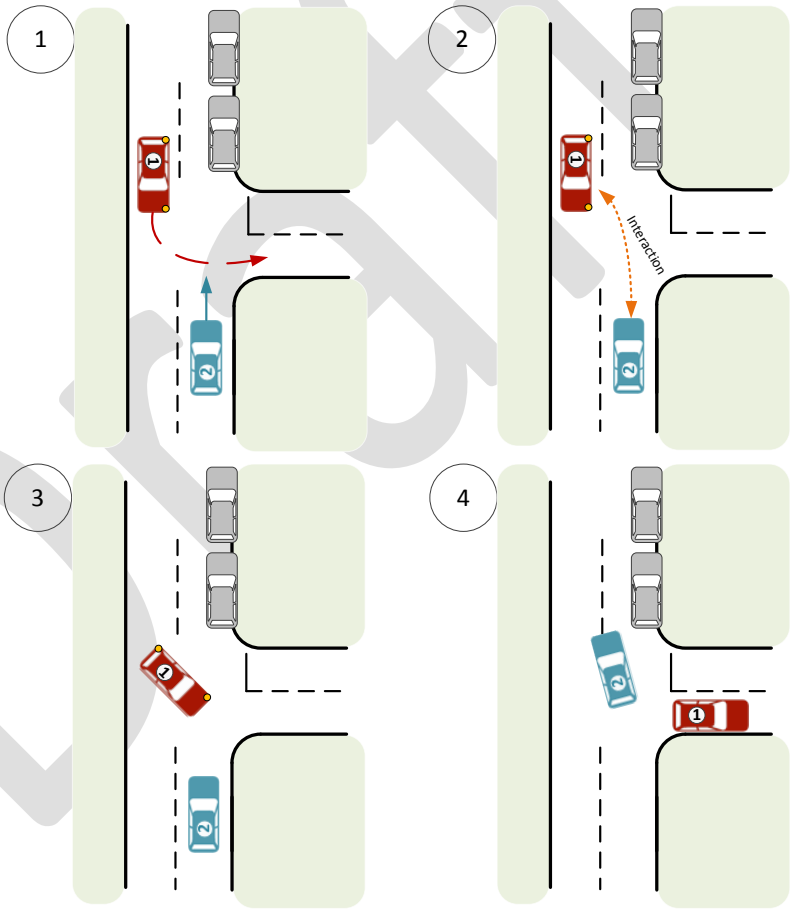
	Number of traffic participants	_1_ AV _0_ Non-motorised TP _1_ Vehicles
	Other TP's intention regarding right of way	☒ Let AV go first ☐ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

Draft

Sequence diagram	

Draft

6.3.5 Scenario: React to a vehicle while turning- Other vehicle yields

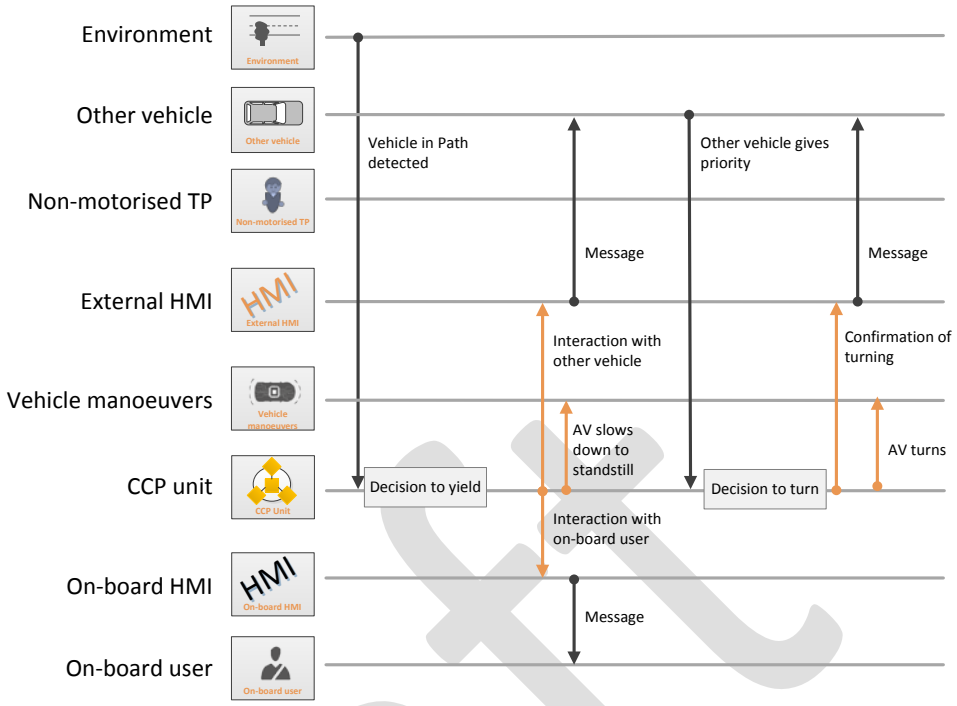
Scenario	React to a vehicle while turning- Other vehicle yields	
Related Use case	React to other vehicles in turning situations	
Author	Marc Wilbrink	
Use case Priority	☐ Must ☒ Optional	
Use case Environment	☒ Intersection ☐ Parking space ☐ On the road	
Graphical representation		
Verbal description	The AV approaches an intersection and intends to turn left. The AV waits for the upcoming (vehicle#2) traffic to pass. Since the path of vehicle#2 is blocked, vehicle#2 wants to yield and signalises to the AV that they can turn in front of vehicle#2. The AV understands the signals of vehicle#2 and turns left.	
Traffic & Environment	Right of way	☐ AV ☒ other TP

		☐ Undefined
	Longitudinal distance (headway)	☐ < 3m ☒ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☒ > 3m
	Speed AV	☐ 0 km/h ☐ 10 km/h ☒ 30 km/h ☐ 50 km/h
	Speed other TP	☐ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☒ 30 km/h ☒ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☒ Ahead ☐ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☒ Let other TP go first

Draft

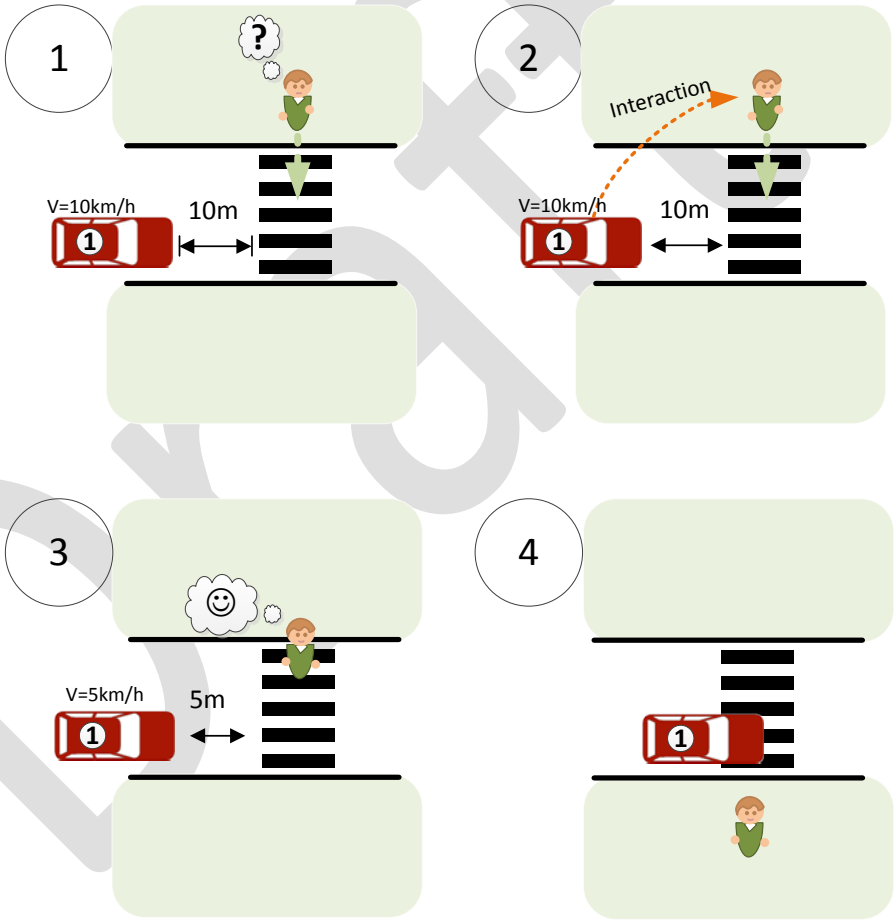
		☐ Go first
	Attention of on-board user	☒ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☒ Driver of other vehicles ☐ Cyclist ☐ Pedestrian
	Number of traffic participants	_1_ AV _0_ Non-motorised TP _1_ Vehicles
	Other TP's intention regarding right of way	☒ Let AV go first ☐ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

Draft

Sequence diagram	

Draft

6.3.6 Scenario: React to a crossing pedestrian at a zebra crossing

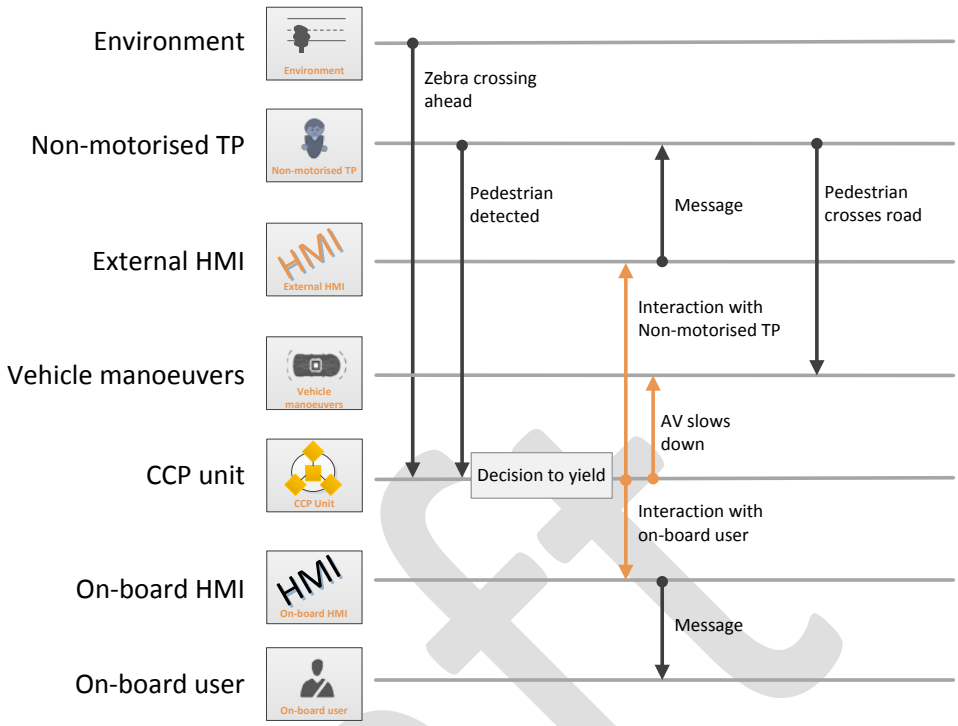
Scenario	React to a crossing pedestrian at a zebra crossing
Related Use case	React to crossing non-motorised TP at signalised crossings
Author	Marc Wilbrink
Use case Priority	☐ Must ☒ Optional
Use case Environment	☐ Intersection ☐ Parking space ☒ On the road
Graphical representation	
Verbal description	The AV approaches a zebra crossing where a pedestrian intends to cross the road. The pedestrian has right of way but is not sure if he was detected by the AV. The AV communicates that it will wait for pedestrian to cross the road. The pedestrian crosses the road and the AV continues driving.
Traffic & Environment	Right of way: ☐ AV ☒ other TP ☐ Undefined

	Longitudinal distance (headway)	☐ < 3m ☒ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☒ > 3m
	Speed AV	☐ 0 km/h ☐ 10 km/h ☒ 30 km/h ☐ 50 km/h
	Speed other TP	☒ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian) ☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☒ Day ☐ Night
	Lighting conditions	☒ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☒ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☐ Ahead ☒ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☐ Let other TP go first ☐ Go first
	Attention of on-board user	☒ Yes, attentive

Draft

		☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☐ Driver of other vehicles ☐ Cyclist ☒ Pedestrian
	Number of traffic participants	_1_ AV _1_ Non-motorised TP _0_ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☒ Go first
	Age of TP	☒ Not in focus ☐ 3-17 years ☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☒ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☒ Yes ☐ No

Draft

Sequence diagram	

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7. Summary and conclusion

The interACT project consortium studies current human-machine interactions in mixed traffic, and will increase the chances of safe deployment of AVs by developing novel software and HMI hardware components for reliable and user-centric interaction among an AV, its on-board user, and other traffic participants in the surrounding.

Because the real environment consists of a countless number of different traffic situations, it is essential that we narrow the focus down to some highly relevant *use case*s. This allows for a collaborative approach and an alignment of effort by project partners to find the right solutions for challenging interaction *scenarios* of AVs in mixed traffic situations. It is assumed, that the communication concepts, which will be developed for the addressed *use cases* within the course of the project can be extended in a way that they are applicable to other several other *use cases*.

This deliverable provides a detailed documentation of the process for selecting the interACT *use case*s within the consortium. It also describes a framework for the description of *use case*s and *scenarios* that provides the basis for standardized documentation within the project. The templates of the framework are intended to provide a living document that can be adapted according to the different WP needs throughout the whole course of the interACT project to support the discussion and documentation of the project results. The main part of this deliverable is the detailed documentation of four selected “must-have” and two “optional” *use case*s for the interACT project. These *use case*s are setting the ground for all technical development and research activities, and will be evaluated and demonstrated in the demonstrator vehicles and simulators. All *use case*s selected for interACT are *use case*s from an urban environment. This is because *scenarios* in urban environment are quite complex and show the need for intensive interaction among different traffic participants, especially in ambiguous or unsignalised *scenarios*. In addition, the relatively low speed of the vehicles allows a sophisticated interaction strategy compared to highway *scenarios* where human drivers are used to indicate their intention by conventional means of communication e.g. by using the vehicle indicator for merging and the vehicle behaviour in general (Färber, 2016). It is expected that this is also applicable for AVs on highways but that we need to find the right solutions for complex urban environment that replace the common human-human interaction that we see today.

The “must-have” *use case*s of interACT cover two main traffic environments: intersections and parking spaces. These are chosen because at intersections as well as at parking spaces there is a need for clear interaction between different traffic participants to allow for a safe and efficient flow of traffic/movements of TPs. The interaction at intersections is quite complex as different traffic participants are involved. These are moving either on the road, or on specific lanes such as a bike lane or a pedestrian walkway. Independently of this, the right of way differs from scenario to scenario. The interACT consortium has chosen the *use case*s carefully to cover different aspects of vehicles on the road and TPs on separated lanes. In addition, the interACT partners agreed to focus on non-regulated intersections with no traffic lights, as it is anticipated that the required interaction between TPs in these situations will be more complex.

The second traffic environment chosen by the interACT consortium are parking spaces. At parking spaces there are only a few traffic rules that regulate the interaction between traffic participants, and all TP move in a shared space. The *use case*s defined for parking spaces are also of specific interest within interACT because automated parking applications will appear very soon in the market. Thus, there is a strong need for specific interaction solutions to increase safety and acceptance for these applications.

Beside the project internal definition of the *use case*s and *scenarios* there is the hope that the framework for describing the *use case*s and *scenarios* (see chapter 5) will also supports the discourse and exchange of knowledge with academic and industrial partners from outside the project, e.g. with our twinning partners in the U.S., or the interACT stakeholder group. For example, for the detection of potential cross-cultural differences and similarities in the interaction behaviour of humans with AVs, it is important to comprehend which *use cases* and *scenarios* are being examined by the different research teams. For this, the framework could play a central role in supporting researchers to find commonalities and differences in their research approaches.

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Annex 1: Use case template

Use Case		
Use Case Priority	☐ Must ☐ Optional	
Use Case Environment	☐ Intersection ☐ Parking space ☐ On the road	
Verbal description		
Use case diagram		
Importance of the use case		
Taxonomy	Addressed interaction partner	☐ Driver of other vehicle ☐ Cyclist ☐ Pedestrian
	Driving direction AV	☐ Driving forward ☐ Reverse

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Annex 2: Scenario template

Scenario		
Related Use case		
Author		
Use case Priority	☐ Must ☐ Optional	
Use case Environment	☐ Intersection ☐ Parking space ☐ On the road	
Graphical representation		
Verbal description		
Traffic & Environment	Right of way	☐ AV ☐ other TP ☐ Undefined
	Longitudinal distance (headway)	☐ < 3m ☐ 3-10m ☐ > 10m
	Lateral distance	☐ 0m ☐ ≤ 3m ☐ > 3m
	Speed AV	☐ 0 km/h ☐ 10 km/h ☐ 30 km/h ☐ 50 km/h
	Speed other TP	☐ 0 km/h (standstill) ☐ 4.4 km/h (Ø Pedestrian)

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		☐ 17.5 km/h (Ø Bicyclist) ☐ 30 km/h ☐ 50 km/h
	Time of day	☐ Day ☐ Night
	Lighting conditions	☐ Photopic (daylight) ☐ Mesopic (twilight) ☐ Scotopic (night)
AV related attributes	Driving direction AV	☐ Driving forward ☐ Reverse
	Perspective (from the perspective of the AV)	☐ Ahead ☐ Sideways / Diagonal ☐ Backward
	AV's intention regarding right of way	☐ Let other TP go first ☐ Go first
	Attention of on-board user	☐ Yes, attentive ☐ No, distracted ☐ No on-board user inside
TP related attributes	Interaction partner (other TP character)	☐ Driver of other vehicles ☐ Cyclist ☐ Pedestrian
	Number of traffic participants	__ AV __ Non-motorised TP __ Vehicles
	Other TP's intention regarding right of way	☐ Let AV go first ☐ Go first
	Age of TP	☐ Not in focus ☐ 3-17 years

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		☐ 18-60 years ☐ > 61 years
	Impairment of the TP's perception	☐ No impairment ☐ View ☐ Acoustic ☐ Both (view and acoustic)
	Attention other TP	☐ Yes ☐ No
Sequence diagram		

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Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

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