# Deliverable **D3.3** /

# Evaluation methods

Version: 1.0 Final

Dissemination level: PU

Lead contractor: WIVW

Due date: 30.09.2019

Version date: 30.09.2019

This project has received funding from the
European Union's Horizon 2020 research and innovation
programme under grant agreement No 723051.

# Document information

Authors

Barbara Metz – WIVW
Christian Rösener- ika
Tyron Louw – University of Leeds
Elina Aittoniemi – VTT
Afsaneh Bjorvatn – SNF
Johanna Wörle –WIVW
Hendrik Weber – ika
Guilhermina Antas Torrao – University of Leeds
Anne Silla – VTT
Satu Innamaa – VTT
Felix Fahrenkrog – BMW
Per Heum – SNF
Karl Pedersen – SNF
Natasha Merat – University of Leeds
Sina Nordhoff – EICT
Anja Beuster – EICT
Mandy Dotzauer – DLR
Thomas Streubel – SAFER

Coordinator

Aria Etemad
Volkswagen Group Research
Hermann-Münch-Str. 1
38440 Wolfsburg
Germany

Phone: +49-5361-9-13654
Email: aria.etemad@volkswagen.de

Project funding

Horizon 2020
ART-02-2016 – Automation pilots for passenger cars
Contract number 723051
www.L3Pilot.eu

# Revision and history chart

| Version | Date | Comment |
|---|---|---|
| 0.1 | November 2017 | 1st proposal of structure |
| 0.2 | July 2018 | Elaborated structure, 1st contend added |
| 0.3 | Sept 2018 | Work on content in section 2, 3, 4 and 5 |
| 0.4 | Jan 2019 | Version provided to Leeds team |
| 0.5 | Feb 2019 | |
| 0.6 | March 2019 | First content for all sub-chapters added, used in WP3.5 meeting |
| 0.7 | May 2019 | |
| 0.8 | June 2019 | All sections included – 1st full draft |
| 0.91 | July 2019 | Version for SP3 review |
| 0.92 | Sept. 2019 | Version for language check |
| 0.93 | Sept. 2019 | Version for L3Pilot review |
| 1.0 | Sept. 2019 | Final version for submission in ECAS |

# Table of contents

# Abbreviations

| Abbreviation | Meaning |
|---|---|
| **ACC** | Adaptive cruise control also known as Active cruise control |
| **AD** | Automated driving |
| **ADAS** | Advanced driver assistance systems |
| **ADF** | Automated driving function |
| **AV** | Automated vehicle |
| **AEB** | Autonomous emergency braking |
| **AIM** | Application Platform for Intelligent Mobility |
| **ay** | Lateral acceleration |
| **ax** | Longitudinal acceleration |
| **BCR** | Benefit/cost-ratio |
| **CAN** | Controller area network |
| **CBA** | Cost-benefit-analysis |
| **Dur** | Duration |
| **dx** | Longitudinal distance |
| **dy** | Lateral distance |
| **FCW** | Forward collision warning |
| **FOT** | Field Operational Test |
| **GTC** | Generalized travel costs |
| **HD** | High definition |
| **HMI** | Human-Machine Interface |
| **L0 – L5** | SAE Level 0 - SAE Level 5 |
| **LeadVeh** | Lead vehicle (vehicle in front of ego-vehicle) |
| **m** | Mean |
| **max** | Maximum |
| **min** | Minimum |
| **N** | Number |
| **NDRA** | Non-Driving Related Activity |
| **NPV** | Net present value |
| **ODD** | Operational Design Domain |
| **OEM** | Original Equipment Manufacturer |
| **PDO** | Property damage only |
| **PET** | Post encroachment time |
| **PI** | Performance Indicator |

| Abbreviation | Meaning |
|---|---|
| **RearVeh** | Rear vehicle (vehicle behind ego-vehicle) |
| **RQ** | Research Question |
| **SAE** | Society of Automotive Engineers |
| **sd** | Standard deviation |
| **SP** | Sub Project |
| **THW** | Time headway |
| **TJA** | Traffic jam assist |
| **TTC** | Time to collision |
| **TOC** | Take-over-controllability |
| **TOR** | Take-over request |
| **T&T** | Technical and traffic evaluation |
| **U&A** | User and acceptance evaluation |
| **v** | Velocity |
| **VSL** | Value of statistical life |
| **WP** | Work Package |
| **WTP** | Willingness to pay |

## List of figures

# List of tables

# Executive summary

L3Pilot is a large-scale, European, real-world pilot study of SAE Levels 3 and 4 automated driving functions with the focus on level 3. The goal of L3Pilot is to demonstrate and assess automated driving functions (ADF) in close to real or in real use contexts and environments. To this purpose, a series of on-road tests are performed, using passenger cars of different classes with ad-hoc equipment capable of implementing automated driving. The functions to be tested include motorway functions, traffic jam functions for motorways, urban functions, and parking functions, all designed to enable the driver to move safely and efficiently through selected road environments. This deliverable describes the methods to be used for evaluating the ADFs and answering the research questions developed and described in L3Pilot deliverable D3.1 (Hibberd et al., 2018).

In L3Pilot, the impact of ADFs on various theoretical concepts will be tested. The topics are partly interlinked and or methods depend on each other. Therefore, methods need to be defined thoroughly to ensure that all planned analysis will be feasible in the end. There will be four primary areas of analysis:

1. Technical and traffic evaluation assessing the effect of the ADF on vehicle behaviour and the surrounding traffic based on data logged directly in the on-road tests.
2. User and acceptance evaluation assessing the evaluation of the tested functions by the driver and their impact on drivers' behaviour and drivers' state (e.g. stress, fatigue).
3. Impact assessment transfers the results to a more general level and assesses the potential impacts of so-called mature ADFs on personal mobility, traffic safety, traffic efficiency and the environment.
4. Socio-economic impact assessment takes the results from all previous parts of the analysis and determines monetary values for the estimated effects, weighting expected costs and benefits.

The structure of this deliverable mostly follows these four areas of analysis. It starts with methodological considerations relevant for all topics, describing in particular the basic principles of assessment (e.g. the definition of baseline and treatment conditions) as well as the characteristics of the tested functions. These common parts are followed by individual chapters that describe in detail the primary methods for each of the four areas. In summary, the following methodological approaches are chosen:

- Technical and traffic evaluation: A driving scenario-based approach has been chosen for the analysis of functions' driving behaviour, which will be compared to human driving. Furthermore, critical driving situations (incidents) will be analysed.
- User and acceptance evaluation: The primary tool for assessing user-related aspects is the pilot site questionnaire (one per ADF) that has been developed within L3Pilot. The questionnaire is supported by other measures such as take-over controllability rating, focus groups, interviews, and annual surveys.

- Impact assessment combines results from on-road tests, traffic simulations, statistics and databases and literature to estimate the potential impacts of ADF on road traffic in Europe.
- The socio-economic impact assessment will further elaborate the results from the impact assessment in order to estimate the potential impact of ADF on society. This will be done by using a snapshot approach that estimates the expected change in terms of benefit to cost ratio compared to today's situation in case part of today's fleet would be equipped with Level 3-ADFs.

The goal of the work presented here is to define methods which can be used for datasets collected at the different pilot sites in L3Pilot with the aim to finally combine results across pilot sites. The set methods will ensure that the research questions of L3Pilot are addressed with the analysis. Furthermore, the methods within L3Pilot need to ensure that the parts of the analysis dealing directly with the data from the on-road tests (technical and traffic evaluation, user and acceptance evaluation) provide the necessary information needed for estimating the impact of ADF on road traffic in Europe (impact assessment) and, in a next step, on society (socio-economic impact assessment).

The development of the methods is based on state-of-the-art literature on the various topics and the expert knowledge of the partners involved in the work. As a consequence, decisions on details of the methods as part of implementing and running the data analysis will be done later. The final methodology deliverable D3.4 Evaluation Plan will add details to the methods presented in this report. Within the structure of L3Pilot, decision on final details of the methodology will be amongst others the task of SP7 Evaluation.

# 1 Introduction

## 1.1 The L3Pilot project

Over the years, numerous projects have paved the way for automated driving (AD). Significant progress has been made, but AD is not yet ready for market introduction. However, the technology is rapidly advancing and is today at a stage that justifies automated driving tests in large-scale pilots.

L3Pilot is taking the final steps before the introduction of automated vehicles in daily traffic. AD is not achieved simply by integrating more and better technology, but also incorporating user behaviour and needs into the design of AD systems. Therefore, user acceptance is a key factor in the success of AD on the market. In addition, there are many broad legal restrictions and considerations which need to be addressed before AD can be rolled out. Thus, the overall objective of the L3Pilot project is to test and study the viability of AD as a safe and efficient means of transportation, to gain knowledge base for exploring and promoting new service concepts to provide inclusive mobility.

The L3Pilot project uses large-scale testing and piloting of AD focusing on SAE Level 3 (L3) functions (Figure 1.1) exposed to different users, mixed traffic environments, including conventional vehicles and vulnerable road users (VRUs), along different road networks.

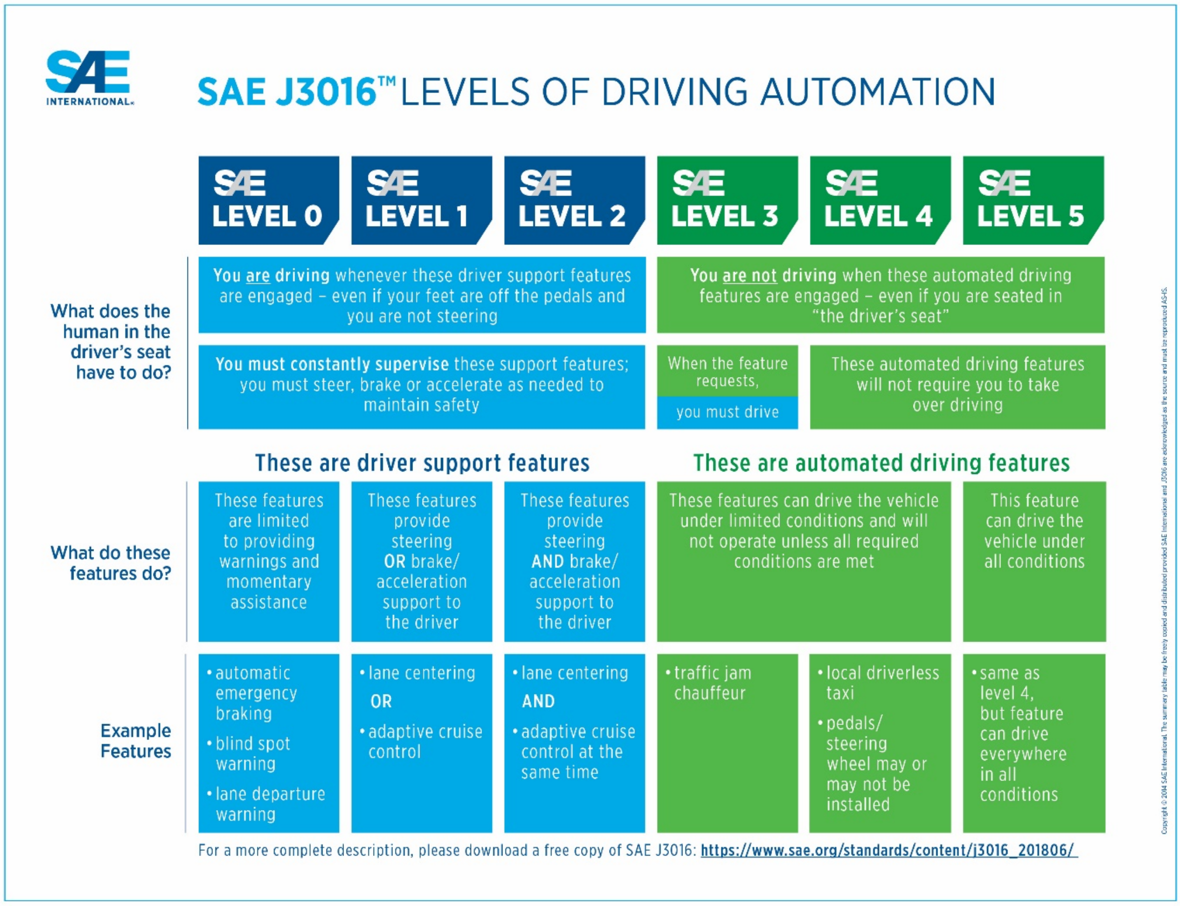



*Figure 1.1: SAE Levels of Driving Automation J3016 JUN2018 (Copyright 2018 SAE International).*

The L3Pilot project focuses on large-scale piloting of automated driving functions (ADF), primarily L3 functions, with additional assessment of some L4 functions. The key to successful piloting is to ensure that the ADFs used are exposed to variable conditions, but where performance is consistent, reliable and predictable. This will ensure a pleasant experience for the users (Figure 1.2), which will facilitate conditions to study the factors that will lead to accelerated acceptance and adoption of the technology, thus improving the business case to deploy AD.

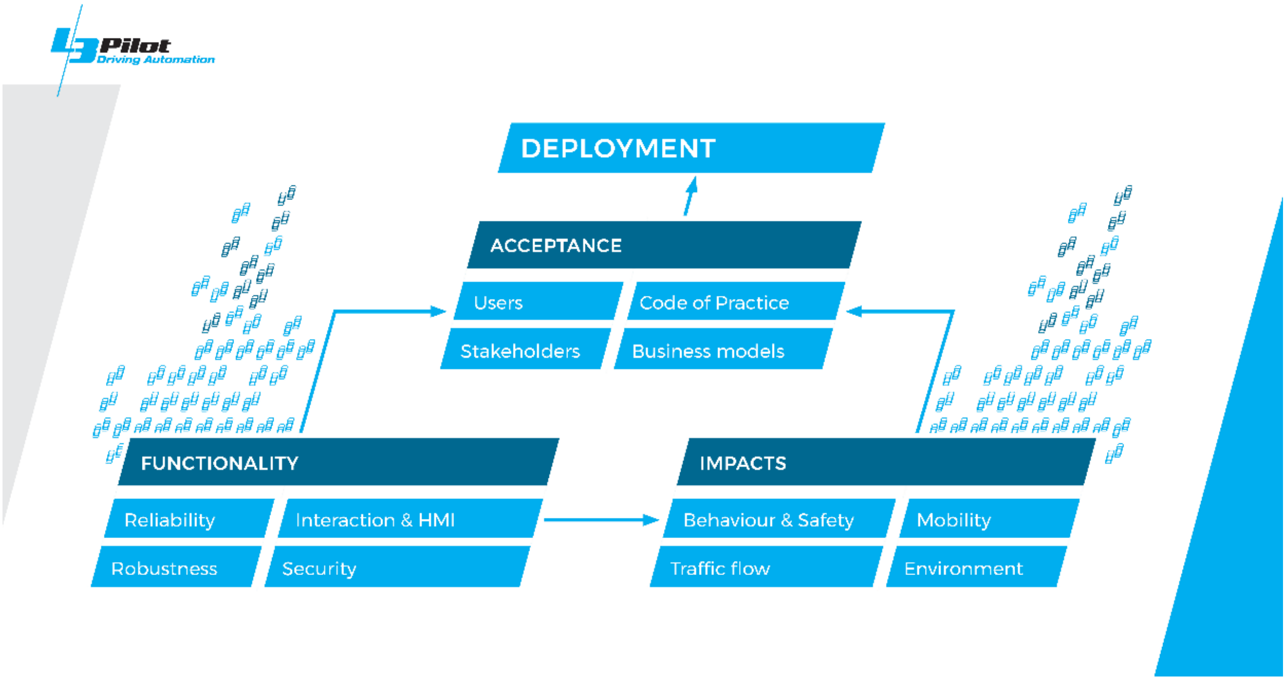



*Figure 1.2: L3Pilot approach and the mechanism for deployment.*

The L3Pilot consortium brings together stakeholders from the whole value chain, including OEMs, suppliers, academic institutes, research institutes, infrastructure operators, governmental agencies, the insurance sector and user groups. Since the development of ADFs, especially at SAE L3, is relatively well progressed, the aim is not only to pilot the ADFs, but also to study user acceptance and evaluation, reactions and willingness to use vehicles equipped with such functionalities. This information leads the consortium to create plans for the market introduction of AD.

The project follows the FESTA V-process methodology of setting up and implementing tests (FOT-Net, 2018). FESTA was created as a testing methodology for advanced driver assistance systems (ADAS) to be used in field operational tests (FOTs). The four main pillars of the FESTA V-process methodology include: (i) Prepare, (ii) Drive, (iii) Evaluate, and (iv) Address legal and cyber-security aspects. These will be adapted to suit L3Pilot needs of piloting ADFs.

In the evaluation stage, a holistic approach will be used by analysing different aspects of AD based on real-world driving data. As such, the approach will follow FESTA evaluation domains: technical, user acceptance, driving and travel behaviour, impact on traffic and societal impacts.

## 1.2 Role of the Methodology sub-project in L3Pilot

The work in L3Pilot is structured into sub-projects following the process proposed by FESTA (FOT-Net, 2018). The objectives of the *Methodology* sub-project in L3Pilot are to:

- Develop a methodology for the piloting, testing and evaluation of ADF for achieving reliable results;

- Reconsider the theoretical background and impact mechanisms required for building a multidisciplinary evaluation methodology;
- Consider not only the expected positive impacts on road and driver safety and traffic flow, but also the unintended, and possibly negative, impacts of AD;
- Facilitate good understanding of a variety of possible effects of AD on the transport system, including the effects on mobility and well-being of people, behavioural adaptation, safety and capacity, fuel consumption and emissions;
- Provide input to a Code of Practice for AD testing, interface design, and investigation of Human-Machine Interaction (HMI).

In this context, the sub-project on methodology provided a list of Research Questions (RQs) as one of its outputs (see L3Pilot Deliverable 3.1 by Hibberd, Louw, Aittoniemi, Brouwer, Dotzauer, Fahrenkrog, et al., 2018) as well as developed innovative and appropriate experimental procedures to collect the data required to answer these questions. The sub-project also developed a structured and robust evaluation plan to ensure that reliable and valid results are achieved from the pilot testing (see L3Pilot Deliverable 3.2 by Penttinen, Rämä, Dotzauer, Hibberd, Innamaa, Louw, et al., 2019), meeting the objectives defined above.

There are close interactions with other sub-projects in order to define a methodological approach that is feasible within the project and fulfils all the needs of L3Pilot, e.g.:

- Sub-project on pilot tools and data (SP5): The data needs for the planned analysis are communicated to and discussed with partners responsible for defining and implementing the common data analysis tools in L3Pilot. The implemented tools are designed to meet the data needs defined by the Methodology sub-project.
- Sub-project on pilot preparation and support (SP4) and sub-project responsible for piloting (SP6): The developed methodology is fitted to the ADFs prepared for testing at the different pilot sites, also considering practical limitations, regarding, for example, the testing environment or legal requirements at the pilot sites.
- Sub-project on evaluation (SP7): The feasibility of the proposed methodology is continuously evaluated, in terms of the available time and budget.

## 1.3 Content of deliverable and relation to other deliverables

This deliverable D3.3 is the third deliverable in the sub-project on Methodology. The first, D3.1 (Hibberd et al., 2018), is titled “From research questions to logging requirements”. The process for data collection was described, and a list of developed research questions to be addressed in the on-road tests was presented. The second, D3.2 (Penttinen et al., 2019), described the test plan and the experimental design in detail. This deliverable includes a theoretical framework for running the tests, a description of the actual plans at the different pilot sites, and recommendations for optimal experimental design.

Deliverable D3.3 describes the outcome of the work in WP3.5 – Evaluation Methods. The aim of this work is to develop and describe the methods to be used in the project by SP7 – Evaluation. The analysis in L3Pilot will cover various levels and topics, starting with the analysis of time-series data collected at the pilot sites and ending in an estimate of the potential benefit of L3/L4-functions for society derived in from a cost-benefit analysis. D3.3 addresses the methods for all levels of the planned analyses. In the progress of defining the methodology and planning of tests at pilot sites, the original RQs of D3.1 were here partly rephrased / improved to facilitate comprehension. A full list of re-phrased RQs can be found in Annex 1.

The future deliverable D3.4 will present the final overall evaluation plan, including possible updates to the topics presented in the previous three deliverables. D3.4 will be a concluding deliverable of the work conducted in SP3.

Within the project, there are also supplementing research activities addressing some specific topics not directly related to road tests. These are the annual surveys and studies on the effects of long term usage of L3/L4 systems. The supplementary methods will be mentioned within this document when used in combination with data from on-road tests. For more detailed information on supplementing research, please refer to "D7.1 – Annual quantitative survey about user acceptance towards ADAS and vehicle automation" and "D.7.2 – L3/L4 long-term study about user experiences" (Metz, Wörle, Zerbe, Schindhelm, & Bonarens, in preparation).

## 1.4 Scope of planned analyses

The overall goal of L3Pilot is to demonstrate and assess ADFs in close to real or in real use contexts and environments via on-road tests. There will be four primary areas of analysis:

1. Technical and Traffic evaluation (T&T), assessing the effect of the ADF on vehicle behaviour and the surrounding traffic based on data logged directly in the on-road tests.
2. User and acceptance evaluation (U&A), assessing users' evaluation and acceptance of, and behaviour while using, the tested ADFs.
3. Impact assessment extrapolates these results and assesses the potential impacts of so-called mature ADFs on personal mobility, traffic safety, traffic efficiency and the environment.
4. Socio-economic impact assessment utilises the above analyses to determine monetary values for the estimated effects, weighting expected costs and benefits of the ADFs.

The areas do not only address different aspects of the evaluation but also work with different data sets. In Figure 1.3, the blue area marks the data sets that will be used for the different areas of analysis and their topics; e.g. socio-economic impact evaluation will deal with a cost-benefit analysis and will use aggregated data to do so or user evaluation will look at acceptance by using data from single vehicles and data combined at a fleet level that is per pilot site. For all the different areas, RQs were defined in D3.1 (Hibberd et al., 2018).

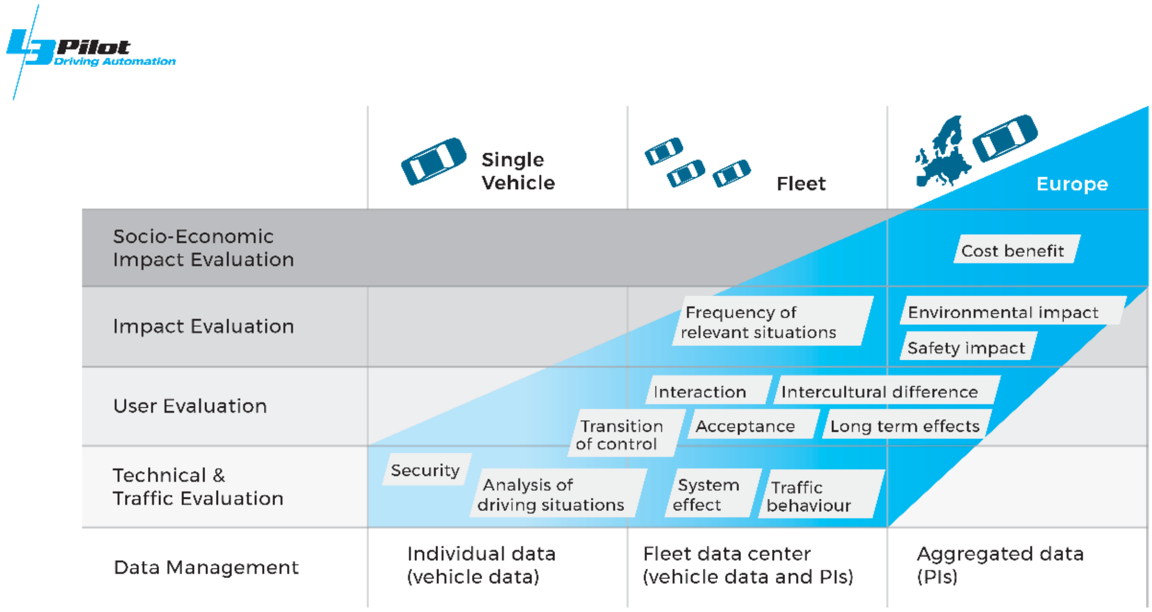



*Figure 1.3: Considered evaluation areas and the scope of assessment.*

Besides answering the related RQs, analyses conducted for the areas 1, 2 and 3 will also provide input needed for the analyses in other areas. The process of L3Pilot data analysis (Figure 1-5) starts with data collection during the on-road-tests in SP6 (piloting). This data is transferred into a common data format (Hiller, Svanberg, Koskinen, Bellotti, & Osman, 2019) used throughout the project. This data format and the required tools are developed within the project, and the conversion to common data format is a part of the work done at the pilot sites. Evaluation starts with an analysis of the data logged at the pilot sites split into the areas of T&T and U&A. The analysis for these two areas can be done in parallel and will be used to answer related RQs, as well as to derive input for impact assessment. Once that input is available, analysis for area 3, impact assessment, can be carried out. Here, the impacts observed and quantified in area 1 and 2 are used in conjunction with other inputs to estimate the expected impacts of ADF (e.g. on traffic safety or on traffic efficiency) in the broader context of use.

Traffic simulation is the primary method for estimating impacts of ADF on traffic safety, traffic efficiency and environmental aspects, while personal mobility assessment mainly utilises results from the user evaluation. Based on these estimated impacts, the socio-economic impact is derived in the area 4 of the analysis.

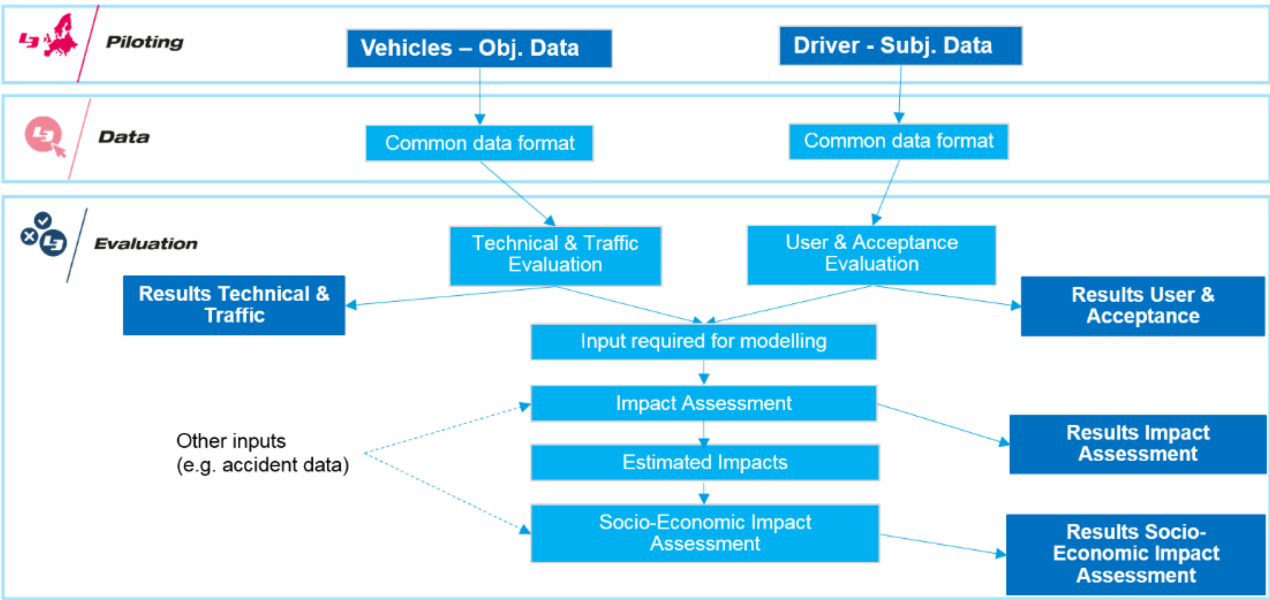



*Figure 1.4: Overview about the expected overall process for data analysis.*

Each research question was allocated to an area of analysis (see Table 1.1). According to the allocation, the method is described in the designated subsection.

*Table 1.1: Allocation of level 1 RQs to the different areas of data analysis.*

| RQ level 1 | Technical & traffic evaluation | User & Acceptance evaluation | Impact assessment | Socio-economic assessment |
|---|---|---|---|---|
| What is the ADF's technical performance? | X | | | |
| What is the impact of ADF on the driving behaviour of the ADF vehicle? | X | | | |
| What is the impact of ADF on the interaction with other road users? | X | | | |
| What is the impact of ADF on the behaviour of other traffic participants? | X | | | |
| What is the impact of ADF on user acceptance & awareness? | | X | | |
| What is the user experience? | | X | | |
| What is the impact of ADF on traffic safety? | | | X | |
| What is the impact of ADF on traffic efficiency? | | | X | |
| What is the impact of ADF on the environment? | | | X | |
| What is the impact of ADF on (personal) mobility? | | | X | |
| What is the socio-economic impact of ADF? | | | | X |

# 2 Evaluated automated driving functions

## 2.1 Technical & traffic evaluation and user & acceptance evaluation

The testing phase in L3Pilot contemplates 16 different pilot sites and various prototype vehicles equipped with at least one among 20 different ADFs (see D4.1 by Griffon, Sauvaget, Geronimi, Bolovinou, & Brouwer, 2019). To be able to analyse the overall impact of these functions, that is, independent of the individual implementations of specific vehicle brands, the ADFs will be grouped in the analysis and indicators will be presented such that they are merged across pilot sites.

For the T&T and U&A areas, the methods will deal directly with data logged and collected in the on-road tests. Here, the grouping of the 20 prototype implementations will be done based on the operational design domain (ODD) of individual functions. ODD describes the conditions that need to be fulfilled for an ADF to work correctly (e.g. driving on a motorway with good lane markings and in appropriate weather conditions).

While describing the methods as well as later to follow the presentation of results, a basic distinction is made between three different groups of ADFs: motorway, parking and urban.

For the evaluation of parking ADF and ADFs operating in an urban environment, the total number of implementations is low and data for all functions with similar ODD will be grouped. Compared to that, more pilot sites will test functions designed for motorways. Therefore, two use cases need to be differentiated for the motorway ODD:

- Traffic jam: high traffic density, speed below 60 km/h.
- Motorway: also covering free-flow conditions, maximum speed variable between functionalities, but up to 130 km/h.

There are implementations that work in both use cases and implementations that work on only one of them. These are ADFs that mainly work in traffic jam conditions only.

In the T&T evaluation, the driving behaviour of the ADFs will be analysed. Separate analyses will be presented for the use case “traffic jam” and for the use case “motorway”, describing the behaviour of ADFs while driving in the use case. The grouping will be done independently of the full ODD of the tested function, always using data logged within the specific use case. This means that data from a traffic jam ADF and a motorway ADF will be merged as long as both systems are driving in traffic jam conditions.

For U&A evaluation, this is different because here, the driver’s evaluation of the tested ADFs as a whole is investigated. It is expected that the evaluation of a tested ADF is based more on the overall ODD and less on the behaviour in a single driving situation. Therefore, motorway functions covering the full speed range and functions working only in traffic jam conditions will be differentiated. Especially relevant for drivers’ evaluation of an ADF is the type of driver participating in the pilots. Therefore, evaluations by professional drivers will be analysed independently from evaluations by non-professional drivers, and similarly for passengers.

In both T&T and U&A evaluations, separate analyses will be performed first for each of the individual pilots and will not be disclosed for confidentiality reasons. The outcomes of those analyses will be anonymously merged across pilot sites, which will allow generic results per ADF groups to be presented. This procedure is in line with the goals of L3Pilot since the project wants to understand the overall implications of L3/L4 ADFs and not of individual implementations. Furthermore, the developed process guarantees data privacy and confidentiality within the project.

## 2.2 Impact assessment and socio-economic assessment

Impact assessment and socio-economic assessment do not evaluate the prototype implementations that are tested in the T&T and U&A evaluations. This is because the focus of impact assessment is to study the potential impacts of mature L3/L4 ADFs in perspective, when they are in use on a larger scale.

It is expected that the ADFs will be developed further from the ones tested in L3Pilot. Therefore, so-called mature functions are defined to represent such future ADFs. In the mature function descriptions, the ODD in which the functions are assumed to work is specified, including types of roads, intersections, lane markings, weather conditions etc. The mature function descriptions were developed in cooperation with ADF developers. Thus, they take into account the knowledge within L3Pilot and represent, to the best of our current knowledge, L3/L4 ADFs that are considered mature enough to be used on roads by ordinary customers. It is important to note in this context that the defined mature ADFs do not represent any particular L3Pilot ADF tested at any of the pilot sites. Rather, they provide a generic description of how these ADFs could look like when adopted by users on a large scale. Four mature functions are defined:

- mature motorway ADF,
- mature traffic jam ADF,
- mature urban ADF and
- mature automated parking function.

All mature functions keep the vehicle on the lane and hold a safe distance to vehicles in front. Lane changes can be performed automatically when needed (e.g. for overtaking slower vehicles or for routing purposes). All mature ADFs operate in similar environmental conditions. They are able to drive both in daylight and at night-time and at good weather conditions or in light or normal rain. However, heavy rain, snow, fog and extreme weather conditions, as well as icy or snowy road surfaces, are outside their ODD. At the end of the ODD, a takeover request is sent to the driver and (s)he is required to take control of driving the vehicle.

### 2.2.1 Mature motorway ADF and traffic jam ADF

Vehicles equipped with the mature motorway ADF and mature traffic jam ADF can drive on motorways and other two-carriage way roads at speeds up to 130 km/h and 60 km/h respectively.

The mature motorway ADF requires infrastructure that ensures a clear division between the opposite directions of traffic and visible lanes or road markings. The mature motorway ADF operation can start after the vehicle has merged onto the motorway, and ends before or when the vehicle leaves the motorway.

The mature traffic jam ADF is a special case of the motorway function and works in the same ODD except that it operates only in congested (traffic jam) conditions and covers speeds up to 60 km/h. The mature motorway ADF function also includes the mature traffic jam function. They are treated separately because they are expected to become available with different time horizons.

### 2.2.2 Mature urban ADF

The mature urban ADF operates on urban roads at speeds up to 50 km/h. It requires lane markings or clear curbs on both sides of the lane. A form of markings is also needed for handling street-side parking, bicycle lanes etc. – either as lane markings or clearly defined on a high definition (HD map) used by the vehicle. It is expected that HD maps are especially important for the deployment of early generations of the mature urban ADF. These maps also enable the vehicle to be rerouted in particular conditions, for example, if roadworks are detected on the planned route.

### 2.2.3 Mature automated parking ADF

The mature automated parking ADF has two functionalities: home zone parking and public parking. Home zone parking is intended for use on private parking grounds, while public parking covers parallel and perpendicular parking in public parking spaces such as street-side parking and parking lots. Both functionalities can deal with static objects and other slow-moving traffic participants.

The home zone parking can handle the actual parking manoeuvres and also drive on the private driveway to reach the parking spot (the possible travelled distance might be limited depending on the function design). This functionality requires pre-training of the trajectory from the driveway entrance to the dedicated parking spot. In-home zone parking, the user can be outside the vehicle and is not required to monitor the manoeuvres.

The public parking functionality requires the driver to be inside the vehicle and monitor the parking manoeuvre. Markings or parked cars are needed to mark the available parking space.

### 2.2.4 Summary of mature ADFs

*Table 2.1: Summarised description of mature ADF – mature urban ADF, mature motorway ADF and mature traffic jam ADF.*

| | | Mature urban ADF | Mature motorway ADF | Mature traffic jam ADF |
|---|---|---|---|---|
| Driving environment | | Urban roads | All motorway and other two-carriageway roads | All motorway and other two-carriageway roads |
| Speed range | | 0–50 km/h | 0–130 km/h | 0–60 km/h |
| Lane changes | | Yes | Yes | Yes |
| Lane markings needed | | Lane separators – curbs or lane markings – needed | Yes | Yes |
| Lane marking quality | | Small gaps ok | Small gaps ok | Small gaps ok |
| Intersection types | Traffic lights | Yes | - | - |
| | Non-signalised intersections | Yes | - | - |
| | Roundabouts | Yes (complex excluded) | - | - |
| | Others: private driveway exits, garage exits etc. | AV coming from driveway not covered (manual driving onto street), other cars from driveways ok | - | - |
| | On-ramps | - | No | No |
| | Off-ramps | - | No | No |
| | Weaving areas | - | Weaving without ramps ok | Weaving without ramps ok |
| Street characteristics | Pavement type | All (asphalt, cobblestone) | - | - |
| | Street width | In 2-way traffic, enough space needed for 2 cars to drive/manoeuvre next to each other | - | - |
| | Street parking | Yes | - | - |
| | Bicycle lanes | Yes | - | - |
| | Tramways and railway crossings | Driving on streets with tram lines ok, crossing tram lines and railway crossings challenging (field of | - | - |

| | | Mature urban ADF | Mature motorway ADF | Mature traffic jam ADF |
|---|---|---|---|---|
| | | vision, detecting oncoming train) | | |
| Special conditions and situations | Interaction with VRU | Yes | | |
| | Weather | Light rain ok, extreme weather excluded | Light rain ok, extreme weather excluded | Light rain ok, extreme weather excluded |
| | Light | All conditions ok | All conditions ok | All conditions ok |
| | Road condition | Icy and snowy roads excluded, standing water excluded | Icy and snowy roads excluded, standing water excluded | Icy and snowy roads excluded, standing water excluded |
| | Road works | No, ADF will re-route | Yes | Yes |
| | Toll stations | - | No | No |

*Table 2.2: Summarised description of mature parking ADF.*

| | | Mature parking ADF |
|---|---|---|
| Environment | | Anywhere (parallel and perpendicular parking manoeuvres)<br>Home zone PC covers larger distance (within yard) |
| Training needed for car (trajectory) | | Needed for home zone PC |
| Direction of parking | | All types of parking on private grounds included (home zone PC)<br>Parallel and perpendicular parking (public PC) |
| User location | | Inside or outside vehicle (home zone PC)<br>Inside vehicle (public PC) |
| Need for monitoring | | No (home zone PC)<br>Yes (public PC) |
| Presence of other vehicles and VRU | | Can be handled |
| Parking space markings | | Not needed (home zone)<br>Markings or other cars needed to mark the space (public PC) |
| Special conditions | Weather | Light rain ok |
| | Light | All conditions ok |
| | Surface condition | Ice and snow excluded |

# 3 General assessment principles

## 3.1 Assessment of scenarios

To ensure that all areas of analysis harmonize and built on each other, a common understanding is needed of the basic methodological principles chosen in L3Pilot. The following chapter describes these basic approach of how driving will be analysed and described the basic assessment principles that are common to all methods. These common definitions ensure that methods generalizing and upscaling the effects (e.g. in impact assessment and socio-economic assessment) can built on the results derived from T&T and U&A evaluations.

To capture the influence of ADF on driving behaviour and its potential effects on traffic safety, traffic efficiency, and the environment, comparable sections of driving with and without ADF need to be compared. In controlled experimental approaches, this comparability is achieved by experimental protocol through which moderating factors are controlled, and unwanted situational variance is minimised. In the on-road tests planned in L3Pilot, this approach is difficult because of uncontrollable variation in traffic density, other traffic participants, on-road situations in general, weather, and other influencing factors. Furthermore, there will be variations between pilot sites in the driving environment, driven distance etc.

To come to reliable results, control of moderating factors is planned by analysing the logged on-road data via the so-called “driving scenarios”. A driving scenario is a short period of driving defined by its main driving task (e.g. car following, lane change) or event (e.g. cut-in). A “driving situation” represents a single segment in time that is assigned to a certain driving scenario. Driving situations from within different driving scenarios differ fundamentally, whereas situations of the same driving scenarios are similar. Furthermore, for impact assessment “traffic scenarios” are used in addition to driving scenarios. These scenarios have a broader horizon than driving scenarios and cover a specific road section with certain traffic characteristics. Table 3.1 provides a summary of the definitions used for different scenario types.

*Table 3.1: Definition of the different types of scenarios used in L3Pilot.*

| | Definition |
|---|---|
| Driving scenario | Driving scenarios describe the development of a situation within a traffic context in which at least one actor performs a (pre-) defined action and or is influenced by a (predefined) event. The action or event is specified without the definition of concrete parameters. The influenced actor may either be the ego vehicle (e.g. performing a lane change or a minimum risk manoeuvre) or another traffic participant (e.g. a lane change in front of the ego vehicle). |
| Driving situation | A driving situation is a specific instance of a driving scenario (e.g. a lane change with defined parameters). Thus, a driving situation describes in detail a situation that can be simulated and analysed.<br>An example of a driving situation is a lane change at 60.8 km/h with a second vehicle driving at a distance of 10 m behind the ego vehicle in the adjacent lane and with a velocity of 65 km/h. |

| | Definition |
|---|---|
| Traffic scenario | Traffic scenarios describe a larger traffic context by covering a longer period of time and longer road sections with certain traffic characteristics. One traffic scenario may include different (not predefined) driving scenarios.<br>An example of a traffic scenario is a 3-lane motorway section of length 10 km with 2 motorway entrances and exits, a speed limit of 130 km/h, traffic volume of 4000 vehicles/h/direction, 10% of heavy vehicles and a time period of 1h. |

### 3.1.1 Driving scenarios

In L3Pilot, driving scenarios are the basic unit of analysis concerning driving behaviour. A list of pre-defined driving scenarios is created aiming to cover driving on motorways and in urban areas and avoiding duplications. Within these scenarios, the behaviour between baseline and treatment is compared. In the scope of the impact assessment, additional driving scenarios are considered, focussing on certain events which only happen during automated driving or transition phases.

Figure 3.1 shows exemplarily speed and time headway of one vehicle for a random section of motorway driving with examples of the associated driving scenarios “car following” and “free driving”. Both speed and time headway vary systematically between the driving scenarios of free driving and car following. This also implies that an analysis of, for example, speed alone would be difficult to interpret if it was merged across different driving scenarios.

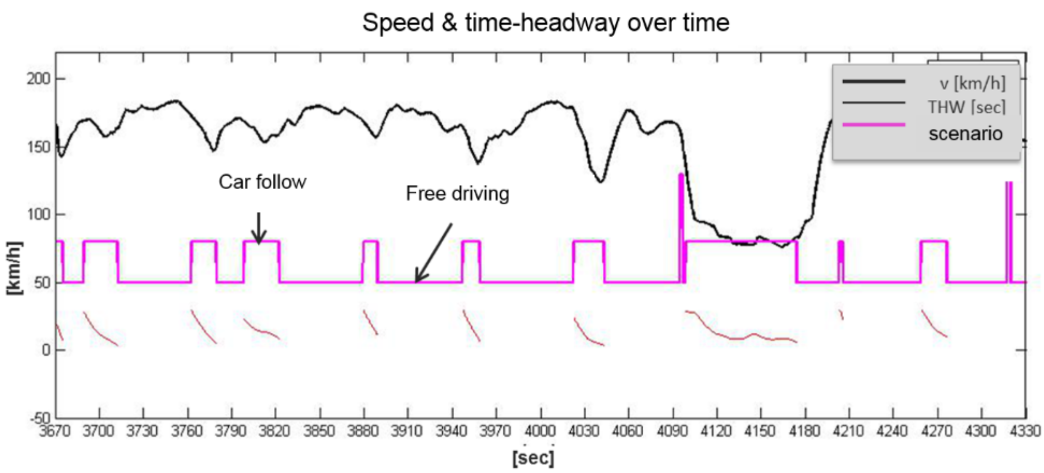



*Figure 3.1: Example of speed and time headway to lead vehicle in a section of motorway driving. Changes in both parameters are related to the driving scenarios car following & free driving.*

In T&T evaluation, all time-series data logged during the on-road tests are divided into driving situations, which all belong to one of the defined driving scenarios. Multiple driving situations of one driving scenario can occur within a single log of driving data (see Figure 3.2). Performance indicators (PIs) are defined for each driving scenario, and they describe driving behaviour in the scenario in a meaningful way. The PIs are calculated for every driving situation identified in the data. By comparing the values of the PIs in baseline and in treatment for all situations of a driving scenario, the impact of ADF on driving behaviour in the defined driving scenario is derived.

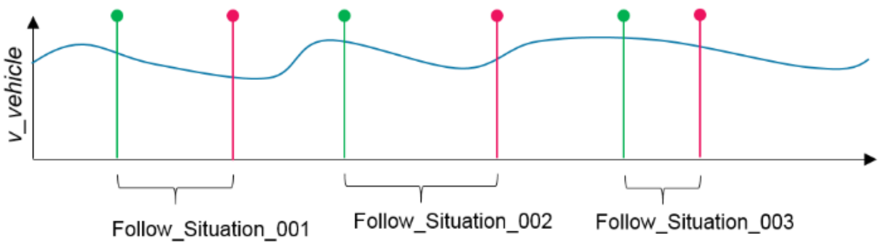



*Figure 3.2: Schematic example for multiple situations of a car following scenario over time.*

In safety impact assessment, each driving scenario will be linked to the relevant accident type(s). This supports the estimation of changes in traffic safety based on the observed changes in driving behaviour in the different driving scenarios.

Many research projects related to AD have applied a scenario-based analysis (e.g. Rösener, Hennecke, Sauerbier, Zlocki, Kemper, Eckstein, & Oeser, 2018; Metz, Landau, Hargutt, & Neukum, 2013; Hargutt, Landau, Metz, & Neukum, 2014). Therefore, these scenario catalogues have been considered for deriving the list of relevant driving scenarios in L3Pilot. A challenge within the definition of a comprehensible scenario catalogue is that it should be able to cover the entire trip of a vehicle during the test. However, driving scenarios should also be mutually exclusive. Since many concepts for deriving driving scenarios use different systematics, two scenario catalogues cannot directly merged.

A comprehensive list of scenarios for safety impact assessment has been derived in Rösener et al. (2018), which was used as a basis for the definition of the driving scenarios in L3Pilot. The scenario catalogue in Rösener et al. (2018) was developed for safety-relevant scenarios and thus only includes scenarios, from which safety-relevant interactions with other traffic participants may arise. In contrast, the T&T within L3Pilot will also consider typically uncritical driving scenarios. For example, in L3Pilot a distinction is made between the driving scenarios ‘approaching’ describing driving scenarios with a decreasing headway to the preceding vehicle, and the scenarios ‘following’ describing scenarios with a nearly constant headway to the preceding vehicle. The relevance of this distinction can be illustrated by the example of the derived measure time-to-collision (TTC), which is often used to measure the criticality of a driving situation. In the ‘approaching’ scenarios, the TTC will be defined and will be in a meaningful range. In the case of ‘following’ scenarios with an approximately constant headway between the two vehicles, the TTC will either be undefined or very high, therefore providing no meaningful description of the driving scenario.

In single-lane traffic, the time headway (THW) to the preceding vehicle is the most relevant parameter to distinguish driving scenarios. For those cases, the lead vehicle is the only relevant traffic participant in addition to the ego vehicle. In case of several lanes in one direction, vehicles in adjacent lanes that might change lanes in front of the ego vehicle are also relevant. This can lead to the driving scenario ‘cut-in’. Interaction with vehicles behind the ego vehicle is not treated as distinct driving scenarios. However, safety-critical interactions are considered as incidents (see Chapter 4.6).

For lane changes made by the ego vehicle, the gap on the target lane and also the subsequent vehicle on the target lane are of relevance. Thus, for the driving scenario “lane change” four sub-categories were defined:

1. After lane change, no preceding and no subsequent vehicles
2. After lane change, preceding vehicle but no subsequent vehicle
3. After lane change, no preceding vehicle but subsequent vehicle
4. After lane change, preceding and subsequent vehicles

Furthermore, a distinction between lane changes to the left and the right is made.

For intersections, Rösener et al. (2018) define the scenarios turning, crossing, and U-turn. In order to further refine the scenarios for the urban use cases, an analogous distinction to the motorway scenarios was made regarding whether the ego vehicle has to consider no object, a leading vehicle (moving object), a laterally moving object or a static object through its way through the intersection. The driving scenarios *crossing with laterally moving object, turning with laterally moving object* and *U-turn with laterally moving object* cover all possible conflicts with objects that are currently not in the path of the ego-vehicle but will enter a conflict zone common with the ego vehicle. Archer (2005) defines a conflict zone to be a “common area used by road-users/vehicles approaching from different trajectories”. This abstract definition of laterally moving objects comprises vehicles moving perpendicular directions at a junction, oncoming vehicles during a left turn as well as crossing pedestrians. In summary, the following list of driving scenarios was compiled (Table 3.2):

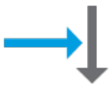
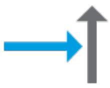
*Table 3.2: List of driving scenarios considered in L3Pilot.*

| Scenario | Definition |
|---|---|
| Free driving | The ego vehicle is following its path without being influenced by objects located in or moving into its path. |
| Approaching a static object | The ego vehicle is approaching a static object located in its path. |
| Approaching a lead object | The ego vehicle is approaching an object located in its path, traveling at a lower speed. |
| Approaching a laterally moving object | The ego vehicle is approaching a conflict zone, which it has in common with another object travelling laterally towards the path of the ego vehicle. |
| Approaching a traffic jam | The ego vehicle is approaching a queue of vehicles in its lane travelling at a low speed. |
| Following a lead object | The ego vehicle is following a lead object. |
| Driving in a traffic jam | The ego vehicle is following a queue of vehicles travelling at a low speed. |
| Lane change | The ego vehicle changes to another lane. |

| Scenario | Definition |
|---|---|
| Cut-in | An object changes (or initiates a lane change) to the lane of the ego vehicle such that the resulting scenario is following or approaching a lead object. |
| Follow obligation to drive on the right/left | The ego vehicle is influenced by an object on the left/right lane of the ego vehicle because passing the object would pose a violation of the obligation to drive on the right/left. |
| Entry | The ego vehicle enters a motorway. |
| Exit | The ego vehicle exits a motorway. |
| Crossing (without conflict) | The ego vehicle is travelling across an intersection without being influenced by another object. |
| Crossing with static object | The ego vehicle is travelling across an intersection with a static object located in its desired path. |
| Crossing with lead object | The ego vehicle is travelling across an intersection while being influenced by a lead object. |
| Crossing with laterally moving object | The ego vehicle is travelling across an intersection approaching a conflict zone, which it has in common with another object travelling laterally towards the path of the ego vehicle. |
| Turning (without conflict) | The ego vehicle is turning at an intersection without being influenced by another object. |
| Turning with static object | The ego vehicle is turning at an intersection with a static object located in its desired path. |
| Turning with lead object | The ego vehicle is turning at an intersection while being influenced by a lead object. |
| Turning with laterally moving object | The ego vehicle is turning at an intersection approaching a conflict zone, which it has in common with another object travelling laterally towards the path of the ego vehicle. |
| U-Turn (without conflict) | The ego vehicle is executing a U-turn at an intersection without being influenced by another object. |
| U-Turn with static object | The ego vehicle is executing a U-turn at an intersection with a static object located in its desired path. |
| U-Turn with laterally moving object | The ego vehicle is executing a U-turn at an intersection, thereby approaching a conflict zone, which it has in common with another object travelling laterally towards the path of the ego vehicle. |
| Overtaking of oncoming traffic (passive) | The ego vehicle is following its lane while a vehicle from the oncoming lane changes into the lane of the ego vehicle with the intention to change back to its initial lane. |
| Overtaking on oncoming lane (active) | The ego vehicle changes into the lane of the oncoming traffic, overtakes some obstacle and changes back to its own lane. |

To further distinguish situations at intersections, subordinate driving scenarios are defined depending on the conflict with other road users (see Table 3.3). The definitions of the possible conflicts are defined based on the possible accident types in NHTSA (2015). Furthermore, cars, trucks, motorcycles, bicycles and pedestrians are differentiated as different types of objects with which conflicts could occur.

*Table 3.3: Conflict types at intersections.*

| **Conflicts at intersections** | |
|---|---|
| (Active) turn across path initial opposite direction |  |
| Passive turn across path initial opposite direction |  |
| (Active) turn into same direction |  |
| Passive turn into same direction |  |
| (Active) turn into opposite direction |  |
| Passive turn into opposite direction |  |
| (Active) turn across path initial same directions |  |
| Passive turn across path initial same directions |  |
| Intersecting paths with object from left |  |
| Intersecting paths with object from right |  |

A further distinction is made based on traffic control at intersections. Different types of traffic light phases were defined by Perdomo Lopez, Waldmann, Joerdens, & Rojas (2017). For L3Pilot, signs are categorised in *right of way*, *yield* and *stop*. Finally, unsignalised intersections are considered, which define priority for vehicles coming from the right (see Table 3.4).

*Table 3.4: Types of traffic control considered in intersection scenarios.*

| Traffic control | |
|---|---|
| None (uncontrolled) | |
| Sign | Right of way (priority) |
| | Yield (give way) |
| | Stop |
| Traffic light | Denied (red) |
| | Protected |
| | Permitted |
| | Permitted on red |

### 3.1.2 Traffic scenarios

Traffic scenarios are relevant for traffic safety, traffic efficiency, and environmental impact assessment. These scenarios have a wider focus than driving scenarios and cover a certain road section with certain traffic characteristics. Within a traffic scenario, several driving scenarios can occur in different combinations. These are not predefined but a result of the behaviour of the traffic participants within the traffic scenario.

The traffic scenarios consider both road infrastructure characteristics, such as number of lanes, speed limits, frequency of motorway entrances and exits, and traffic characteristics. Apart from the infrastructure properties, relevant parameters to define a traffic scenario are the penetration rate of the ADF as well as fleet composition and traffic volume. The traffic scenarios to be used will be defined in the work on impact assessment as part of SP7-Evaluation. The objective is to define the traffic scenarios in a way that they cover a large proportion of the characteristics of European roads. Examples for traffic scenarios to be analysed in impact assessment include a section of a three-lane motorway with a speed limit of 120 km/h and high traffic density or a small urban network consisting of intersections with and without traffic lights and little traffic.

## 3.2 Baseline and treatment

### 3.2.1 Overview

For evaluation purposes, a comparison of the situation before the introduction of the ADF in focus (in the following called *baseline*) with the situation after their introduction (called *treatment*) is required. In other words, to assess the potential effects of ADF, driving with the investigated ADF is compared to reference driving behaviour in order to derive how the ADF change driving behaviour, traffic safety, traffic efficiency, etc. Therefore, not only driving with the ADFs (treatment) needs to be described; the baseline needs to be defined as well, which describes driving without the respective ADF.

In theory, there are several options of how a baseline scenario could be defined: It could be based on (1) *pure manual driving*, which represents the majority of vehicles today. However, in today's traffic, some vehicles are equipped with ADAS. For the ADAS systems a distinction has to be made between functions that are active for a considerable time span (e.g. adaptive cruise control, ACC) and thus can be classified using the SAE automation levels (SAE, 2018), and active safety functions, such as forward collision warning (FCW) or autonomous emergency braking (AEB), which are only active in safety-critical events. These active safety functions are out of the scope of the SAE automation levels (SAE L0). Nevertheless, they arguably have a substantial impact e.g. on traffic safety. Both types of ADAS are already available in today's vehicles and could therefore be part of a baseline scenario, either taking (2) only the active safety functions (assuming otherwise *SAE L0* vehicle) or taking (3) also the continuous systems like ACC to the baseline according to the penetration rates in today's situation (*SAE L0-1*). Furthermore, in the areas of impact and socio-economic impact assessment, it is also possible that not today's situation is used for comparison but an estimate of the (4) *future ADAS situation* without the ADF. This would mean that, for instance, already available ADAS would be part of the baseline scenario but with estimated future penetration rates. Table 3.5 summarises the alternative options for the baseline.

*Table 3.5: Options for defining the baseline.*

| | Pure manual driving | SAE L0 | Today's situation | Future ADAS situation |
|---|---|---|---|---|
| ADAS | None | Active safety systems with today's penetration rates<br>No continuous systems (SAE L1-2, e.g. ACC) | ADAS distribution as today, including continuous systems | ADAS distribution with expected penetration in future, e.g. in 5 years (including ACC) |
| Pro | Quite simple and straightforward | Compromise between effort and accuracy | Most realistic scenario<br>Matches best with the transport related statistics | Relevant for future scenarios |
| Contra | It does not represent today's situation → theoretic scenario | Active safety needs to be defined<br>Difference to purely manual driving mainly in critical driving situations | ADAS need to be defined and data collected for all the ADAS.<br>Impacts need to be assessed also outside ODD of the ADF | Requires assumptions and/or data collection for all the systems in the assumed future situation<br>Requires assessment of the impacts also for the baseline situation for all impact areas<br>High uncertainties |

In L3Pilot, the baseline will be used make an *approximation of the traffic today* (alternatives 1–3 in Table 3.5) as the requirements for the use of future ADAS baseline would be beyond our possibilities and it is more reliable to base the assessment on existing statistics and not to increase the uncertainty by also attempting to predict the future baseline situation.

In practice, the relevance of different systems and the feasibility of making the assessment leads to slightly different baseline definitions for each impact area. Therefore, depending on the area of analysis within L3Pilot, the baseline to be used varies. A summary is given in Table 3.6, followed by an explanation of the decisions, per area.

*Table 3.6. Overview of baseline and treatment used in the different areas of evaluation.*

| Evaluation area | Baseline | Treatment |
|---|---|---|
| Technical and traffic | SAE L0 (in ODD) | SAE L3/L4 (in ODD) |
| User and acceptance | Current situation (users' own car) | SAE L3 |
| Impact assessment - safety | Manual driving<br>SAE0 with active safety system AEB (incl. FCW) | Variation of penetration rate of SAE L3 (in ODD) and active safety systems (everywhere)<br>Penetration rates: 5%, 10%, 30% & 100% |
| Impact assessment - efficiency and environment | Manual driving (in ODD) | Variation of SAE L3 penetration rate (in ODD), equal to the ones in safety impact assessment |
| Socio-economic assessment | Today's situations<br>(Latest statistics) | Variation of SAE L3 penetration rate (in ODD), equal to the ones in safety impact assessment |

### 3.2.2 Technical and traffic evaluation

For T&T evaluation, neither baseline nor treatment can be freely defined. Since the analysis is directly based on data logged during the on-road tests, baseline and treatment are set by the cars used in the tests. For all on-road tests, treatment refers to the specific L3/L4 ADF used in the on-road tests. At most pilot sites, baseline data is logged actively as a separate experimental condition during the pilot tests.

To reduce the complexity of the analysis and the experimental protocol, manual driving will be logged as a baseline and to compare driving with the ADF to that data. As the vehicles used in the pilots will be fitted with active safety systems, the baseline data logged in the pilot tests and analysed for T&T corresponds to SAE L0 (see Table 3.5).

### 3.2.3 User and acceptance evaluation

For U&A evaluation, treatment conditions are the same as for T&T evaluation because the evaluation will assess drivers' opinions on ADFs tested in the on-road tests. For questionnaires, no separate baseline data will be collected as part of the experimental protocol. Instead, questionnaire items are phrased such that the comparison to today's driving incorporated into the question. For

RQs to be answered using video coding, the same baseline conditions as for technical and traffic evaluation are used. Therefore, for U&A evaluation, the baseline is not defined explicitly within L3Pilot but mostly through test participant sample selection. Depending on the type of vehicles used by the participants during their daily driving, the within-subject baseline in U&A evaluation can either be pure manual driving in case of a vehicle without active safety systems, SAE L0 for vehicles with active safety systems but without continuous ADAS, or a higher SAE level already available on the market. The systems available in everyday vehicles of the sample are asked for in the questionnaire. This allows describing and classifying the baseline used for U&A evaluation afterwards, but it is not actively varied within L3Pilot.

### 3.2.4 Impact Assessment

Two baseline scenarios will be used in impact assessment: pure manual driving (i.e. without any ADAS) and SAE L0. The system AEB, including FCW will be included as ADAS in the SAE L0 scenario. To model realistic baseline scenarios, penetration rates of the considered ADAS need to be defined based on available statistics. The starting point is an estimate of the penetration rates of ADAS in today's fleet in Europe (see Table 3.7 and Table 3.8). The final values will be set by SP7-Evaluation during the process of implementing the simulations. For the simulations, not the penetration rate of ADAS in today's fleet is relevant and needs to be set, but the usage rate in daily traffic.

To estimate the current (2017) vehicle stock penetration in EU28, three main sources were used: Eurostat statistics on the vehicle stock and new passenger car registrations (overview presented in Table 3.7), Öörni (2016) estimated on the EU28 penetration rates in 2015, and Frost & Sullivan (2018) estimate on the share of newly sold vehicles equipped with different systems in Western Europe (AT, BE, CH, DE, DK, ES, FI, FR, GR, IE, IT, LU, NL, NO, PT, SE and UK) in 2017. The process to calculate the estimated penetration rates was the following:

1. Calculate the number of equipped vehicles in 2015.
2. Calculate the number of equipped newly registered vehicles in 2016 and 2017.
3. Calculate the number of equipped vehicles in 2016 (sum of the number of equipped vehicles in 2015 and the number of equipped newly registered vehicles in 2016) and 2017 (sum of the number of equipped vehicles in 2016 and the number of equipped newly registered vehicles in 2017)
4. Calculate the equipped share of vehicle stock in 2016 and 2017 (share of the number of equipped vehicles from total vehicle stock in the respective year)

The following assumptions were made for the estimation:

- All newly registered passenger vehicles are new passenger vehicles
- There is no retrofitting of the systems
- Frost & Sullivan's estimate for Western Europe can be transferred to EU28
- Frost & Sullivan's estimate for 2017 can be applied to 2016 by linear backwards forecasting

*Table 3.7: Total vehicle stock and number of new passenger car registrations in EU28 during 015–2017 (Eurostat, 2018). Number of vehicles need to be multiplied x1000.*

| | Year | | |
|---|---|---|---|
| | 2015 | 2016 | 2017 |
| Total vehicle stock in EU28[1] | 253 721 | 258 122 | 261 697 |
| New registrations of passenger cars in EU28[2] | 15 432 | 16 696 | 17 297 |

[1]RO missing data for 2016–2017 - substituted with 2015 data; IT missing data for 2017 - substituted with 2016 data
[2]RO missing data for 2016 - substituted with 2015 and 2017 average

*Table 3.8. Estimation of ADAS penetration rates in EU28 in 2017. Number of vehicles need to be multiplied x1000.*

| | Year | AEB | FCW |
|---|---|---|---|
| Equipped share of vehicles (Öörni 2016) | 2015 | 1% | 1%[1] |
| Number of equipped vehicles | 2015 | 2537 | 2537 |
| Equipped share of new passenger vehicles sold in western Europe[2] (Frost&Sullivan, 2018) | 2017 | 49% | 50% |
| Equipped share of new passenger vehicles sold in western Europe[3] (backwards linear forecast of 2017) | 2016 | 48% | 48% |
| Number of equipped newly registered vehicles | 2016 | 8014 | 8014 |
| | 2017 | 8476 | 8649 |
| Number of equipped vehicles | 2016[4] | 10718 | 10885 |
| | 2017[5] | 19194 | 19534 |
| Equipped share of vehicle stock | 2016[6] | 4.20% | 4.20% |
| | 2017[7] | 7.30% | 7.30% |

[1]Used definition: obstacle warning (incl. ACC&FCW) and penetration rate: 1–5%. Lower bound was chosen since the share for ACC was larger than FCW in all countries in 2015's iCar - implementation status survey by use of OEM data (2015)
[2]AT, BE, CH, DE, DK, ES, FI, FR, GR, IE, IT, LU, NL, NO, PT, SE and UK
[3]AT, BE, CH, DE, DK, ES, FI, FR, GR, IE, IT, LU, NL, NO, PT, SE and UK
[4]Sum of number of equipped vehicles in 2015 and number of equipped newly registered vehicles in 2016
[5]Sum of number of equipped vehicles in 2015, number of equipped newly registered vehicles in 2016 and number of equipped newly registered vehicles in 2017
[6]Share of number of equipped vehicles in 2016 from total vehicle stock in 2016
[7]Share of number of equipped vehicles in 2017 from total vehicle stock in 2017

The treatment covers driving with the ADF in use. As explained above (Chapter 2.2), mature function descriptions have been defined as a basis for impact assessment. The mature function descriptions were developed together with OEMs in several workshops. The first objective was to find a high-level verbal description; specific parameters needed for simulations will be agreed later within the impact assessment work.

Because ADFs are not available on the market yet, penetration rates for the simulations cannot be based on available statistics but need to be set based on theoretical considerations. The impact of ADF will not only be estimated for one penetration rate value; instead, the penetration rate will be varied to gain insight into the potential benefits of the functions at different levels of use. Penetration rates of 5%, 10%, 30% and 100% will be used. The aim is to cover the range between more realistic rates such as 5% equipped vehicles in the not too far future and the maximum possible impact with 100% of equipped vehicles.

It is expected that vehicles equipped with ADF will also be equipped with a full set of active safety functions. This assumption is made based on the fact that the automated vehicles have an increased sensor setup, which can facilitate the operation of such systems. The direct consequence is that for the treatment simulation, not only the penetration rate of the ADF changes but also the penetration rate of the ADAS. The exact penetration rates for ADAS in the treatment condition will be defined by SP7-Evaluation.

#### 3.2.5 Socio-economic assessment

For socio-economic assessment, a “snapshot” of the world today is used as the basis for analysis. The baseline scenario is the world of today, which is without the technology in question (mature ADFs). Alternative scenarios (treatment) then show how the world of today would look like if a certain proportion of current vehicles were replaced with vehicles having the ADF in use within ODD. In this way, it is possible to assess the pure impacts of implementing ADF technology in estimating what would change concerning traffic safety, traffic efficiency, and the environment if different fractions of the vehicles were replaced with vehicles equipped with ADFs. The penetration rates used for socio-economic assessment will be the same as for impact assessment: 5%, 10%, 30% and 100% of passenger cars having ADF in use (see section 8.1.4).

## 3.3 Merging of data across pilot sites

The methods for T&T and U&A evaluation will first be implemented per pilot site. For evaluation of the investigated ADF, the results will be merged and aggregated over pilot sites. From a theoretical point of view, the on-road tests logged and analysed at the different pilot sites can be treated as separate studies; then the process of data merging resembles the work done in a meta-analysis. According to Field & Gillett (2010), a “Meta-analysis is a statistical tool for estimating the mean and variance of underlying population effects from a collection of empirical studies addressing ostensibly the same research question.”

In theories on meta-analytical methods two approaches are differentiated.

- The classic approach is based on work by Glass (1976). “Since Glass (1976) coined the term “meta-analysis,”[..] these developments have centred on aggregated data meta-analysis, using summary statistics from primary studies to compute an effect size that is combined across studies.” (Piegott, 2012 p.109).

- The second approach is a meta-analysis that uses individual participant data (IPD). According to Simmonds & Higgins (2007) this can be considered to be the gold standard. It is mainly used in the field of medical research there often not only the publication of aggregated study results but also of single trial data is recommended.

Coining the two approaches to the process of data analysis planed in L3Pilot the two options shown in Figure 3.3 can be differentiated. For option 1, performance indicators (PI) are derived at the different pilot sites and then combined in a common database. That database is then used for statistical testing. This process is in theory comparable to a meta-analysis using IPD. For the second options, statistical testing is done separately at each pilot site for its own data. Then, results from statistical testing and aggregated PIs (e.g. means and standard deviation for PIs) are taken from every pilot site and are aggregated. This process resembles the classical approach for a meta-analysis.

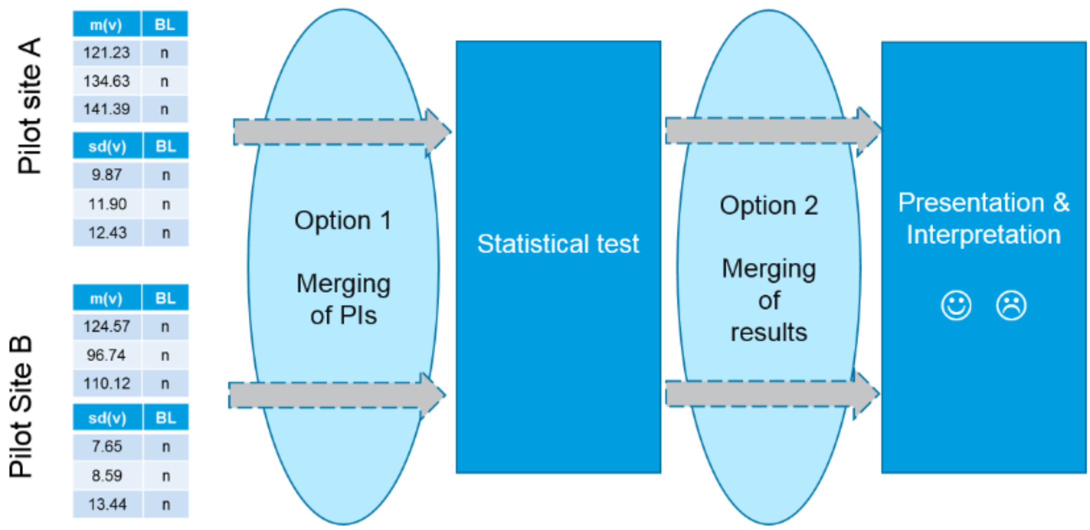



*Figure 3.3: Options for merging of data across pilot sites.*

Because the methods on how to derive PIs are harmonized within L3Pilot, there is an advantage compared to meta-analyses done based on publications: For most research questions and PIs, it is not necessary to use standardized values because it is ensured by the common methodology that aggregation of unstandardized calculated indicators (e.g. mean speed, rated acceptance) across pilot sites will be feasible.

Besides scientific aspects that need to be considered for defining the appropriate method for merging of data, there are also other relevant factors that influence this decision within L3Pilot:

- To avoid that benchmarking could be feasible within L3Pilot, the results need to be presented in a way that the different pilot sites (vehicle owners) cannot be identified.

- The pilot site or other factors that allow identifying single pilot sites (e.g. country of origin) cannot be used as moderating factors.
- Furthermore, for some PIs special requirements of confidentiality might apply that restrict sharing information on a disaggregated level within the project.

From a scientific point of view, it is recommended to use option 1 - merging of PIs across pilot sites wherever feasible. To be feasible, it has to be ensured during the analysis or by the used methodology that the PIs coming from the different pilot sites are similar enough to be taken together without using the pilot site as a moderating factor. This requires that it is possible to create PIs through the commonly used methodology that is comparable enough between different pilot sites to be taken together and analysed as one test.

In U&A evaluation, this comparability is mainly achieved by using a common L3Pilot questionnaire at all pilot sites. The answers given by participants can be combined per questionnaire item and analysed in one step for the whole L3Pilot sample per ADF type. Therefore, based on current knowledge, it is recommended for U&A evaluation to use option 1 for all ADF types.

For T&T evaluation the picture is different. Here, the analysis should confirm that PIs (derived from time-series data logged in the vehicles) are comparable between pilot sites. Through the scenario-based approach chosen for motorway, traffic jam and urban ADF, the defined methodology will allow comparable PIs to be derived. Therefore, here option 1 – "merging of PIs" is recommended also for T&T evaluation. For the parking ADF, it is expected that PIs will differ between pilot sites although there is a common approach for data analysis. This is mainly because the setup of the parking manoeuvres tested at the different pilot sites will vary due to different ADF implementations. Manoeuvre types (e.g. parallel or perpendicular parking) are expected to have a large impact on PIs. Consequently, option 2 – "merging of results" is currently recommend for T&T evaluation of the parking ADF.

*Table 3.9: Options for data merging recommended for the different parts of analysis.*

| ADF Type | Process of data merging | |
|---|---|---|
| | Technical and traffic evaluation | User and acceptance evaluation |
| Traffic jam ADFr | Option 1 - merging of PIs | Option 1 - merging of PIs |
| Motorway ADF | Option 1 - merging of PIs | Option 1 - merging of PIs |
| Urban ADF | Option 1 - merging of PIs | Option 1 - merging of PIs |
| Parking ADF | Option 2 - merging of results | Option 1 - merging of PIs |

The final decision for the different options will be taken later in the project by SP7 (Evaluation) based on the data available from the different pilot sites. Presumably, the final decision will not be taken for the different parts of analysis (as done in Table 3.9) but on the level of single PIs. This will be done in a way that scientifically meaningful results can be achieved while maintaining the confidentiality of individual pilot sites and ADF implementations.

# 4 Methods for technical and traffic evaluation

## 4.1 Overall concept of technical and traffic evaluation

This section introduces the methods for Technical and Traffic evaluation (T&T), addressing the following areas:

- What is the ADF's technical performance?
- What is the impact on the driving behaviour of the ADF vehicle?
- What is the impact of ADF on the interaction with other road users?
- What is the impact of ADF on the behaviour of other traffic participants?

All high level RQs are split down into more precise RQs on a lower level (see Annex 1). The low level RQs for T&T evaluation can be grouped based on their content. The different contents are directly linked to different approaches for T&T evaluation. A distinction can be made between:

- RQs dealing with the behaviour of the ADF while driving undisturbed within its ODD, this section dealing with processes / actions at the end of ODD, and
- RQs dealing with changes in frequency and severity of potentially critical situations.

Due to the prototype nature of the ADF, the vehicles fitted with ADFs are either driven by professional drivers who are specially trained in using and supervising the ADF or – in case of drivers without specialised knowledge are on the driver's seat - there is a safety driver on the passenger's seat who supervises the ADF and intervenes whenever necessary. Both approaches aim to guarantee safety throughout all test drives, but they make a quantitative analysis of critical situations (as well as potential system failures or system errors) hardly possible. Therefore, the original research questions dealing with unplanned take-over requests and traffic violations are considered to be not answerable within T&T evaluation in L3Pilot, RQs on planned take-over requests and incidents are kept. The list with RQs that are panned to be answered with T&T evaluation can be found in Annex 1.

Fundamentally different approaches are chosen for analysing motorway / urban ADFs on the one hand, and parking ADFs on the other hand. Continuously operating ADFs, such as motorway or urban functions, are assessed with a driving scenario-based approach (Rösener, 2016) using driving data logged in treatment and in baseline condition (see chapter 3.1.1). The approach different for parking ADFs, which will be assessed with a use-case based approach.

## 4.2 Input for technical and traffic evaluation

For the T&T evaluation, the data logged in a single vehicle (CAN-data, videos) is analysed stepwise. The evaluation workflow is illustrated in Figure 4.1.

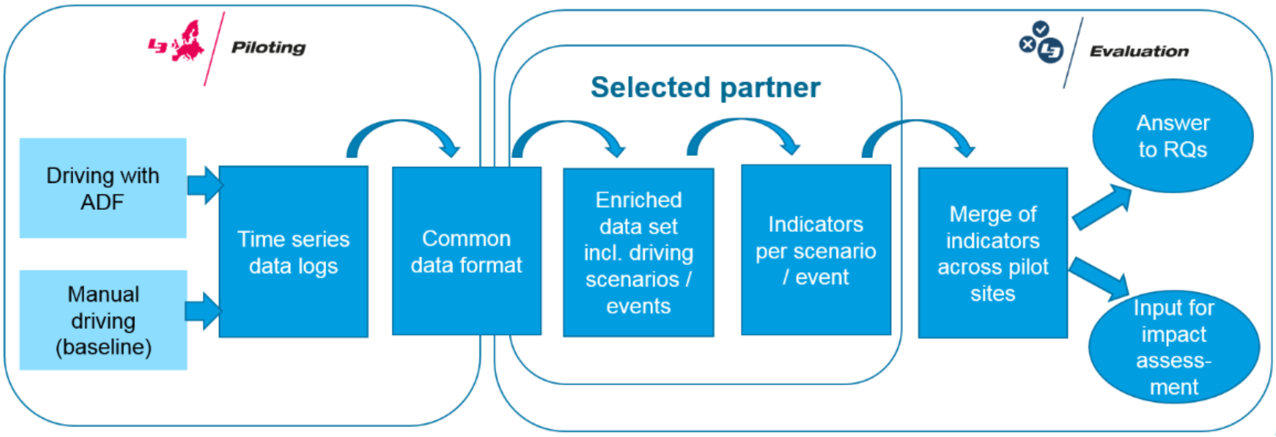



*Figure 4.1: The overall workflow for technical and traffic evaluation in L3Pilot.*

The starting point for analyses will be time-series data coming mostly directly from the tested vehicles. Signals (e.g. velocity, distance to lead vehicle) needed for analysis of vehicle data are described in D3.1 (Hibberd et al., 2018) and D5.1 (Nagy et al., 2018). For baseline and treatment data, data processing starts with data enrichment. In this step, logged signals are pre-processed (e.g. filtered) and derived measures are computed. For derived measures, logged signals are combined, and new signals are created (e.g. velocity and distance to lead objects are used to calculated time headway). The analysis described here starts at the point where data from individual test runs have been converted into the common data format including all derived measures (see D5.1, Nagy et al., 2018) and after signal pre-processing including interpolation, filtering, or correction of sensor errors is completed. The pre-processing is part of the work done individually for the different datasets at the pilot sites, and, therefore, it is not part of the common methodology described in this deliverable. The RQs and hypotheses will be answered based on the PIs that are defined for each driving scenario. The PIs are chosen such that they reflect relevant aspects of driving in the scenario. An example of a PI is the mean speed during free driving or mean time headway while following a lead object.

For analysing the potential impacts of the ADFs on areas such as the environment or traffic safety, impact assessment is carried out (see chapter 6). It aims to predict the effectiveness or utility of the mature ADF on a broader scale than which can be achieved in a single pilot of the size used in L3Pilot. In order to perform the calculations needed for impact assessment, input from the data logged in the on-road tests is needed. The data from the prototype vehicles will be merged across all pilot sites to create the input needed for impact assessment. For more details, see chapter 4.7.

The main sources of data for T&T evaluation are in road tests conducted at the different pilot sites. Neither studies in a driving simulator nor Wizard Of Oz-studies will contribute to technical and traffic evaluation.

For the urban environment, the data logged in the vehicles will be supplemented with data collected by means of the Application Platform for Intelligent Mobility (AIM) Mobile Units. This method allows measuring detailed information on surrounding traffic (e.g. other vehicles but also bicyclists, pedestrians) at selected locations. The AIM Mobile Units are part of the Application Platform for Intelligent Mobility (AIM) of the German Aerospace Center in Braunschweig, Germany. AIM serves as a platform for application-oriented science, research, and development. The system comprises a total of three masts. Each installation consists of a pole holding a sensor head and different antennas. Each mast is also equipped with a weather-proof cabinet containing the different processing computers as well as several electric and electronic devices. Each pole installation is based on a transportable concrete foundation (Figure 4.2). The field of vision of the associated sensors can be fused for better performance and a wider field of detection (e.g. detecting all traffic participants approaching, entering, and exiting a traffic circle). The poles can be remotely accessed due to an LTE connection. All poles are equipped with stereo-camera systems and an active infrared lighting system for artificial scene illumination. Therefore, traffic detection is also possible during nighttime and in adverse weather conditions.

Generally, the sensor data are fused and processed in order to produce the main output: trajectories of the detected traffic participants. These trajectories contain information about the classification and dimensions of the object as well as its location, velocity, and other dynamic state variables. The trajectories are tracked and stored at a rate of 25 Hz. They are automatically stored in a database for offline analysis purposes with the respective scene videos for manual assessment and validation.

*Figure 4.2: AIM Mobile Unit and sensor head.*

With the AIM traffic acquisition platform motorized as well as non-motorized road users are detected, tracked, and classified as, for example, cars, trucks, railways and pedestrians, and cyclists. The related video and numerical trajectory data are used for research purposes (e.g. analysing the behaviour of an AV manoeuvring through a roundabout and interacting with other motorised and non-motorised traffic participants). Based on the virtual image of the traffic flow, it is possible to calculate surrogate safety measures (e.g. PET or TTC) or aggregated information such as traffic volume. Specific events, such as critical situations between an AV and other traffic participants can be analysed, and effects on road traffic safety derived.

## 4.3 Parking ADF: Evaluation of driving within ODD

The technical and traffic evaluation of parking ADFs in L3Pilot is expected to be limited to home zone parking. For most of the tested parking functions, the vehicle is taught a trajectory (e.g. from the entrance of premises to the final parking spot). After the learning phase, the vehicle is capable of driving along the pre-learned trajectory and park in the spot at the end of its route. During this manoeuvre, the driver can be either inside or outside the vehicle. Because the type, length, and complexity of the AV’s path to a parking spot and the performed parking manoeuvres will differ between implementations of the ADF and different test runs, the T&T analysis for parking will be based on single parking manoeuvres. It is required that for every type of tested manoeuvre, a comparable baseline with manual driving will be logged. For parking ADFs, comparability between ADF data and baseline will be ensured by experimental protocol, not by the analysis.

Depending on the type and length of the manoeuvre supported by the ADF, either the full ODD can be analysed in one step for T&T analysis, or the ODD can be split into the parts ‘approach to parking spot’ and ‘parking manoeuvre’. In the case of complex parking manoeuvres (e.g. parallel parking into small parking spaces), the manoeuvre can be divided into separate parking attempts. In summary, if needed parking can be divided into the parts listed in Table 4.1 and shown in Figure 4.3.

In case take-over requests or emergency manoeuvres are part of the functionality and occur during the test, their frequency can be analysed as well.

*Table 4.1: Definition of different sections of a parking manoeuvre.*

| Parts of parking manoeuvre | Description |
|---|---|
| Entire ODD | One whole driving sequence that is supported by the ADF. If applicable, it can be divided into an approach to a parking spot and parking manoeuvre. |
| Approach to parking spot | Path between the starting point of the ODD and a place very close to the final parking spot. Depending on the ADF and tested manoeuvre, this part can be rather lengthy (e.g. driveway of several 100 m) or non-existent (activation of ADF in front of garage). |
| Parking manoeuvre | The vehicle is steered/moved into its final parking position. This can be done in one attempt for simple manoeuvres or in multiple attempts for more complex manoeuvres. |
| Parking attempt | One movement during a parking manoeuvre. Normally separated by a change of driving direction (forward vs. backward). |

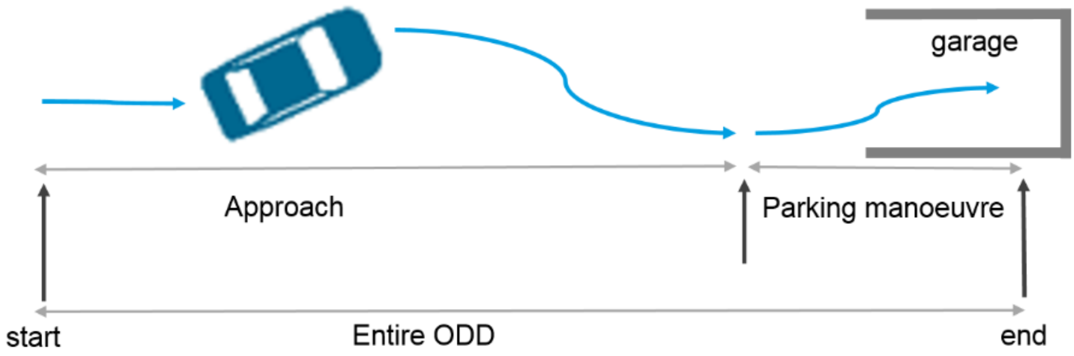



*Figure 4.3: Division of parking into parts for T&T evaluation.*

## 4.4 Motorway and urban ADF: Analysis of driving within ODD

To analyse the impact of ADF on driving within ODD, driving scenarios are identified in the data with the ADF active and during baseline driving (driving scenarios, see chapter 3.1.1). Then, indicators describing the behaviour under investigation (e.g. average speed or headway) are calculated individually for all identified driving situations (calculation of PIs).

The defined driving scenarios serve to structure the evaluation process, and certain PIs are only applicable for certain driving scenarios. It is thus necessary to determine which PIs need to be evaluated for which driving scenarios. Some PIs need to be evaluated over the entire ODD of the functions such as the frequency of take-over requests.

Table 4.2 shows the assignment of PIs to driving scenarios. These PIs are valid for motorway and traffic jam functions. For urban functions, these cover the driving scenarios in the ODD where the vehicle is not travelling through intersections.

*Table 4.2: Link between driving scenarios and performance indicators.*

| Performance Indicators | Entire ODD | Scenarios: Free driving | Scenarios: Following a lead object, Driving in Traffic Jam | Scenarios: Approaching: Lead object, Static object | Scenarios: Approaching: Traffic jam | Scenarios: Lane Change | Scenarios: Merge | Scenarios: Cut-In | Events: TOR: Planned |
|---|---|---|---|---|---|---|---|---|---|
| Proportion of time ADF available, Duration of sections with ADF available | X | | | | | | | | |
| Frequency of planned TORs, Number of planned TORs by number of all TORs | | | | | | | | | X |
| Minimum long. accel., Maximum long. accel., Standard deviation of long. accel. | | X | X | X | X | | | X | |
| Maximum absolute lat. accel., Standard deviation of lat. accel. | | X | X | | | X | X | | |
| Mean velocity,<br>Max velocity,<br>Standard deviation of velocity,<br>*for Traffic Jam and Urban ADFs:*<br>Frequency of events with slower velocity than 0.2 km/h,<br>Mean duration of events with velocity slower than 0.2 km/h | X | X | X | | | | | | |
| Standard deviation of position in lane,<br>Mean position in lane | | X | X | X | X | | | | |
| Mean energy consumption per 100 km | X | | | | | | | | |
| Frequency of harsh brakings | X | | | | | | | | |
| Frequency of manoeuvres, Proportion of time in driving scenario by time in ODD | | | X | | | X | X | | |
| Frequency Cut-Ins | | | | | | | | X | |

| Performance Indicators | | Scenarios | | | | | | | Events |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Approaching | | | | | TOR |
| | Entire ODD | Free driving | Following a lead object, Driving in Traffic Jam | Lead object, Static object | Traffic jam | Lane Change | Merge | Cut-In | Planned |
| Mean time headway,<br>Standard deviation of time headway,<br>Minimum time headway,<br>Minimum time-to-collision,<br>*For Traffic Jam Assist:*<br>Mean long. distance to lead vehicle,<br>Standard deviation of distance to lead vehicle | | | X | X | | | | | |
| Frequency of lane changes by lead vehicle,<br>Mean velocity of lead vehicle,<br>Standard deviation of velocity of lead vehicle | | | X | X | | | | X | |
| Mean time headway of rear vehicle, Standard deviation of time headway of rear vehicle,<br>Minimum time headway of rear vehicle,<br>Minimum long. accel of rear vehicle | | X | X | | | | X | | |
| Frequency of long. accel. of rear vehicle below threshold | X | | | | | | | | |
| Frequency of time headway of read vehicle below threshold,<br>Frequency of time-to-collision of rear vehicle below threshold,<br>Frequency of long. distance of rear vehicle below threshold | X | | | | | | | | |

For the urban ADF, driving through intersections also needs to be considered. As many of the intersection scenarios also consider a lead vehicle, several PIs originally defined for lane bound driving scenarios like following can be transferred to driving through intersections. Furthermore, laterally moving objects (e.g. vehicles coming from a perpendicular direction in an intersection) need to be considered in urban scenarios. It is questionable whether sensor view ranges and obstructions would allow calculating PIs that would typically require a birds-eye point of view, such as the post encroachment time (PET). However, these situations are covered by the AIM Mobile Units in some locations for part of test drives (see chapter 4.2). Thus, for interactions with other objects at intersections, distances, as well as the TTC for laterally moving objects, are calculated from the vehicle data. If recorded data by urban vehicles allows calculating PIs such as PET, these will be added to the overall urban PI list. Table 4.3 shows the link between urban-specific driving scenarios and performance indicators.

*Table 4.3: Link between urban driving scenarios and performance indicators.*

| **Performance Indicators** | **Approaching laterally moving object** | **Crossing** | | | | **Turning** | | | | **Overtaking of oncoming vehicle** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **without conflict** | **with static object** | **with lead object** | **with laterally moving object** | **without conflict** | **with static object** | **with lead vehicle** | **with laterally moving object** | |
| Minimum long. accel.,<br>Maximum long. accel,<br>Standard deviation of long accel. | X | X | X | X | X | X | X | X | X | X |
| Maximum absolute lat. accel,<br>Standard deviation in lat. accel | X | X | X | X | X | X | X | X | X | |
| Mean velocity,<br>Maximum velocity,<br>Standard deviation of velocity,<br>Frequency of events with velocity below 0.2km/h,<br>Mean duration of events with velocity below 0.2km/h | X | X | X | X | X | X | X | X | X | X |
| Frequency of harsh brakings | X | X | X | X | X | X | X | X | X | X |
| Frequency of manoeuvres,<br>Proportion of time in driving scenario by time in ODD | X | X | X | X | X | X | X | X | X | X |
| Mean time headway,<br>Standard deviation of time headway,<br>Minimum time headway,<br>Mean long. distance to lead vehicle,<br>Standard deviation of distance to lead vehicle | | | | X | | | | X | | |
| Minimum time-to-collision | X | | | X | | | | X | | X |

| Performance Indicators | Approaching laterally moving object | Crossing | | | | Turning | | | | Overtaking of oncoming vehicle |
|---|---|---|---|---|---|---|---|---|---|---|
| | | without conflict | with static object | with lead object | with laterally moving object | without conflict | with static object | with lead vehicle | with laterally moving object | |
| Mean time headway of rear vehicle,<br>Standard deviation of time headway of rear vehicle,<br>Minimum time headway of rear vehicle,<br>Minimum long. accel. of rear vehicle | X | X | X | X | X | X | X | X | X | |
| Frequency of long. accel. of rear vehicle below threshold | X | X | X | X | X | X | X | X | X | |
| Frequency of time headway of rear vehicle below threshold,<br>Frequency of time-to-collision of rear vehicle below threshold,<br>Frequency of longs distance of rear vehicle below threshold | X | X | X | X | X | X | X | X | X | |
| Minimum time-to-collision,<br>Minimum long. distance,<br>Minimum lat. distance | X | | | | X | | | | X | |

## 4.5 Analysis of the end of ODD

For L3 functions, reaching the end of the ODD will result in a take-over request (TOR) by the ADF. For L4 functions the end of ODD is either indicated by a TOR or by a safe stop manoeuvre. Either way, the end of the ODD is directly related to specific system states that are logged in the common data format. Driver reaction at the end of ODD will be evaluated based on video data with a method called take-over-controllability rating (TOC-rating). The procedure and content of TOC-rating are described in the section on U&A evaluation in detail (see chapter 5.3.2).

For RQs in the area of T&T, the frequency of TORs is analysed for those pilot sites where the experimental procedure makes this analysis meaningful. This indicator can be derived directly from the logged data without complex calculation.

## 4.6 Analysis of potentially safety-critical situations (incidents)

### 4.6.1 Background

According to FESTA (FOT-Net, 2018), an incident is (...) "something unforeseen in the course of action. In driving a vehicle in traffic, something which changes the foreseeable action (speed, direction) of the vehicle". A near-crash is "a conflict situation requiring a rapid, severe evasive manoeuvre to avoid a crash". The basic idea behind the analysis of potentially critical situations is the assumption that such situations are predecessors of accidents. However, because actual accidents are too rare to be systematically assessed in an on-road test setup, critical driving situations are analysed in order to learn about the potential safety impact of a certain condition (e.g. a specific ADAS or distraction). It is expected that there is a relation between the severity of a safety-relevant event and its frequency: with growing severity it is expected that events occur less frequently. It is also expected that a measured reduction of less severe events (e.g. incidents) allows concluding a reduction of more severe events such as accidents (Faber, Jonkers, Aust, Benmimoun, Regan, Jamson, et al., 2012) Therefore, through an analysis of changes in incident frequency, impacts on accident frequency can be inferred.

As an input for the T&T evaluation and to a certain extent as well for the impact assessment, incidents and near-crashes have to be detected in the pilot data. In past research projects, this was done in different ways. For example, in euroFOT (Benmimoun, Fahrenkrog, Zlocki, & Eckstein, 2011), incidents were defined using a rule-based detection by applying a threshold for time headway, time-to-collision as well as longitudinal and lateral acceleration. The classification was completely achieved by a rule-based detection, which was adjusted in its development by using video data. An approach based on perception and vehicle data, including video validation of all detected events, was used in the 100-Car-Study (Dingus, Klauer, Neale, Petersen, Lee, Sudweeks, et al., 2006, similar approaches in Hickman, Hanowski, & Bocanegra, 2010; Olson, Hanowski, Hickman, & Bocanegra, 2009). A sensitivity analysis was performed by setting the trigger criteria to a very liberal level reducing the chance of a missed valid event to a minimal level while allowing a high number of invalid events (false alarms) to be identified. Data reductionists then viewed all of the events produced from the liberal trigger criteria and classified each event as valid or invalid. The number of valid events and invalid events that resulted from this baseline setting was recorded. The trigger criteria used were: lateral acceleration, longitudinal acceleration, event button, forward time-to-collision, rear time-to-collision, and yaw-rate.

### 4.6.2 Analysis of incidents in L3Pilot

Based on a review of the state-of-the-art, an approach based on rule-based incident detection with video-based validation of the detected incidents similar to the approach used in the 100-Car-Study (Dingus et al., 2006) is proposed. In the first step, the driving data will be reduced by filtering with thresholds set on a very liberal level. Afterwards, the detected events will be validated by using video data, see Figure 4.4.

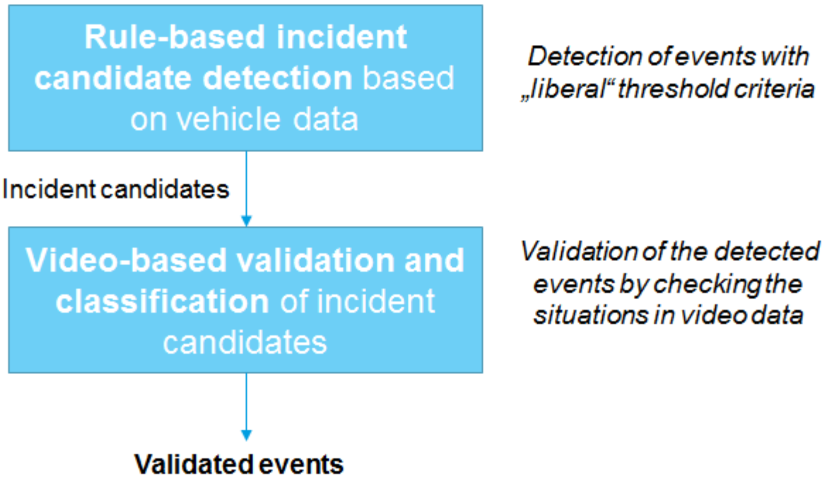



*Figure 4.4: Process for incident detection and validation in L3Pilot.*

Incidents will be detected based on vehicle data available in the common data format. As the considered ADFs are operating in a longitudinal as well as in a lateral direction (in case of a lane change or turning manoeuvre), incidents have to be detected to the front, to the side, and behind the vehicle. The proposed thresholds for detection are based on those used in euroFOT (Benmimoun et al., 2011) and are listed in Table 4.4. A distinction is made between incidents due to small (time) distances to other traffic participants and incidents due to high vehicle dynamics.

*Table 4.4: Criteria for incident detection.*

| Incident type | | Required signals | Proposed criteria |
|---|---|---|---|
| Distance-based | Front | THW [sec]<br>TTC [sec]<br>Δv [km/h] | Forward THW < 0.35 s & Δv < 20 km/h<br>Forward THW < 0.5 s & Δv > 20 km/h<br>Forward TTC < 1.75 s |
| | Side | Distance [m]<br>TTC to rear [sec] | Distance to side vehicle < 0.5 m &<br>projected TTC to vehicle in target lane < 1.75 s to vehicles approaching from rear (in case of lane change) |
| | Rear | THW to rear [sec]<br>TTC to rear [sec]<br>Δv to rear [km/h] | Rear THW < 0.35 s & Δv < 20 km/h to rear vehicle<br>Rear THW < 0.5 s & Δv > 20 km/h to rear vehicle<br>Rear TTC < 1.75 s |
| Vehicle dynamics based | | ax[m/s²]<br>ay[m/s²]<br>yaw rate [°/sec] | Longitudinal acceleration:<br>ax < - 6 m/s² (at 50 km/h)<br>ax < - 4 m/s² (at 150 km/h)<br>Lateral acceleration:<br>ay >= 2.5 m/s² (at 0 km/h)<br>ay >= 7 m/s² (at 50 km/h)<br>yaw rate >= 50 °/s 2 (at 50 km/h)<br>yaw rate >= 15 °/s (at 80 km/h) |

To ensure that all events included in the analysis are indeed incidents / safety-critical events, video validation is done for all candidate events selected based on the listed criteria. For video validation, a distinction is made between five categories: While in uncritical *normal driving* no safety-relevant circumstances are present, an *increased risk incident* (level 1) is usually caused by the driver and results in higher driving risk. An incident requiring an evasive manoeuver is called *crash-relevant incident* (level 2). If the required evasive manoeuver approaches the limits of vehicle capabilities, the incident is called *near-crash* (level 3). If the incident resolution is not successful, a *crash* occurs. The used coding scheme for video-based validation of incidents is shown in Figure 4.5.

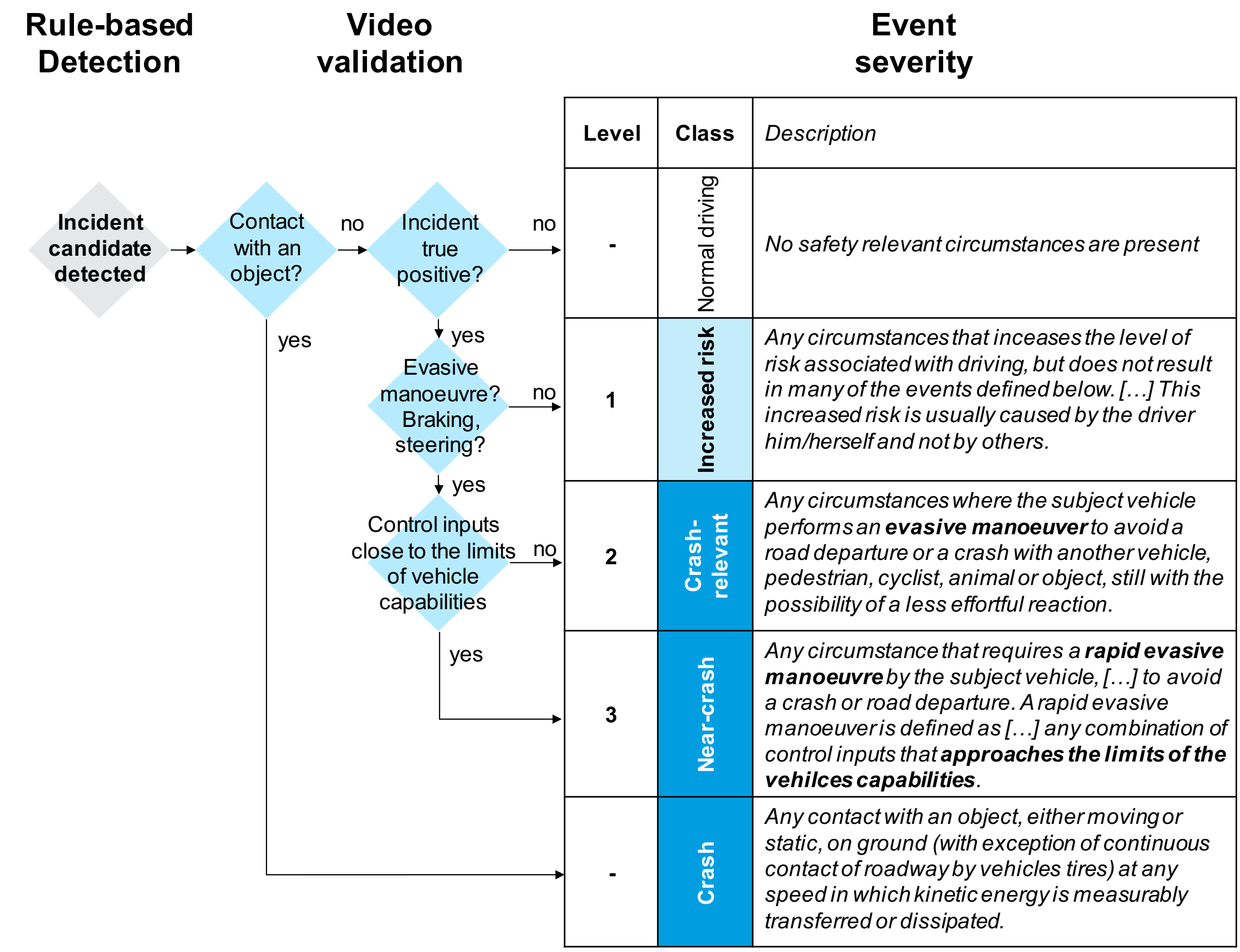



*Figure 4.5: Coding scheme for video-based incident validation.*

## 4.7 Input for impact assessment

Besides answering the T&T RQs, the pilot data in L3Pilot is used as input for the impact assessment. The pilot data gives a state-of-the-art picture of how (current prototype versions of) ADF behave in real traffic as well as how other road users interact with the vehicles. The behaviour of ADF can mainly be estimated by the results of the T&T evaluation. Further information is needed regarding the interaction of other road users with the ADF. Performance indicators can express the interactions with other road users for certain driving scenarios. Especially for the safety impact assessment, detailed information on the safety-relevant situations with ADF involvement is needed. Those situations will then be evaluated with simulation tools.

Similar to the PIs for T&T evaluation, the PIs required for safety impact assessment are structured by driving scenarios. Every safety-relevant driving situation gives one value per PI. In contrast to T&T PIs, impact assessment requires more detailed data: In order to simulate valid safety-relevant situations, it is necessary to incorporate the correlation between certain PIs. For instance, it is of relevance whether the distance with which other vehicles cut in front of the ego vehicle is correlated with the ego speed as shown in Figure 4.6. Thus, PIs for safety impact assessment can be represented as data points linking multiple PIs per driving situation.

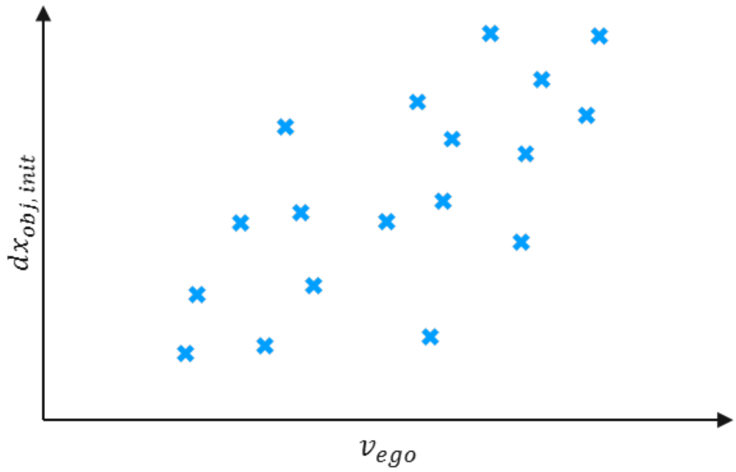



*Figure 4.6: Example of a link between two PIs derived all driving situations of a driving scenario. $v_{ego}$ = velocity of ego vehicle, $dx_{obj,\ init}$ = distance to lead vehicle at start of the cut-in.*

As driving scenarios will be simulated for mature functions, a process eliminating the differences among the different ADFs (see chapter 2.2), and the behaviour within the specific situations, is not of much relevance. The focus is on the initial conditions of the relevant driving situations, which will then be simulated using the mature functions. Therefore, the driving-scenario specific data points from each pilot site will be merged across the pilot sites using the consolidated database. Data are separated according to the criteria on whether the trip was a baseline or treatment drive and whether or not the ADF was active during the situation and per ADF type.

Besides driving scenarios, incidents that happen during the pilots are of relevance for impact assessment. Incidents are expected to be very rare. One special case is incidents with a rear vehicle. These are not considered as a separate driving scenario and are thus treated separately.

# 5 Methods for user and acceptance evaluation

## 5.1 Overall concept for user and acceptance evaluation

This section introduces the evaluation methods for user and acceptance (U&A) RQs listed in Annex 1. The methods for U&A evaluation centre mainly on data collected at the pilot sites. The main source of data from the pilot sites is the ADF-specific pilot site questionnaire while supporting data is collected via other methods, such as video analysis, vehicle based-data, interviews, and focus groups. Supplementary data for U&A evaluation will be collected via the annual surveys, Wizard of Oz studies, and driving simulator studies. The data sources collected at the pilot sites and used for U&A evaluation include:

- Pilot site questionnaires, completed by participants testing the ADFs;
- Video- and vehicle-based data, to assess frequency of interactions with the ADF, to track drivers' posture, their engagement with non-driving related tasks, and their stabilization of vehicle control, following resumption of control from automation (e.g. Take-over controllability rating; Naujoks, Wiedemann, Schömig, Jarosch, & Gold, 2018).
- Interviews and focus groups to assess drivers' views of ADFs, for situations that either cannot be observed or explained by the other methods employed.

In addition, driving simulator and Wizard of Oz studies will be the source of supplementary data which will be used to address specific RQs relating to the long-term and experience-based study on trust and acceptance of L3/L4 functions. These methods are relevant to address this topic since it cannot be addressed fully in the pilots. Additional information will also be gathered through an annual large-scale international online survey of drivers' acceptance of ADFs ("Annual survey", described in more detail later in this chapter). Table 5.1 shows for the different RQs which data sources will be used to answer them.

*Table 5.1: User and acceptance RQs and the data sources that will be used to address them. Vehicle and video data includes TOC rating.*

| RQ Level 1 | RQ Level 2 | Keyword | Pilot site | | | Other methods | | |
|---|---|---|---|---|---|---|---|---|
| | | | Vehicle & Video data | Pilot site questionnaire | Interview/Focus group | Driving Simulator | Wizard of Oz | Annual Survey |
| What is the impact on user acceptance & awareness? | Are drivers willing to use an ADF? | Willingness to use | x | x | x | | | |
| | How much are drivers willing to pay for the ADF? | Willingness to pay | | x | x | | | x |
| | What is the user acceptance of the ADF? | Perceived safety | | x | x | x | x | x |
| | | Perceived comfort | | x | x | x | x | x |
| | | Perceived reliability | | x | x | x | x | x |
| | | Perceived usefulness | | x | x | x | x | x |
| | | Perceived trust | | x | x | x | x | x |
| | | Acceptance and system behaviour in unexpected use cases | | x | x | x | x | x |
| | What is the impact of ADF on driver state? | Driver stress | | | x | x | | |
| | | Driver fatigue | | | x | x | | |
| | | Driver workload | | | x | x | | |
| | What is the impact of ADF use on driver awareness? | Driver attention to the road & other road users | x | x | x | x | | |
| | | Risk perception /behaviour | x | x | x | x | | |
| | What are drivers' expectations regarding system features? | Drivers expectations | | x | x | x | x | x |
| What is the user experience? | What is drivers' secondary task engagement during ADF use? | Drivers' secondary task engagement | x | x | | x | x | |
| | | Take-over performance | x | x | x | x | x | |

| RQ Level 1 | RQ Level 2 | Keyword | Pilot site | | | Other methods | | |
|---|---|---|---|---|---|---|---|---|
| | | | Vehicle & Video data | Pilot site questionnaire | Interview/Focus group | Driving Simulator | Wizard of Oz | Annual Survey |
| | How do drivers respond when they are required to retake control? | Take-over performance | x | x | x | x | x | |
| | How often and under which circumstances do drivers choose to activate/deactivate the ADF? | Frequency of activation/ deactivation | x | x | x | x | x | |
| | What is the impact of ADF use on motion sickness? | Motion sickness | | x | | | | |
| | What is the impact of motion sickness on ADF use? | Motion sickness | | x | | | | |

Independent of the ADF, data source and driver type, the analysis for U&A follows this approach:

1. Selection of relevant evaluation methods based on the U&A RQs;
2. Calculation of performance indicators (PIs) for the relevant evaluation method;
3. Identification of the relevant user groups that will be considered in the analysis;
4. Analysis (statistical/descriptive) of the derived PIs in order to answer the RQs and hypotheses.

## 5.2 Pilot site questionnaire

### 5.2.1 Structure of questionnaire

The pilot site questionnaires are designed to gather subjective data from the pilot-site participants that will take part in the on-road tests. Because there are differences between ADFs, three different pilot-site questionnaires were designed, with function-specific questions for parking, traffic jam / motorway and urban ADF. The questionnaires are structured as follows:

- ***Part 1: Screening questions (pre-drive)***, covering test participants' sociodemographic information (age, gender, country of residence, education level, employment status, income, and family size), vehicle purchasing decisions, driving history, in-vehicle system usage (baseline), and trip choice. This information will be used to create different user groups for the evaluation.

- ***Part 2: Pilot site questionnaire (post-drive)***, covering test participants' impression of the ADF's performance, including acceptance, safety and comfort, among others.
- ***Part 3: Willingness to pay (post-drive)***, covering how much extra the participants would be willing to pay in order to have the particular ADF installed in their new vehicle.
- ***Optional: Take-over controllability (mid-drive)***, being optional and evaluating users' performance during take-over situations in the traffic jam / motorway and urban on-road tests.

### 5.2.2 Implementation at the pilot sites: Translation and implementation

All pilot sites use a common questionnaire structure to ensure that a harmonized analysis will be possible in the evaluation stage. However, the questionnaires were adapted where relevant to answer questions specific to the three ADF types: motorway/traffic jam ADF, parking ADF and urban ADF. Motorway and traffic jam ADF are dealt with in one questionnaire because they have a rather similar ODD. In addition, there are some questions that require modification to reflect the context of the different pilot sites. For example, the socio-demographic questions regarding household income will be adjusted based on the pilot site region/country (e.g. £ for UK) and the same approach will be used for the willingness to pay questions.

The questionnaires were translated to the languages needed at the different pilot sites, including German, French, Italian, Swedish, including also verification to ensure that the correct wordings were used. The questionnaire was implemented by SP5 in LimeSurvey (https://www.limesurvey.org/), which is an online tool that is proposed to all pilot sites. This approach ensures that the questionnaires are administered consistently and their output (i.e. coding of questionnaire items and answers) integrates seamlessly into a common data format which can be transferred to the consortium consolidated database. This is important in order to analyse the combined results from all the pilot sites.

### 5.2.3 Implementation at the pilot sites: Pseudonymisation and anonymisation

Before transferring pilot site questionnaire data to the consortium consolidated database, the responses need to be pseudonymised, which is a process whereby personally identifiable information fields within the data record are replaced by one or more artificial identifier. This is, to ensure that test participants' personal data will be protected. However, it is also important for the evaluation to be able to link the questionnaire data and the objective vehicle-based data. For example, to link a participant's self-reported trust in automation with the number of automation disengagements during the pilot. Therefore, pilot sites will be provided with a set of token codes, which participants will use when completing the questionnaire. This anonymises participants' responses but allows researchers to link those responses to other data collected during the pilots.

### 5.2.4 Implementation at the pilot sites: Scope of the questionnaire

While the questionnaires generally cover all project U&A RQs, the scope of the L3Pilot project and the practical constraints of extended data collection phases mean that not all aspects can be included. For example, as the pilots will be using prototype vehicles which may be modified over the course of data collection, there is less focus on drivers' opinions of the vehicle's HMI. However, some pilot sites may wish to collect this kind of additional data at some points during the pilots. Therefore, all pilot sites will be free to expand the common pilot-site questionnaires with items that are needed for internal purposes. However, this data will not be included in the overall L3Pilot U&E evaluation. Moreover, the pilot sites will be strongly encouraged to maintain the original content and structure of the questionnaire to ensure consistency across sites.

An important aspect of U&A evaluation is the impact that users' interaction with the ADFs in real-world settings has on their acceptance of, perspectives/ experience while using, the system. Therefore, pilot site questionnaires are specifically designed to capture changes in these areas from pre to post drive. The questionnaire also aims to gather information on users' impressions regarding ADF behaviour and performance, willingness to use, and willingness to pay.

### 5.2.5 U&A information needed for impact assessment and upscaling

User acceptance evaluation provides input for the impact assessment on personal mobility. Since the L3Pilot tests take place in an experimental setting and not in participants' daily life, it is not feasible to measure actual changes in travel behaviour in L3Pilot tests. Therefore, complementary data and methods, such as interviews and focus group discussions, will be used to assess the potential impacts of ADFs on personal mobility. The evaluation methods for the mobility impact area will utilise both objective travel data and survey data on current travel behaviour in different European countries as a baseline. Subjective data about the potential mobility impacts of automation will be gathered through the pilot site questionnaires, annual survey (the method is presented in section 5.5) and focus groups. The implementation of the pilot site questionnaires will enable the analysis of the perceptions and views of people (test participants/drivers) that have actually experienced driving with automation in L3Pilot ADFs.

Subjective data reflecting the test drivers' willingness to use the ADF and their perception of the ADFs' value for different trips is important for personal mobility impact assessment when aiming to capture possible changes in travel behaviour. Where possible, questionnaire items on mobility and travel behaviour will be analysed across different user groups, and thus background information such as participants' age, household structure, household income, vehicle purchasing decisions (intention for next car acquisition, frequency of changing cars, and intention for car investment), technology acceptance, driving history, and use of different travel modes are relevant. Questionnaire items will be analysed to provide research insights for the mobility impact evaluation area.

Both the pilot site questionnaire and the annual survey also include questions regarding the willingness to pay (WTP) for ADFs. The aim is to capture the demand for ADFs by revealing individuals' preferences for how much they are willing to pay for equipping their vehicles with ADFs. The WTP and other relevant data along with the socio-demographic background data will provide supplementary information for the socio-economic impact assessment regarding the demand for ADFs.

## 5.3 Evaluation of take-over situations

### 5.3.1 Driver's evaluation during the trip

In case it is feasible (not recommended for professional drivers, requires an experimenter/second person the vehicle), drivers are asked directly after a take-over scenario to rate the controllability of the preceding situation as a whole. The rating involves a ten-point scale (see Figure 5.1) to judge the criticality of the situation, ranging from harmless to uncontrollable. The scale is based on Neukum, Lübbeke, Krüger, Mayser, & Steinle, (2008) and allows a direct comparison between subjective evaluation and post-drive evaluation by experts through TOC-rating (see 5.3.2).


*Figure 5.1: Scale used for evaluation of take-over scenarios by the driver during a drive.*

### 5.3.2 Expert's evaluation after the trip

To evaluate the controllability and safety of take-over situations, a video-based rating procedure will be used. The take-over-controllability-rating (TOC-rating) was developed in cooperation between BMW and WIVW, as part of the German research initiative KO-HAF (Hohm, Klejnowski, Skibinski, Bengler, Berger, Vetter & Krug, 2018). It provides a uniform and easy to understand approach to evaluate take-over situations. Especially in real-world testing, take-over requests can be expected to occur in a variety of environmental and traffic situations. A variety of different driver responses may be suitable to resolve the situation safely. This makes it difficult, if not impossible, to define the driving parameters that accurately reflect the quality of the take-over reaction.

TOC-rating requires as input a video of the complete take-over situation including some seconds before the warning and after the actual take-over that shows the driving scene in front of and behind the vehicle as well as the driver. In a hierarchical process, the whole situation (that includes traffic as well as environmental situation, ADF behaviour, and driver reaction) is evaluated. The overall rating is given by a trained expert on a 1 to 10 scale, ranging from perfect performance to uncontrollable driving situation.


*Figure 5.2: Scale used for TOC-rating.*

First, there is an assessment of whether there was some kind of accident (either collision or loss of vehicle control), leading to the situation being classified as 'uncontrollable'. Next, there is an evaluation of whether the overall situation was dangerous or included a non-acceptable risk leading to an evaluation of the situation as 'dangerous'. In case the situation was neither uncontrollable nor critical, the quality of the take-over reaction is assessed. In case there are driving errors or other risky behaviours, the take-over reaction is evaluated as being not well performed. For take-over reactions without errors, there is a further division into good and perfect performance.

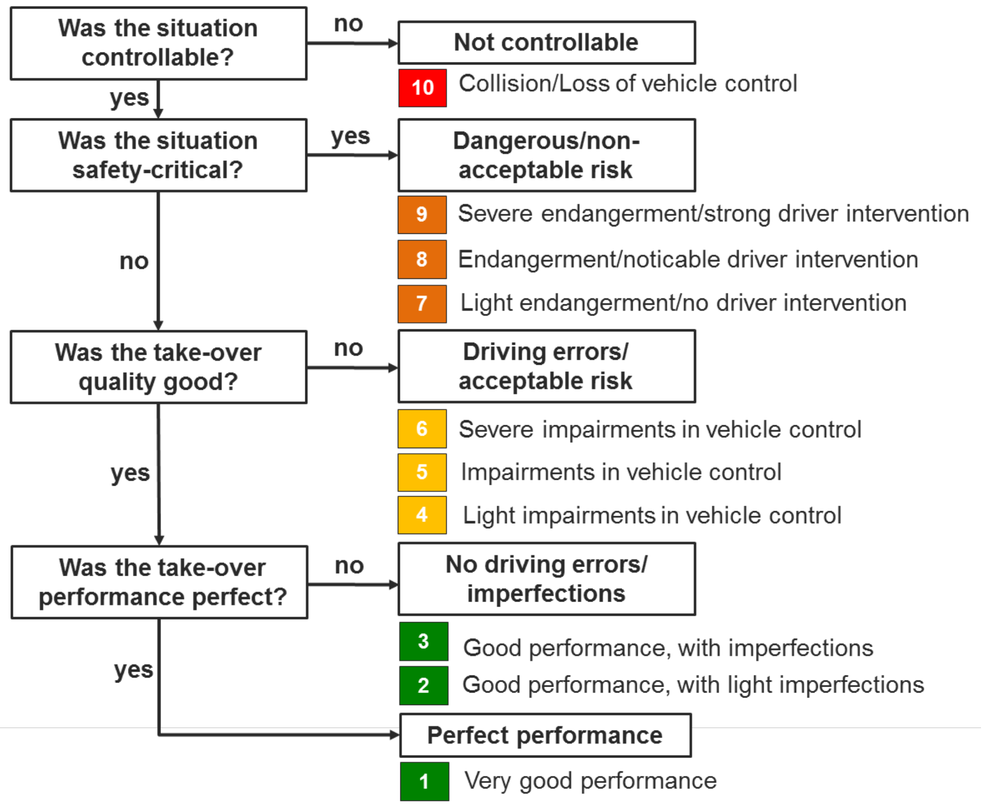



*Figure 5.3: Rating process of TOC-rating.*

Besides describing a standardized procedure for the evaluation of take-over situations, the relevant dimension for evaluation is provided with defined criteria for the different rating categories. The following dimensions are considered to be relevant for take-over performance.

- Longitudinal control including braking,
- Lateral control of vehicle,
- Lane change/lane choice,
- Securing & communication with other road users,
- Vehicle handling and
- Driver state/driver reaction.

For the evaluation, a coding sheet and an app are available which can be used to collect TOC-ratings in a standardised way for every rated take-over scenario. The app, training material including videos and more detailed information are available at https://toc-rating.de/.

## 5.4 Evaluation of vehicle and video data

In case it is feasible, parts of the results for U&A can be based on data logged during the on road tests (besides using questionnaire data). The following RQs (besides RQs on take-over situations) could be answered partly based on vehicle data:

- What is drivers' secondary task engagement during ADF use? Type and frequency of secondary task engagement will be coded from the video; only recommended for ordinary drivers and if the experimental protocol allows secondary task engagement.
- What is the impact of ADF on driver state? Driver state can be coded from the video. In case eye-tracking data is available (e.g. simulator study and wizard of Oz-study), this data can be used to calculated PIs like PERCLOS, percentage of on-road glances, etc.
- Are drivers willing to use an ADF? & How often and under which circumstances do drivers choose to activate/deactivate the ADF? Frequency of ADF activation and deactivation can be analysed. For in-depth analysis, it can be evaluated in which situations drivers prefer to drive manually; only recommended for ordinary drivers and if the experimental protocol allows free activation and deactivation of ADF.

For video coding, the codebook that was developed and will be used is based on the codebook developed and used in the UDRIVE project (http://www.udrive.eu/, Bärgman, van Nes, Christoph, Jansen, Heijne, Carsten, et al., 2017).

## 5.5 Annual survey

### 5.5.1 Motivation and objectives

Complementing the other U&A evaluation methods, a three-wave questionnaire study covering 78 items will be executed in several countries to investigate the acceptance of ADFs and monitor changes over time during a three-year period. The first questionnaire study was conducted among a representative sample of 9,000 car drivers between April and June 2019. The questionnaire will be repeated annually, with the next studies being conducted in Q2 2020 and 2021, respectively, with car drivers from seven European countries (i.e. UK, Sweden, France, Germany, Italy, Hungary, Finland), and two non-European countries (i.e. China, the USA).

One of the main objectives of the survey is to examine cross-national differences in the acceptance of conditionally automated cars. To the best of the authors' knowledge, this is the first longitudinal study on users' acceptance of L3 automated vehicles.

The questionnaire is based on the Unified Theory of Acceptance and Use of Technology (UTAUT) which was proposed by Venkatesh, Morris, Davis, & Davis (2003). UTAUT provides a comprehensive synthesis of research to model technology acceptance and integrates eight influential acceptance models (e.g., Theory of Planned Behaviour, Technology Acceptance Model). It postulates that performance expectancyapplewebdata://CEF0D914-4368-477E-91B2-FF6E33E5DC18/ - _ftn1, effort expectancy, social influence, and facilitating conditions influence the behavioural intention of an individual to use a technology, while behavioural intention and facilitating conditions determine actual system usage.

- Performance expectancy is the degree to which using a technology will provide benefits to users in performing certain activities.
- Effort expectancy is the degree of ease associated with the use of technology.
- Social influence describes the extent to which users perceive that important others believe they should use a particular technology.
- Facilitating conditions refer to users' perceptions of the objective resources and support available in the environment to perform a behaviour (Venkatesh et al., 2003).

Age, gender, and experience moderate the relationship between performance expectancy, effort expectancy, social influence, and facilitating conditions and behavioural intention. UTAUT2, which follows from UTAUT1, suggests that an individual's behavioural intention to use information technology is influenced by three additional constructs in addition to the original UTAUT, i.e. hedonic motivation (i.e., fun or pleasure derived from using a technology), price value (i.e., monetary cost of technology use), and habit (i.e., extent to which an individual believes the behaviour to be automatic) (Venkatesh, Thong, & Xu, 2012). Table 5.2 provides an overview of the research objectives and questions that the questionnaire addresses.

*Table 5.2: Research objectives and questions for the annual survey.*

| Research objective | Research questions |
|---|---|
| To examine the effect of the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation on | To what extent is the intention to use ADF influenced by performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation? |

| Research objective | Research questions |
|---|---|
| individuals' behavioural intentions to use ADFs. | |
| To examine the interrelations between the UTAUT constructs and its effect on the intention to use ADFs. | To what extent are the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation correlated with each other, and how do their interrelations affect the intention to use ADFs? |
| To examine the perceived safety, willingness to share data, and trust in ADFs and their correlations with the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and intention to use. | What is the perceived safety of ADFs? |
| | Are respondents willing to share data with an ADF or the entities operating it? |
| | What is the perceived trust in ADFs? |
| | To what extent are perceived safety, willingness to share and trust correlated with the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation and intention to use ADFs? |
| To examine the willingness of drivers to engage in secondary tasks during the ride with an ADF. | Are drivers willing to engage in secondary activities while driving with an ADF and if so, which activities would they like to engage in? |
| To examine the willingness to pay for using ADF in different conditions (i.e., in urban traffic, on (congested) motorways, in traffic jams) and its correlation with the UTAUT constructs performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and intention to use. | How much are drivers willing to pay for ADF, and to what extent does their willingness to pay differ with regard to the conditions in which they use ADF? |
| | To what extent is the willingness to pay correlated with the UTAUT constructs performance/effort expectancy, social influence, facilitating conditions, hedonic motivation, behavioural intention, trust and willingness to share data? |
| To examine differences in acceptance of ADF between groups and countries. | To what extent does the acceptance of ADF differ between groups (e.g., age, gender, income) and countries? |

### 5.5.2 Procedure and recruitment

To inform the design of the questionnaire, desk research was conducted to identify research needs and to get an overview of the state of the literature on user acceptance of ADAS and the vehicles of higher automation levels. Research on theoretical models on technology acceptance, and the key factors predicting the acceptance was performed. Several workshops were held with experts of the consortium to further refine the design of the questionnaire.

The questionnaire was implemented by the German market research institute INNOFACT AG (www.innofact.com) using the survey tool EXAVO (https://www.exavo.de/surveytainment/). It was administered in English, Swedish, French, Germany, Italian, Hungarian, and Chinese in the respective countries. Taloustutkimus Oy was used to collect the same questionnaire data in Finland for an additional 1000 car-drivers using a Finnish translation of the survey questions.

In line with the guidelines in Nordhoff, De Winter, Kyriakidis, Van Arem, & Happee (2018), the respondents were informed that the survey would take around 20 minutes to complete and that the data would be treated anonymously. Respondents were further informed that the survey is being conducted as part of the EU-funded project L3Pilot. Respondents were provided with instructions on the functionality of ADF before beginning the survey to increase the likelihood that they had an accurate understanding of ADF.

### 5.5.3 Annual survey content

The survey addresses various topics around acceptance, mobility, privacy, trust, perceived safety, technology readiness, experience with road vehicle automation, and knowledge of ADF. After the respondents received the instructions, they were asked to provide socio-demographic information (Q1–Q7). Next, respondents had to answer some knowledge questions to check whether they had correctly understood the instructions (Q8–Q12). Question Q13 asked respondents whether they had heard about automated cars before taking part in the present questionnaire survey, and if so, which sources of information they use and how often (Q14). Q15–Q18 asked respondents to indicate their level of agreement with items pertaining to their technology readiness. Q19 asked respondents whether they would like to engage in non-driving related activities, and if so, in which activities (Q20). As the effective functioning of an ADF depends on driver monitoring, questions Q20–Q22 were then presented to assess respondents' level of comfort with an ADF collecting driver information. Q23-Q44 pertained to items measuring the UTAUT constructs performance and effort expectancy, social influence, hedonic motivation, facilitating conditions, and intention to use, which were adjusted to the L3 context. Q45 asked respondents to indicate the amount of money they are willing to spend on their next car. After this question, the sample was split into four so that 250 respondents indicated their attitudes towards using ADF in one of the four conditions: on urban roads, congested motorways, motorways, and in parking situations. Q46–Q47 asked respondents to indicate their intended use of and willingness to pay for an ADF in one of the four stated conditions, respectively. Q48–Q59 asked respondents to indicate their level of agreement with items intending to capture their expectations regarding the perceived comfort, safety and trust in taking over control from an ADF. Q60 asked respondents to indicate which types of trips they are planning to use an ADF for. Next, respondents were asked to indicate how ADFs will affect their personal mobility (Q61). With the final questions (Q62–Q68), respondents were asked to provide information on their current mobility behavior.

### 5.5.4 Annual survey analysis

Descriptive statistics (i.e., frequencies, mean, standard deviation) will be calculated per questionnaire item. To investigate the correlations between the latent constructs in this study, structural equation modelling will be performed.

# 6 Methods for impact assessment

## 6.1 Overall concept for impact assessment

The impact assessment performed in L3Pilot and described in this chapter deals with the potential impacts of ADFs in passenger cars on traffic safety and efficiency, the environment, and personal mobility. This work provides valuable information in itself, but the impact assessment is also needed to provide input to the socio-economic assessment of L3Pilot (chapter 7). Therefore, the needs of the socio-economic assessment have to be considered when setting up the methods for the impact assessment. One important element to consider is the snapshot approach (see chapter 3.2) taken in the socio-economic impact assessment, meaning that no estimates for ADF use in the future will be made but the potential impacts of automated driving will be assessed as if it was introduced into the current traffic system.

Overall, nine research questions were defined for impact assessment in deliverable D3.1 (Hibberd et al., 2018), see the updated version in Table 6.1. The planned approach for finding answers to these questions is presented per impact area in sub-chapters 6.5−6.4 individually. In addition to the questions regarding the impact on traffic safety, efficiency and environmental aspects, the fourth main category deals with mobility and exposure-related questions. The mobility impact assessment – as stated earlier – contributes to the other impact assessment indirectly impacts on travel behaviour. Therefore, the related research questions are also relevant for traffic safety, traffic efficiency, and environmental impact assessment.

*Table 6.1: Research questions for the impact evaluation and their relevance for the different ADF-types.*

| RQ Level 1 | RQ Level 2 | Relevant for | | | |
|---|---|---|---|---|---|
| | | Motorway | Traffic jam | Parking | Urban |
| What is the impact of ADF on traffic safety? | What is the impact of ADF on the number of accidents in a certain driving scenario / for certain road users? | X | X | X | X |
| | What is the impact of ADF on accidents with a certain injuries level / damage in a certain driving scenario? | X | X | X | X |
| What is the impact of ADF on traffic efficiency? | What is the impact of ADF on transport network efficiency (throughput) in a certain traffic scenario? | X | X | | X |
| What is impact of ADF on the environment? | What is the impact of ADF on energy demand / pollution in a certain traffic scenario? | X | X | | X |

| RQ Level 1 | RQ Level 2 | Relevant for | | | |
|---|---|---|---|---|---|
| | | Motorway | Traffic jam | Parking | Urban |
| What is the impact of ADF on (personal) mobility? | What is the impact of ADF on the amount of travel? | X | X | | X |
| | What is the impact of ADF on travel patterns? | X | X | | X |
| | What is the impact of ADF on quality of travel? | X | X | | X |

To answer the posed questions, impact assessment needs a large amount of data beyond the information that is provided by T&T and U&A evaluation. This includes, for example, accident statistics, in-depth accident data, travel behaviour, road and infrastructure data as well as mileage and traffic data. As the pilot tests are limited in scope, specific methodologies were developed within L3Pilot for scaling up the potential impacts to a European level (EU-28), thus estimating the implications in a wider context of use.

It needs to be borne in mind that the ADFs and vehicles tested in L3Pilot are still prototypes. For these prototype vehicles, additional safety measures (e.g. safety drivers) are taken to ensure safe testing in the pilots. However, it is assumed in impact assessment that once an ADF becomes available to operate on public roads by ordinary users, the technology has advanced to a level that safe operation is ensured (e.g. number of take-over requests, sensor performance and wider operational design domain). Therefore, instead of assessing impacts of piloted (prototype) automated driving functions, mature L3Pilot functions have been defined for each of the four ADF considered in L3Pilot (motorway ADF, traffic jam ADF, urban ADF and parking ADF). The mature functions used in the assessment are described in detail in chapter 2.2.

The potential impacts of the ADF are highlighted directly by potential changes in driver behaviour, and indirectly through changes in personal mobility (travel behaviour). Therefore, other impact areas depend on the input of the mobility assessment, Figure 6.1. The objectives of the Methodology sub-project in L3Pilot include considering not only expected direct impacts on the traffic system but also indirect ones.

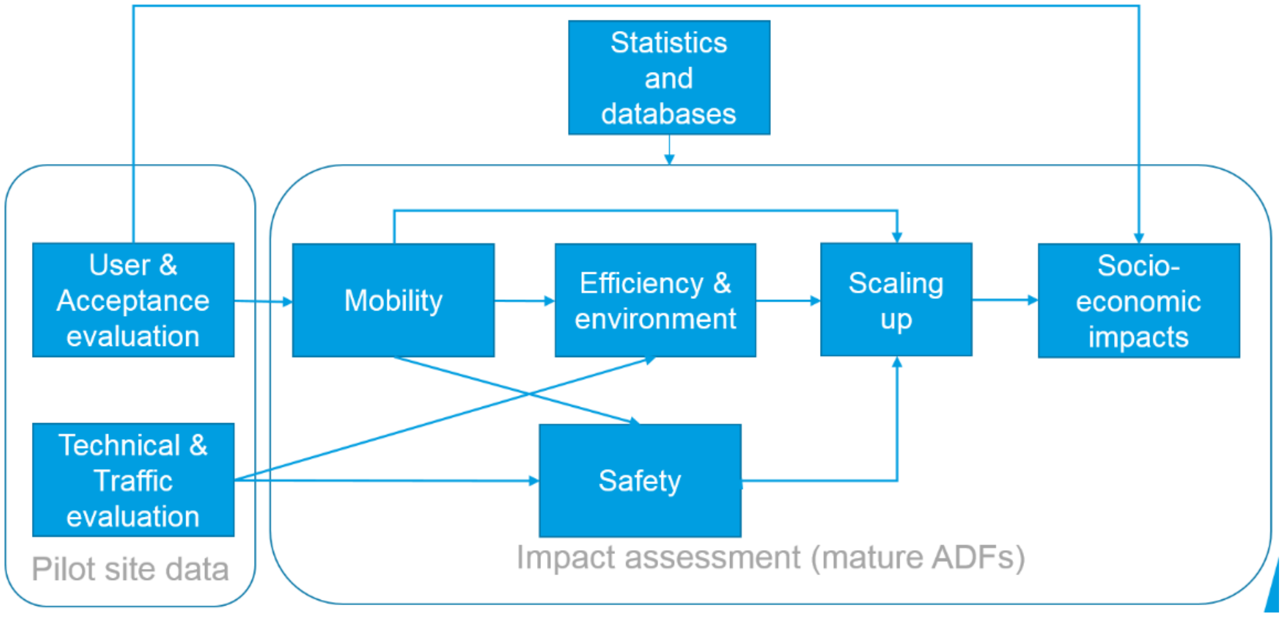



*Figure 6.1: Schematic picture of the hierarchy of different types of impacts.*

In order to identify both direct and indirect impacts, the nine impact mechanisms are used. Kulmala (2010) originally developed nine safety impact mechanisms for evaluation of intelligent transport systems, adapted from mechanisms formulated by Draskóczy, Carsten, & Kulmala (1998). The purpose of the mechanisms was to provide an assessment framework for systematic consideration of potential impacts, including both direct and indirect impacts while avoiding overlaps and the resulting risk of "double counting". Innamaa, Smith, Barnard, Rainville, Rakoff, Horiguchi, & Gellerman (2018) modified these mechanisms for automated driving and to be generic. Therefore the mechanisms as defined in Innamaa et al. (2018) can – and are recommended to – be used in addition to safety impacts, the mechanisms will be applied to the assessment of efficiency, environmental, and personal mobility impacts.

- *Mechanism 1: Direct modification of the driving task, drive behaviour or travel experience* which refers e.g. to direct impacts due to the vehicle driving itself and to direct impacts of differences in drive behaviour of automated vehicles and human driver. This refers e.g. to impact on accidents via changes in situational awareness, perception, speed, car-following behaviour and/or reaction times.
- *Mechanism 2: Direct influence by physical and/or digital infrastructure* which refers e.g. to direct impacts due to connectivity and to the direct impacts due to physical infrastructure in case it is different for automated vehicles (e.g. special lanes).
- *Mechanism 3: Indirect modification of automated vehicle user behaviour* which refers e.g. to (long-term) impacts of change in driving skills and (long-term) impacts of behavioural adaptation in drive behaviour of the users of automated vehicles (when driving in non-AD mode). This could concern e.g. reallocation of attention resources, or ability to drive or take over driving task).

- *Mechanism 4: Indirect modification of non-user behaviour* which refers e.g. to impacts of the behavioural adaptation of the other road users.
- *Mechanism 5: Modification of interaction between automated vehicles and other road users* which refers e.g. to impacts on the interaction between the automated vehicles and other road users (also including new forms of interaction) due to change in detection and situation interpretation of other road-users.
- Mechanism 6: Modification of travel behaviour (exposure / amount of travel) which refers e.g. to impacts on the number and length of journeys.
- *Mechanism 7: Modification of travel behaviour (mode choice)* which refers e.g. to impacts on the use of different transport modes / transport mode share. The mode selection affects the safety via risk levels of different transport modes.
- *Mechanism 8: Modification of travel behaviour (route choice)* which refers e.g. to impacts of automated vehicle's routes (road type, level of congestion) being different from those of the baseline.
- *Mechanism 9: Modification of consequences due to different vehicle design* which refers e.g. to impacts of the automated vehicle's design being different from the baseline and impacts of automated vehicles including more passive safety systems. (Innamaa et al., 2018)

For all mechanisms, a comparison of the situation prior to the introduction of ADFs (*baseline*) with the situation after the introduction (*treatment*) is required. The analysis is done for different driving and traffic scenarios. For each of the scenarios, it is necessary to define relevant traffic / driving situations (see chapter 3.1) and penetration rate (chapter 3.2.4). Within the impact assessment, each mechanism will be reviewed in terms of whether and in which way it is affected by the ADFs under assessment. The functions to be assessed are described in chapter 2.2 and the scenarios in chapter 3.1.

## 6.2 Scenarios considered in the impact assessment

The impact assessment will apply simulations to quantify the effects of ADF. For those simulations the scope in the sense of scenario needs to be clarified since to identify potential effects, different types of simulation are necessary. The impact assessment considers two categories of scenarios: traffic scenarios and driving scenarios (see chapter 3.1). An overview of the type of scenarios used in impact assessment of different impact areas is provided in Table 6.2.

Each of the identified driving scenarios is implemented in driving simulation programs to investigate how ADF equipped vehicles behave in certain driving scenarios (e.g. car following, lane change, cut-in). The simulation of driving scenarios is limited in time and space – meaning that the simulation time is short and the number of involved traffic participants is low compared to traffic scenario simulations (explained below). The driving scenarios typically involve certain critical driving behaviour that is either caused by a human driver or by automated driving. The performance of a human driver and the function will be determined and compared by simulating the driving scenarios in a replicable way. This type of scenario is mainly used in order to determine the safety impact of ADF in terms of avoided accidents or reduced degree of accident consequences that can be achieved by the ADF.

Simulation of a traffic scenario, on the other hand, considers a larger road section for an extended amount of time (e.g. 1 hour). Thus, it can involve a large number of traffic participants and their interactions. The virtual traffic environment has the objective to analyse the ADF behaviour in the traffic context. Changes in the frequency of certain driving scenarios can be derived. In contrast to the driving scenario, no driving manoeuvres are pre-defined. Instead, the manoeuvres result from the (possibly stochastic) behaviour of the models used in the analysis. Traffic scenarios are utilised in the assessment of traffic safety, efficiency, and environmental impacts.

As the definition for the exact driving scenarios and traffic scenarios to be simulated is part of the impact assessment carried out in SP7-Evaluation, a complete list of the scenarios relevant for simulation cannot be provided at this stage of the project. Driving scenarios are defined and described in chapter 4.1. Traffic scenarios will be defined in the next steps of work. The traffic scenarios will be selected with the scaling up task in mind.

*Table 6.2: Overview about relevant scenario types for the simulation-related impact assessment.*

| | Traffic Scenario | Driving Scenario |
|---|---|---|
| Safety | X | X |
| Environment | X | |
| Traffic Flow & Efficiency | X | |

## 6.3 Safety Impact Assessment

### 6.3.1 Overall concept

The main objective of the safety impact assessment is to investigate the effect of ADFs on traffic safety. According to the generally accepted theoretical background proposed by Nilsson (2004), traffic safety consists of three dimensions: (1) exposure, (2) risk of an accident to take place during a trip, and (3) consequences (i.e. risk of an accident to result in injuries or death). The changes in the exposure of road users are covered as part of chapter 6.5 and therefore the remaining important research questions to be handled during the safety impact assessment concern accident severity and frequency of accidents:

- What is the impact of ADF on the number of accidents in a certain driving scenario / for certain road users?
- What is the impact of ADF on accidents with a certain injuries level / damage in a certain driving scenario?

In general, the assessment of these research questions requires both the quantification of possible positive and negative effects of ADFs on traffic safety, as shown in Figure 6.2.

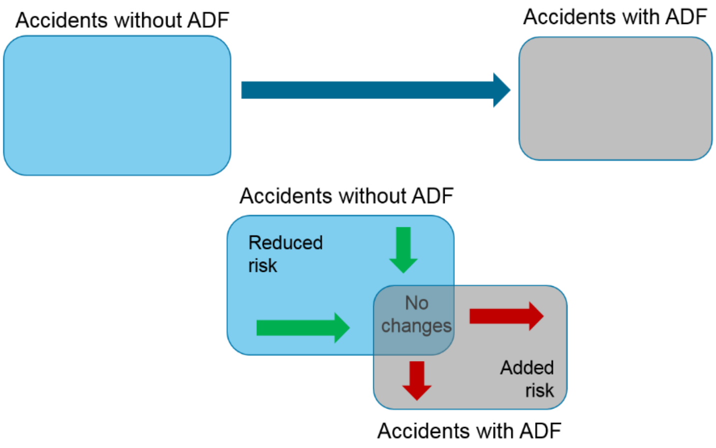



*Figure 6.2: Basic principle of an ADFs impact on traffic safety.*

The adequate quantification of the effects of ADF on traffic safety is a challenging task that requires a comprehensive method combining different known approaches and input data (as presented in Figure 6.3).

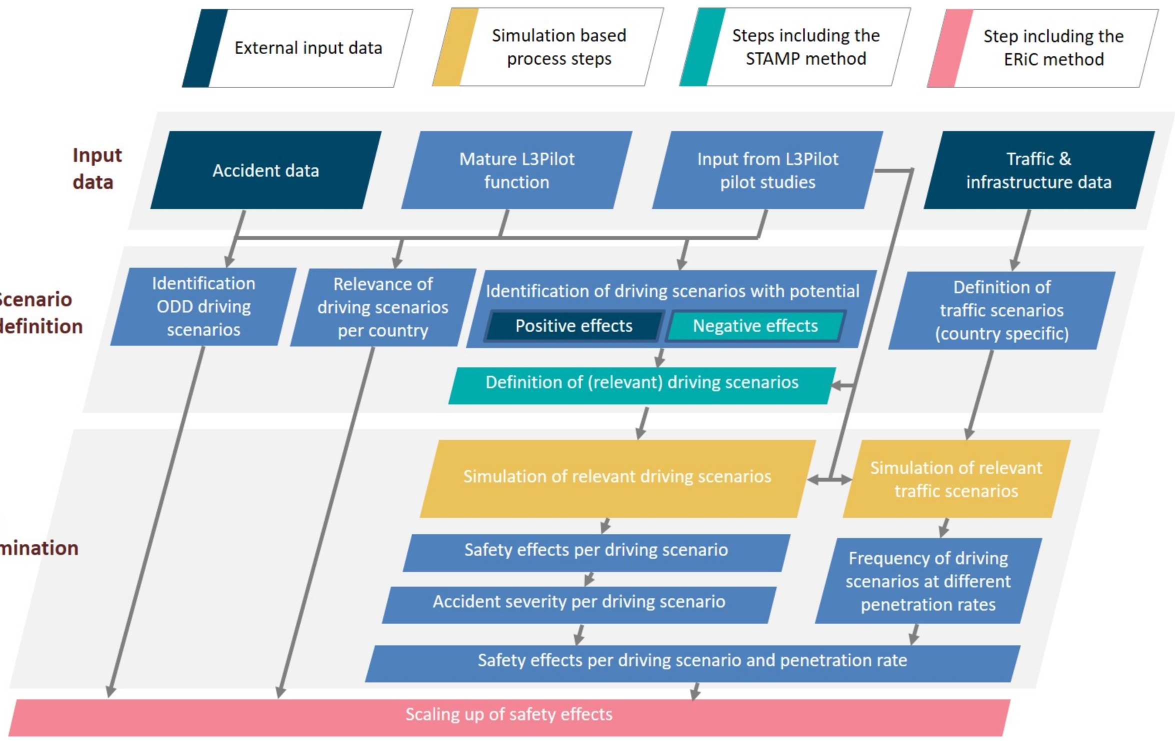



*Figure 6.3: L3Pilot approach for the safety impact assessment.*

The starting point for the safety impact assessment is the compilation of the relevant input data ("Input data" in Figure 6.3) for the assessment. This input data consists of:

- data collected during the L3Pilot pilot studies to describe the ADF behaviour and parameterise the driving and traffic scenarios,

- road accident data to adequately identify the driving scenarios for simulation and to scale up the results,
- descriptions of the mature ADF to be assessed, and
- traffic and infrastructure data for the definition of the representative traffic scenarios.

As a second step ("Scenario definition" in Figure 6.3), the relevant driving scenarios are identified and described. Within this step, the focus is on identifying the driving scenarios, which will be defined by means of accident data and the STAMP (Systems-Theoretic Accident Model and Processes) method (see chapter 6.3.2). Our analysis focusses on two types of driving scenarios: 1) those where the ADF is expected to have a positive effect on safety, and 2) those in which unintended negative safety impacts may occur. Defining driving scenarios, for which positive effects are expected, accident databases are reviewed regarding the current accident situation and scenarios. The logic behind this is that ADFs can only have a positive effect on driving scenarios that are an issue today from a traffic safety perspective. These driving scenarios cover accidents normally involving human or technical related failure(s). Typical examples of current accident types are rear-ended collisions, lane change, intersection or crossing traffic as well as single-vehicle accidents. In order to ensure that the simulated driving scenarios are in line with the accident situation in Europe, links between driving scenarios and different accident types will be analysed.

The identification of the driving scenarios, in which ADF might lead to negative effects, is a more challenging task, as these scenarios do not occur in the same way in today's traffic with human-driven vehicles. Therefore, the STAMP method (see chapter 6.3.2) should help to take a systematic approach to identify mechanisms leading to these driving scenarios. Basically, it can be expected that the scenarios are associated with technical shortcomings. A scenario that is often discussed in the context of ADF is the transition of control between the driver and the automated system.

However, the analysis cannot be limited to short driving scenarios only as the interactions in traffic between different traffic participants is also relevant for traffic safety. Therefore, the safety impact assessment must also cover the impacts of ADF in a larger traffic context (traffic scenarios, see chapter 3.1.2), as some effects are expected to change with penetration rate. Furthermore, it must be recognised that an ADF – in contrast to active safety systems, which typically become active just shortly before an imminent collision – can be active throughout the drive within the entire ODD. Hence, it can be expected that the ADF also has an influence on the frequency of driving scenarios. This assumption is supported for instance by field tests analysed in the Adaptive project (Rösener, Sauerbier, Várhelyi, & de Gelder, 2017). Therefore, in order to identify this effect, simulations of traffic scenarios will be conducted as a part of the safety impact assessment. In addition, the ODD of the ADFs will be taken into account at this stage, since it has a strong influence on the upscaling of the results.

During the third step ("Effect determination" in Figure 6.3) the required simulations will be carried out on a driving scenario level as well as on the traffic scenario level. The results of different simulation activities will be evaluated afterwards, and the required outputs are calculated in terms of changes in the frequency of driving scenarios per traffic scenario, the changes in probability of accidents in each driving scenario and the severities of these accidents. These outputs are eventually used in the upscaling of the results to derive the safety impact of the analysed ADF on a European level (EU-28).

### 6.3.2 Used methods

Simulation approaches for the safety impact assessment

Simulations are used to derive the potential impacts of ADF on traffic safety in different driving and traffic scenarios, as it is not expected that the L3Pilot pilot studies will provide a statistically relevant number of accidents for the assessment. Furthermore, extensive experiments in controlled environments (driving simulator or test track) would require significant financial resources and time, and the single analysis of accident data would not provide enough detailed results. A challenging aspect of simulations is the requirement of driver models when a system requires driver input or interacts with other human-driven vehicles. Three complementary approaches are available for the simulation of driving scenarios in safety impact assessments (ISO, in prep.):

**1.** Simulation of real-world driving situations

This is a straightforward approach in which real-world driving situations, which have either been reconstructed from accident data or recorded in NDS/FOT studies, are simulated with the function under assessment. These "what-if" simulations determine what could have happened in specific critical events if the driver had behaved differently (Bärgman, Lisovskaja, Victor, Flannagan, & Dozza, 2015) or an assistance system would have been triggered (Kusano & Gabler, 2012; Lindman & Tivesten, 2006).The simulated cases are represented according to parameters found in the corresponding database (e.g. collision speed and collision angle (Van Noort, Bakri, Fahrenkrog, & Dobberstein, 2015; Wille & Zatloukal, 2012; Lindman, Ödblom, Bergvall, Eidehall, Svanberg & Lukaszewicz, 2010; Kolk, Tomasch, Sinz, Dobberstein, & Bakker, 2016).

**2.** Simulation with modified cases of real-world driving situations

The second approach uses the same situation as the first approach as a starting point. However, the original parameters are modified in order to cover inaccuracies in the data measurements or to transform the cases that were measured with old vehicles to also be representative of modern vehicles. How the cases are modified needs to be decided based on the function to be assessed. Since the baseline scenario is modified, the case must be simulated for both conditions – baseline and treatment (Kolk et al., 2016; Kolk, Kirschbichler, Tomsch, Hoschopf, Luttenberger, & Sinz, 2016; Tomasch, Kolk, Sinz, Hoschopf, & Kirschbichler, 2015). For most systems, this approach requires models for how a driver may have reacted for both the baseline and treatment.

**3.** Simulation with synthetic driving scenarios based on relevant real-world traffic characteristics

In this third approach, the cases to be simulated are generated based on the understanding of contributing factors involved in the targeted driving situations (Kates, Jung, Helmer, Ebner, Gruber, & Kompass, 2010; Helmer, Neubauer, Rauscher, Gruber, Kompass, & Kates, 2012; Luttenberger et al., 2014). Sampling methods, such as Monte Carlo, can be used to vary the characteristics of the cases including driver and vehicle properties, vehicle trajectories, and traffic and environmental variables (Helmer, 2014; Bärgman, Boda, & Dozza, 2017). This flexibility enables longer scenarios – for example, up to traffic scenarios – to be simulated. The simulation cases are randomly generated based on distributions that are derived by accidents statistics or measured in the pilot studies. Via the distributions, the simulated case is linked to the real world. Similar as for the second approach, also for this approach, both conditions (treatment and baseline) must be simulated for the derived cases. Likewise, the actions of the drivers also need to be considered as part of the simulations.

In the L3Pilot safety impact assessment, mainly the third approach will be applied since the input data from the L3Pilot pilot studies will be aggregated distributions of driving characteristics of the AD vehicle (e.g. absolute and relative speed, time-headway, etc.). In addition, the advantage of the third approach is that the number of analysed cases can theoretically be increased arbitrarily (limits occur of course by the available resources), which guarantees statistically significant results. This enables the analysis to cover a larger situation space than would be possible for the first two approaches, which are limited to the number of recorded situations. To ensure an assessment of realistic conflict situations, characteristics of critical situations can be retrieved from external data sources (accident databases) and are incorporated into the simulation (e.g. harsh braking of a lead vehicle).

On the other hand, the third approach only provides the starting conditions and not defined trajectories, as is the case for the other two approaches. Hence, the third approach requires driver behaviour models for human-driven traffic that derive the actions of the agents (combination of vehicle and virtual driver) correctly also for simulating the baseline condition (which is also required for baseline in approach two). Consequently, for the third approach to yield meaningful, relevant and valid results, the underlying models of drivers and their interaction need to be valid, across the range of the parameters that are used. In addition, the generalizability of the underlying distributions of variables (e.g., THW, relative speeds, lane position) and agent parameters (e.g., reaction times, response model parameterisation) need to be valid. The simulations in this project use state-of-the-art models and parameters, but as models and parameters are continuously being developed, the simulations can be updated. For the simulation in the treatment condition, the ADF must be implemented in all three approaches.

The simulation of the traffic scenarios for safety impact works basically analogous to the simulation of traffic scenarios for the impact assessment of traffic efficiency and the environment (see chapter 8.5). However, slight differences are necessary due to the different focus of the assessments – in particular the applied metric in the evaluation and the used driver behaviour model. The metric in the safety simulations is focused on the detection of collisions or critical driving scenarios. In addition, the driver behaviour model in the safety simulations must be capable of covering the driving process including safety-critical situations as well as limitations of human drivers and faulty behaviour. Therefore, the major focus of the driver behaviour model must be on the modelling of the driver response process (including perception and actions) and the situation understanding of the computer agents.

The simulation process of driving scenarios combines aspects from the second and third approach for the simulation mentioned above. The start conditions for the AVs as well as the parameters of the involved agents are chosen randomly from the pre-defined distributions established by the pilot data. During the simulation the behaviour of each agent is controlled by the driver behaviour model. The characteristics of this behaviour are not only derived from driving in normal traffic but also based on behaviour observed in crashes and near-crashes (e.g. harsh braking). These observations are retrieved from real-world data (accident databases and NDDs) and ensure the creation of realistic conflict situations in the simulation. However, in contrast to the traffic scenario, the simulated time and distance is shorter and involves only the relevant traffic agents that are to interact with the automated vehicle. Furthermore, in the driving scenario, specific pre-defined driving manoeuvres will be executed. Thus, the focus of the driving scenarios is critical situations, whereas to a large extent the traffic scenario simulation also covers non-critical driving scenarios.

There are different simulation tools (e.g. openPASS, Virtual Test Drive, VISSIM, MATLAB based, etc.) available to the L3Pilot partners that can cover driving scenarios as well as traffic scenarios on motorways, urban roads as well as in parking environments. These tools, which have already been used successfully in the past for other functions (e.g. in EU project Adaptive; AdaptIVe, 2017), will be used for the traffic safety simulation in L3Pilot. The safety simulations will provide information on changes in accident risk and severity within each single driving scenario, as well as the changes in the frequency of each driving scenario. These changes will be calculated for automated driving within ODD and in other situations for additional active safety systems.

STAMP approach to identify relevant scenarios

As stated earlier, the process for the identification of driving scenarios where ADF can be expected to have positive effects on traffic safety is evident. The positive effects of ADF in terms of safety can only be obtained in those situations, which are currently challenging in terms of traffic safety. The identification of the driving scenarios that could also cause negative effects is more challenging because the factors leading to these scenarios are not currently well understood. In order to clarify the picture, the STAMP approach shall be applied. It is typically used to identify a priori safety requirement for a technology – in this case, automated driving.

The STAMP method was originally defined by Leveson (2012) and implemented by Leveson and Thomas (2018). Application to automated driving has also been initiated in recent years (see for example Alvarez, 2017). In contrast to the simulation approaches that provide a tool and method to quantify the effects of automated driving, STAMP has a qualitative and system theory approach. In STAMP, safety is seen as a dynamic control problem in a systems' control structure that behaves according to the set safety constraints. Hence, accidents occur when the systems' safety constraints are violated. Systems-theoretic process analysis (STPA) is a method based on STAMP for analysing hazards and their contributing scenarios (Leveson & Thomas, 2013). The method to determine the scenarios takes a systematic approach and includes four steps (some modifications to the approach are required for L3Pilot):

1. The system engineering foundation is established by defining the target accidents, the associated hazards and resulting constraints (how can the hazard be eliminated?).

Furthermore, a control structure is defined that includes all components, which are in connection with the analysed technology as well as the sub-structure of the technology.

2. Identification of potentially unsafe control actions. The unsafe control actions are aspects that cause a hazard if they are not provided (e.g. automation does not send TOR when the ADF conditions are no longer met).
3. Definition of safety requirements, which shall prevent the occurrence of unsafe control actions. For the given an example, the safety requirement would be that the ADF must send a takeover request when the ADF conditions are no longer met.
4. Determination of how each unsafe control action could occur – meaning to define the corresponding scenarios – and to establish additional (refined) safety requirements. The definition of the scenarios associated with unsafe control actions is relevant for L3Pilot.

#### 6.3.3 Methodology for scaling up safety impacts

The objective of the scaling up is to estimate the safety effects of ADFs on a European level (EU-28). This estimation will be done in two parts. First, the impact mechanisms through which the ADFs affect traffic safety will be determined. Secondly, the quantitative estimates for the safety impacts of ADFs in the EU-28 will be calculated. The numerical estimates will be based on the road accidents documented in the CARE database (European Commission, 2019), which was chosen for the analysis due to its coverage of road accidents on a European level. CARE has some limitations, for example, in terms of quality of accident data entered in CARE by country and hence if seen necessary, and if data is available, the CARE data can be complemented with national (possible in-depth) road accident statistics.

To allow the incorporation of the results of the pilots into the scaling-up process, the driving scenarios defined in chapter 3.1.1 are mapped to the time-series data analysed in T&T evaluation and to the accident codes used in the CARE database according to Rösener et al. (2018). By this, the effects from the pilot that are investigated per driving scenario (see chapter 4.1) can be incorporated in the impact assessment and thus in the scaling-up. This process is illustrated in Figure 6.4. On the one hand, the accident statistics provided by the CARE database are delivering the number of accidents. (e.g. for a “turning with laterally moving object” scenario). On the other hand, the data recorded by the pilots deliver the necessary input to obtain the effects induced by the ADF in the considered driving scenario. These can be utilised for assessment (e.g. by simulation). Both the number of accidents per driving scenario and the effect per driving scenario are necessary to scale up the effects observed in the pilot.

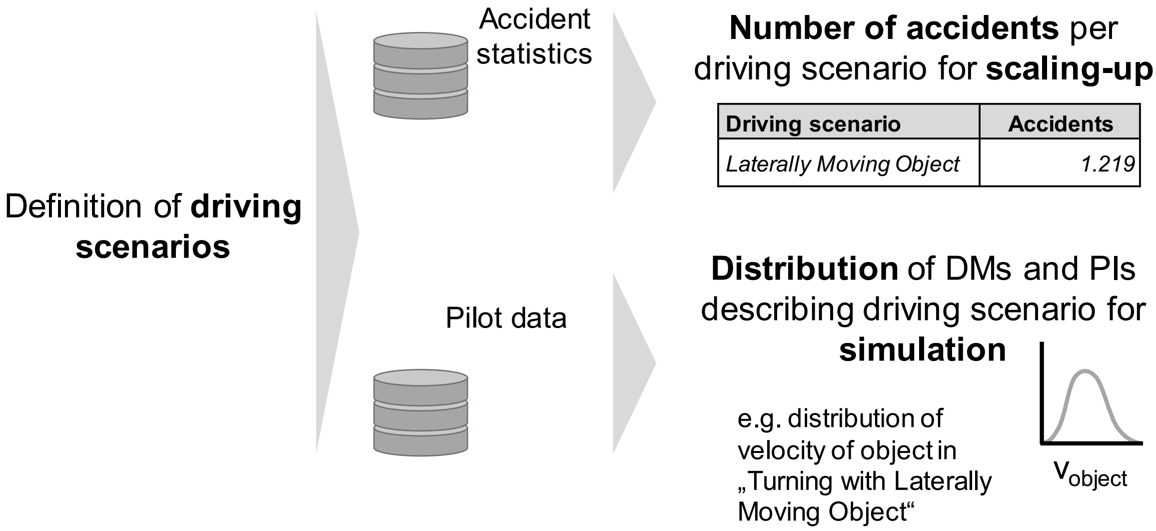



*Figure 6.4: Types of input data for scaling-up of safety impacts,  to Rösener et al. (2018).*

The assessment of the numerical safety effects in the European accident data will utilise the ERiC (European risk calculation) tool (see e.g. Silla, Leden, Rämä, Scholliers, van Noort, & Bell, 2017; Malone et al., 2014), which has been formed based on the assessment method of Kulmala (2010). The safety impact assessment in ERiC follows the earlier mentioned theoretical background of Nilsson (2004) according to which traffic safety consists of three dimensions.

In order to cover these three dimensions of traffic safety in a systematic manner, our approach will utilise the set of nine mechanisms introduced in chapter 6.1. The scaling up task starts by reviewing all nine mechanisms to assess which mechanisms are addressed by ADF under assessment – the assumption is that not all mechanisms are relevant for all ADF. Next, the list of relevant safety mechanisms for each studied ADF will be defined and the expected changes in vehicle, driver, and road user behaviour will be described and documented for each selected mechanism. This will be done based on the results of safety simulations and other assessments that are carried out in L3Pilot. In case L3Pilot does not provide sufficient data, other information sources (e.g. literature review and expert assessment of L3Pilot partners involved in the safety impact assessment) are searched.

Next, the earlier described effects of each relevant safety mechanism will be presented in terms of percentage of increase or decrease in the number of relevant accidents. The reference case for the estimates will be the baseline scenario defined in chapter 3.2.4. The safety assessment is typically carried out stepwise, starting with the definition of target accidents and proceeding by providing an estimate of effectiveness (low, medium, high). Experts will draw these estimates via an iterative approach based on the L3Pilot pilot study results, safety simulations, literature, statistics (mobility, vehicle fleet etc.), and in-depth road accident statistics. However, it is noted that the safety simulations will be the main input for mechanism 1. Some part of the expert work could be done, for example, in a workshop among partners involved in the safety impact assessment. In the end, the estimates will be reviewed and agreed upon among the experts within the safety impact assessment. In the following, some examples of potential input data (in addition to literature and expert assessment) are presented:

- Direct effects (mechanisms 1–2): Safety simulations (which are based on pilot study results), STAMP method, in-depth road accident statistics.
- Indirect effects (mechanisms 3–4): In-depth road accident statistics.
- Interaction (mechanism 5): Safety simulations, in-depth road accident statistics, AIM.
- Exposure (mechanisms 6–8): Annual survey/mobility impact assessment, pilot study results, statistics.
- Consequences (mechanism 9): In-depth road accident statistics.

When estimating the impact of ADFs on the number of fatalities and injury accidents at the EU-28 the effect estimates per mechanism will be used to calculate the overall low, medium, and high estimate on the effect of the ADF. These effects will be applied to the EU-28 road accident data, so that the distribution of the main classifying variable (e.g. accident type) weights the estimate. For example, it could be that the ADF under assessment is assumed to be effective in preventing fatalities and injuries in only one or two specific accident categories (e.g. accidents with parked vehicles and accidents with pedestrians). For some other ADF, different accident types might be considered. In weighting, the effect estimate indicated in percent changes will be multiplied by the share (%) of relevant accidents. The overall effects by mechanism will be translated into an overall effect of the ADF on all road fatalities/injuries at 100% penetration rate according to an illustrative example shown in Table 6.3. This example assumes a linear development of effects. However, in L3Pilot the validity of this assumption will be evaluated separately for each ADF under assessment.

*Table 6.3: An illustrative example of calculation of the total effect on fatalities based on percent coefficients (all mechanisms with nonzero effects are included).*

| Mechanism | Effect on fatalities | Effect, % | Coefficient of efficiency |
|---|---|---|---|
| Mechanism 1 | Decreases | -10% | 0.90 |
| Mechanism 3 | Increases | +0.5% | 1.005 |
| Mechanism 6 | Increases | +2% | 1.02 |
| Total effect (100% penetration rate of fleet) | | -8% ← (0.90*1.005*1.02=0.92) | |
| Total effect (48% of active use of ADF in traffic) | | -8%*48%=-3.8% | |

The calculation starts by converting the estimates given in percentages to coefficients of efficiency. Secondly, the total effect will be computed by multiplying the coefficients for each relevant mechanism and giving this total effect as a percentage, on the row labelled 'Total effect'. This simplified example considers only three mechanisms and one accident type. In reality, all mechanisms (with non-zero effects) will be taken into account. Also, the fleet penetration rate and the estimated non-usage of the ADF will be considered as factors reducing the effect.

The calculations to obtain the changes in the number of fatalities and injury accidents will be carried out by the ERiC tool adapted from the tool by Kulmala (2010), for structuring the accident data and effect estimates. This calculation will exploit the data from European-wide CARE database and official EU road safety statistics.

## 6.4 Efficiency and Environmental Impact Assessment

### 6.4.1 Overall concept

The objective of efficiency and environmental impact assessment is to estimate potential changes in traffic flow, travel times, average fuel consumption, and emissions with the introduction of Level 3 ADF equipped cars in everyday traffic. Key performance indicators are traffic flow, travel time and its variance, speed distributions as well as the change in average energy demand in traffic and $CO_2$ emissions. The main tool to be used in the assessment is traffic microsimulation software.

All nine impact mechanisms (see chapter 6.1) will be considered when setting up the simulation framework and defining the simulation parameters to be varied to ensure that both direct and indirect impacts are taken into account. Due to the dynamic nature of traffic, where interactions between vehicles – and road users in general – play a crucial role, the impact assessment on traffic efficiency requires considering a sufficiently large scenario at a time to allow for the dynamic situations to be captured. Therefore, only traffic scenarios are simulated in this part of the impact assessment.

Figure 6.5 shows the planned approach for efficiency and environmental impact assessment. Both direct and indirect impacts, as suggested by the nine impact mechanisms, are taken into account. Direct impacts occur through direct modification of the driving task (mechanism 1) and are due to the changes in longitudinal and lateral driving behaviour (such as headway and gap) with the introduction of ADF. Driving behaviour affects the detailed vehicle operational level, such as braking, acceleration and steering manoeuvres (assessed in L3Pilot through T&T evaluation). These direct impacts are studied with microsimulation using specific traffic scenarios with varying penetration rates.

In addition to the direct impacts through driving behaviour, also indirect impacts on traffic efficiency and the environment are possible. For example, if the ADF lead to improved traffic safety and a reduced number of accidents, also incident-induced congestion will be less frequent, improving the overall transport network performance. Similarly, impacts on traffic efficiency and the environment can occur through changes in travel behaviour (personal mobility) of individuals. For example, changes in modal split have consequences for the transport network. In addition, users may change routes favouring roads within the ODD of the functions, to avoid handovers. Indirect impacts are taken into account by varying the traffic flow in the simulations and by qualitative assessment.

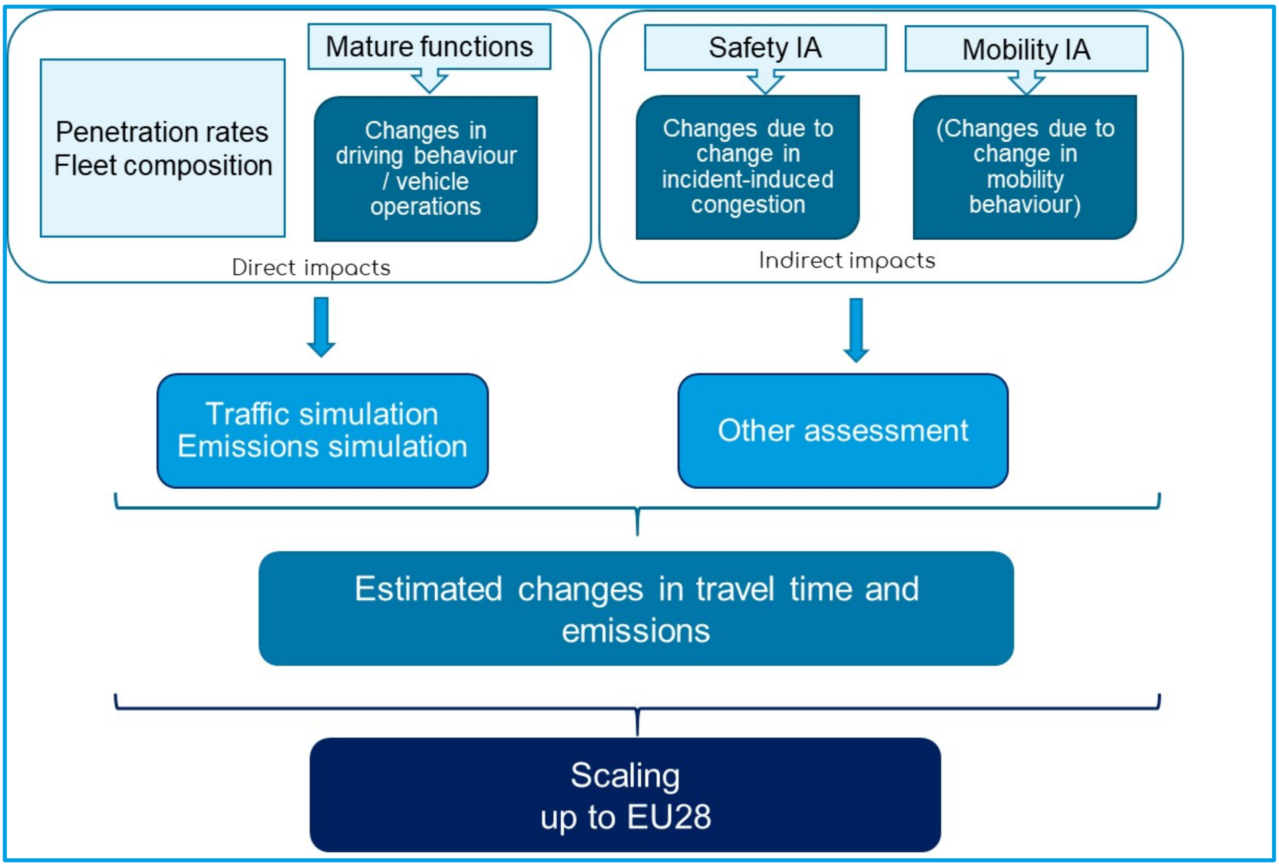



*Figure 6.5. Steps of efficiency and environmental impact assessment.*

Mature ADF descriptions are a starting point in the process, as they define the operating conditions (ODD) of the automated vehicles (see chapter 2.2). In the next step, the relevant traffic scenarios will be defined for implementation in the simulations. As additional parameters of the traffic scenarios for simulations, also fleet composition characteristics and estimates on ADF penetration rates (see chapter 9) are required. Those values can be changed in different simulation runs to study the changes in impacts with different penetration rates. Next, the actual traffic simulations are carried out for different traffic scenarios, penetration rates and fleet compositions. The results are then consolidated in workshops.

### 6.4.2 Used methods

Due to the complex nature of traffic, evaluation of impacts with direct measurements is usually not feasible. Instead, traffic simulation is a commonly used tool for impact assessment of different measures in the transport system. Simulations can be done on different levels, e.g. microscopic and macroscopic.

Microscopic models simulate the behaviour of individual vehicles on a network. Every vehicle's position, speed, headway etc. are calculated for each time step. Boundaries for the values are given as desired distributions. Microscopic modelling is often used when analysing potential impacts of changes to the traffic environment or driver or vehicle behaviour. The analysis can cover single intersections, road stretches or small networks. Simulations are flexible and adjustable and different situations such as varying penetration rates, speeds and driving behaviour can be studied quite easily. Macroscopic traffic models assess traffic flow as a whole, cover larger networks at a time and use aggregated values. They are not planned to be done in L3Pilot.

The microsimulation software PTV Vissim (PTV 2019) will be used for the simulations. Selected results of traffic simulations will then be fed into the emissions tool EnViVer (TNO 2019) for estimated changes in emissions. The potential impacts are indicated by the changes in PIs with and without the ADF.

As all models have their restrictions, it is important to be aware of the models' assumptions, restrictions and uncertainties when performing traffic simulation as well as what these restrictions mean for the validity of results. For example, conventional simulation models build on existing driver behaviour models, which are difficult to formulate and may not accurately represent human driving in all situations, and further may not be suitable for modelling automated vehicles. Therefore, it is important to realise and take into account these uncertainties. The available literature on modelling of automated driving will be exploited. In addition, sensitivity analysis can help in identifying the most relevant factors affecting the impacts of ADF on traffic efficiency and the environment.

The validity of modelling increases with the number of simulations performed as well as the number of models used. Ideally, simulations are performed with several different models to study whether similar impact estimates are found.

### 6.4.3 Evaluation plan for the research questions

Table 6.4 gives the link between the different RQs and the PIs for efficiency and environmental impact assessment.

*Table 6.4: PIs used for analysing RQs on impact on efficiency and environmental aspects.*

| RQ Level 2 | Keyword | RQ Level 3 | PI |
|---|---|---|---|
| What is the impact of ADF on transport network efficiency (throughput) in a certain traffic scenario? | Traffic flow | What is the impact of the ADF on throughput in a road section or intersection? | Nr of vehicles per hour |
| | | What is the impact of the ADF on reliability of travel time? | Travel time variance and its SD |
| | | What is the impact of the ADF on travel times? | Travel times |
| | | What is the impact of the ADF on speed differences between vehicles? | Speed distribution for whole section, also between lanes |
| | | What is the impact of the ADF on network capacity? | Network capacity, qualitative assessment |

| RQ Level 2 | Keyword | RQ Level 3 | PI |
|---|---|---|---|
| What is the impact of ADF on energy demand / pollution in a certain traffic scenario? | Fuel consumption | What is the effect of the ADF on fuel consumption? | % change in average fuel consumption in traffic |
| | Energy demand | What is the effect of the ADF on energy demand? | % change in energy demand in traffic (unit: kJ) |
| | CO2 emissions | What is the impact of the ADF on CO2 emissions? | % change in CO2 emissions in traffic |
| What is the impact of ADF on trip duration/distance? | Speed | What is the impact of a changed travel speed? | Distribution of speed, probability density function of driven velocity |

### 6.4.4 Scaling up of efficiency and environmental impacts

After impacts have been assessed for the proposed driving and traffic scenarios, upscaling is needed in order to provide estimations on the potential impacts in wider use on EU level. The methodology for upscaling of traffic efficiency and environmental impacts leans on the scaling up performed in the ecoDriver project (Jonkers, Wilmink, Nellthorp, Gühnemann, & Olstam, 2016). EcoDriver (2011–2016) was an FP7 funded project aiming to support drivers in conserving energy and reducing emissions by encouraging eco-friendly (“green”) driving. Different solutions for promoting eco-driving were developed and tested, and their potential impacts on efficiency and the environment assessed with field tests and simulation. Afterwards, the local impacts were scaled up to EU-28 level, for which a new methodology was created.

The database used for scaling up in ecoDriver will be used as a basis in scaling up of efficiency and environmental impacts of ADF. Due to the complexity and wider scope of automated driving compared to eco-driving assistance, adjustments need to be done to reflect the ODD definitions in mature ADF. This requires adding new categories to the ecoDriver database, determined by the mature ADF descriptions (see chapter 2.2). After these adjustments have been made, the data available from ecoDriver will be updated where possible. As the ecoDriver table is from 2015, no major changes are expected.

Three main groups of data are needed for scaling up: Infrastructure, traffic and weather data (Figure 6.6). In addition to these values, also combined estimates are needed, such as traffic flow information per road type and weather conditions. For some of the categories, data is available from the ecoDriver approach and can be used directly. To collect the missing data and data combinations, different databases will be explored and combined. Sources will include for example national and international statistics and map and traffic information providers, such as OpenStreetMaps. The most suitable data sources will be specified during the process.

**Infrastructure**

- Road type
- Road width, nr of lanes
- Intersection / ramp density
- Intersection types
- Speed limit
- Lane markings, road condition
- Parking, bicycle lanes

**Traffic**

- Traffic flow
- Travel times
- Peak hour traffic flow

**Weather**

*Figure 6.6: Preliminary data needs for scaling up efficiency and environmental impacts.*

Where sufficient data is not available for each country, values will be adapted from countries with similar circumstances through clustering. Categories, for which no comprehensive data will be found across Europe, transparent coefficients will be determined and applied to the data that is available. These coefficients will be determined based on all the data available from different databases, literature review and expert assessment.

## 6.5 Mobility Impact Assessment

### 6.5.1 Overall concept

Overall approach and process

Methods for mobility impact assessment aim to assess the potential impacts of ADFs on personal mobility, including travel behaviour. Multidisciplinary literature on mobility and mobility frameworks were used to define the research questions, questions to be included in user interviews, and the overall mobility assessment approach. The mobility frameworks on which the L3Pilot mobility impact assessment method bases include a mobility model that was originally developed in TeleFOT project (Innamaa, Axelson-Fisk, Borgarello, Brignolo, Guidotti, Martin Perez, et al., 2013) and used later in the DRIVEC2X project (Malone, Rech, Hogema, Innamaa, Hausberger, Dippold, et al., 2014; Mononen, Franzen, Pagle, Morris, Innamaa, Karlsson, Touliou, Montanari, & Fruttaldo, 2012). This model is described in FESTA handbook (FOT-Net, 2018) as well. Regarding mobility impacts, three points of view are identified in FESTA: amount of travel, travel patterns, and quality of travel. The main focus in mobility impact assessment in L3Pilot is on these three aspects.

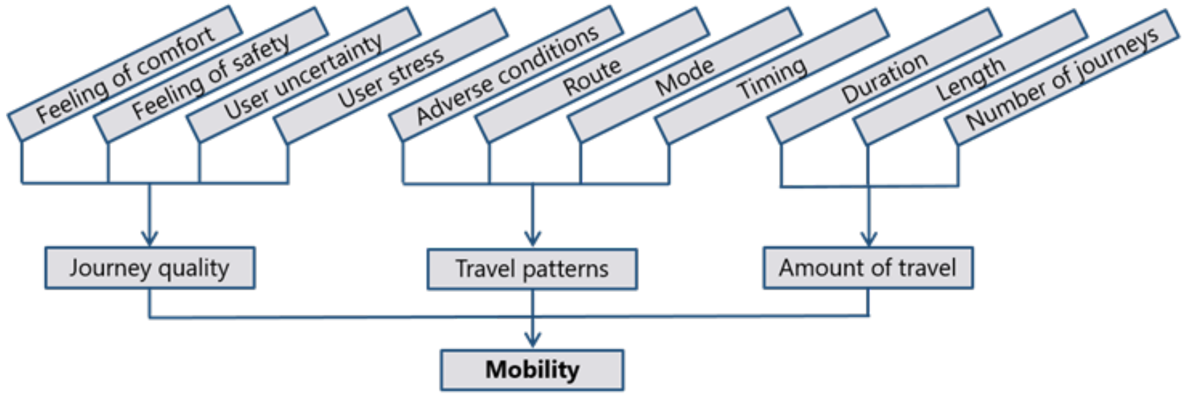



*Figure 6.7: Mobility model for impact assessment (Innamaa et al., 2013). Edited.*

As it is not possible to empirically measure the changes in the amount of travel and travel patterns based on data collected in L3Pilot tests – as the ADFs are prototypes and not yet on the market and as testing takes place in defined scenarios and not in participants' daily life – it is necessary to use complementary data and methods to assess the potential mobility impacts of ADFs. A conceptual mobility framework (Kuisma, 2017), which bases on multidisciplinary literature on the main factors affecting travel behaviour, is utilised in applying different methods, for example, interviews and focus group discussions, to learn about the potential impacts of ADFs on mobility.

The L3Pilot project provides a good opportunity to use a multidisciplinary mobility assessment approach and frameworks to define the potential mobility impacts of ADFs, and further, to answer questions about potential impacts on actual travel exposure. The L3Pilot methodology will combine actual quantitative and qualitative data on current travel behaviour in different European countries with the analysis of the perceptions and views of people that have actually experienced driving with automation in L3Pilot tests. Thus, the mobility impact assessment is linked with user evaluation and requires input from those. The user experiences are relevant for mobility in two ways: First, the experienced usefulness and comfort of ADFs presumably affect people's travel behaviour, resulting in changes in travel exposure. Second, potential changes in journey quality are relevant as such for personal mobility of people. Also, the general acceptance of ADF can make a significant difference in the future impacts of automated driving on mobility, and the results of the annual survey (see chapter 6.5) carried out in the project are therefore important input for mobility impact assessment besides the test users' experiences. Results of the mobility impact assessment will provide input for assessing ADFs impacts on efficiency, environment, and safety. They will also be used later in the scaling up of the impacts.

The overall approach for mobility impact assessment within L3Pilot has three major phases:

1. Definition of the baseline,
2. Definition of the scope for impact, and
3. Assessment of the potential mobility impacts of the ADFs (Figure 6.8).

Ultimately, the evaluation process aims to answer questions regarding how ADFs might affect the amount of travel, travel patterns, and trip quality (see Hibberd et al. (2018) for an overview of the development of the project research questions (update in Annex I of this report) and logging requirements).

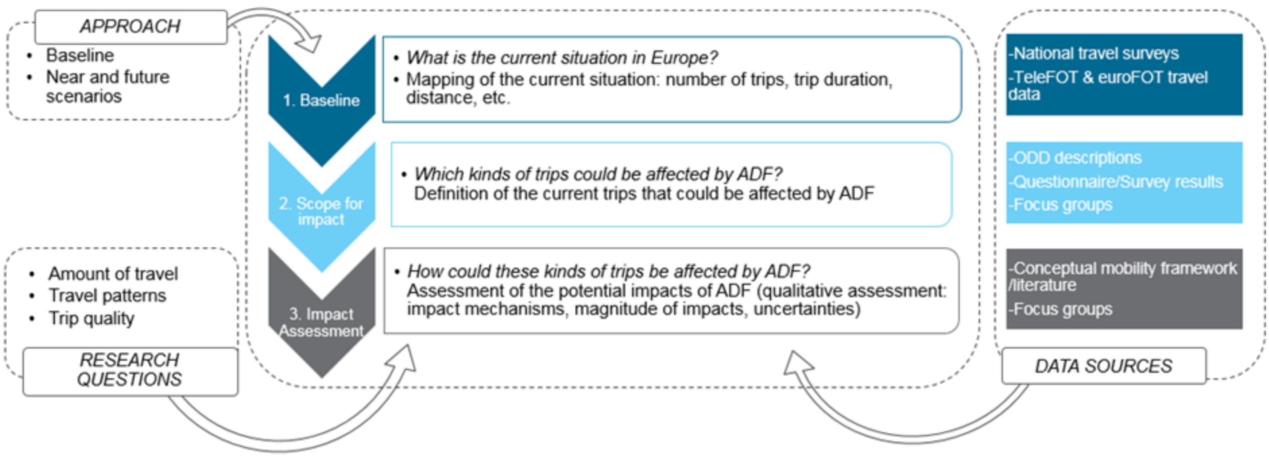



*Figure 6.8: Overview of the L3Pilot methodology for mobility impact assessment.*

### 6.5.2 Evaluation plan: Defining the baseline

The baseline used for analysis will be data collected on current travel exposure in Europe. During this phase, a broad range of sources will be explored, such as data sets derived from national travel surveys (subjective data) and actual travel data from previous projects, for instance, TeleFOT (Innamaa et al., 2013; Schulze, Mäkinen, Kessel, Metzner, Stoyanov, 2014) or euroFOT (Kessler, Etemad, Alessandretti, Heinig, Selpi, Brouwer, Cserpinkzky, Hagleitner & Benmimoun, 2012). The existing travel data includes information about the amount of travel and travel patterns. The trips made by people can be clustered by any number of factors, for example, by the place of residence or household structure socio-economic factors. This way, baseline data can be set for different groups of people according to the requirements for assessment. Some datasets, such as certain travel surveys, include also trip quality aspect. Baseline data on the subjective experiences of current travel patterns can also be set by using data from the L3Pilot test site questionnaires, annual survey, focus groups, and interviews.

### 6.5.3 Evaluation plan: Defining the scope for impact

The scope for impact phase addresses the potential users' current trips and travel options that could be affected by using one or more of the four ADFs. This phase is based on two main sources of information. First of them is the ODD defined for each ADF, specifying the conditions under which the ADFs are assumed to work (see mature function definitions, chapter 3.2). These conditions include, for example, infrastructure needs or road types, weather conditions, and speed limits. In other words, it is to be defined for what trips automation would be available. The second source of information is drivers' willingness to use the ADF and their perception of the ADFs' usefulness for different trips. This information comes from user and acceptance evaluation performed during the project. This will be done for the four ADF types investigated in L3Pilot.

Besides the scenarios, the user groups in focus of the L3Pilot approach are going to be defined to meet the evaluation needs and to provide insights for the mobility research questions. Examples of the aspects that can be analysed include users' age, household structure, household income, vehicle purchasing decisions (intention for next car acquisition, frequency of changing cars, and intention for car investment), technology attractiveness, driving history, and use of different travel modes.

### 6.5.4 Evaluation plan: Assessing the potential impacts

The last phase of L3Pilot approach, the assessment of the potential mobility impacts, will focus on the use of qualitative assessment methods, in addition to quantitative analyses on potential magnitudes of impacts. As this project relies on pilot testing of prototype vehicles and the test users are experiencing the ADFs under test situations – not in their everyday lives – using real measurement data of the trips in assessment is not possible. We, however, have valuable access to the perceptions and views of users that have experienced the ADFs. User surveys (questionnaires) and focus group discussions are used to gain information about the ways the users assess automation as a part of their mobility. The real experience with ADFs also gives higher reliability to, for example, stated preferences regarding individual travel behaviour.

In the assessment of the potential mobility impacts of automation, the multidisciplinary literature on mobility and mobility frameworks will be utilised together with results from interviews and focus groups. After defining the baseline and the scope for impact, this phase of approach is aimed at assessing the potential impacts within the defined scope. The assessment will aim to answer the research questions.

### 6.5.5 Methods and data sources for answering specific research questions

Table 6.5 summarises the methods and data sources used for assessing the impact of ADFs on mobility.

*Table 6.5: Methods and data sources used for analysing RQs on impact on mobility. Detailed information on questionnaire items to be used can be found in Annex 2.*

| Research question | Potential methods | Data sources |
|---|---|---|
| What is the impact of ADF on number of trips made? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects<br>Impacts: pilot site surveys annual survey, focus groups |
| What is the impact of ADF on trip distance? | Baseline definition, analysis of survey responses (per each user group), focus groups, alternative route analysis, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects<br>Impacts: pilot site surveys, annual survey, focus groups |

| Research question | Potential methods | Data sources |
|---|---|---|
| What is the impact of ADF on trip duration? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects<br>Impacts: pilot site surveys, annual survey, focus groups |
| What is the impact of ADF on mode choice? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects<br>Impacts: pilot site surveys, annual survey, focus groups |
| What is the impact of ADF on timing of trips? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects<br>Impacts: pilot site surveys, annual survey, focus groups |
| What is the impact of ADF on the frequency of road type usage? (urban, rural, motorway) | Baseline definition, analysis of survey responses (per each user group), focus groups, alternative route analysis, scaling up of impacts | Baseline: objective travel data from earlier projects, national travel survey<br>Impacts: pilot site surveys |
| What is the impact of ADF on quality of travel? | Interpretation of the results of user evaluation (impacts of ADF on user comfort, stress, reliability and perceived safety, possibly the use of travel time to other than driving activities), focus groups | User evaluation results |

# 7 Methods for socio-economic impact assessment

## 7.1 Overall concept of socio-economic impact assessment

The fundamental research question in L3Pilot concerns the socio-economic impact of ADFs, which are designed for motorway, traffic jam, urban and parking environments: What is the overall socio-economic impact of ADFs?

This implies that the assessment of the socio-economic impacts is concerned with the net welfare gain of each ADF for society. However, the economic impacts may also be estimated for different stakeholders. The purpose of the socio-economic impact assessment is to clarify whether the benefits of equipping vehicles with ADFs outweigh their costs. If this is the case, the implementation of the technology is considered to be beneficial to society and/or the stakeholders.

The impact of ADFs may be assessed for each ADF in isolation or as a bundle of all functions. The focus of the socio-economic impact assessment will be on the former, but may also consider the assessment of the impacts as a bundle. There are several reasons for assessing the socio-economic impacts of each ADF in isolation. ADFs are tested separately in the on-road tests. Hence, the advantage of conducting separate analyses instead of analysis of bundled functions is that it would be possible to isolate the impact of each ADF, and hence avoid double counting of the impacts. In addition, not all drivers will be interested in equipping vehicles with a bundle of ADFs. They may only be interested in one particular ADF and consider the cost for purchasing a bundle of ADFs as high. However, since some sensors in an ADF, e.g. motorway ADF, can also serve in another ADF, e.g. traffic jam, then the marginal cost of equipping a vehicle with several functions may not be as high as the costs in isolation for each ADF.

### 7.1.1 Cost-benefit analysis

A commonly used method of socio-economic impact assessment is cost-benefit analysis (CBA). CBA is a systematic method for evaluating expected costs and benefits of implementation of a project, for example, investment in transportation systems, a technology, or a service, compared to a situation without the implementation of that project. CBA is grounded in welfare economic principles and is widely used to clarify whether the implementation of a project is beneficial from the society's point of view. Therefore, CBA often serves as an important support tool for the authorities in their decision making.

### 7.1.2 Traditional CBA approach

In CBA, a reference scenario (baseline) is compared to one or more alternative scenarios. This implies that the baseline is a reference point that reflects how the world is expected to develop in the absence of a particular project or product, while the alternative scenario reflects how things would develop with that project or product. Hence, the impact of the project is measured by the difference between these scenarios.

In many cases, such as transportation-related investment projects, benefits and costs of a project accrue over a period of time, for example, 10 to 30 years. Therefore, the main policy concern is to clarify whether such an investment is a good way of using society's scarce resources and to decide whether to invest in the project or not. This is an ex-ante perspective. By assigning economic values to the impacts of a project over a specific time period, the net present value (NPV) of the project can be calculated. The NPV represents the total present value of the project's benefits minus the present value of all costs over the project's life cycle.

### 7.1.3 Simplifying the traditional CBA approach

In L3Pilot, the experiments are based on testing of vehicles (prototypes) equipped with ADFs in real-life-traffic situations, thereby providing the basis for assessing the impacts of ADFs with regard to traffic safety, efficiency, and the environment. Since the ex-ante perspective is forward-looking, it is necessary to compare an expected development without ADFs (baseline) to a situation with these functions (alternative scenario/s).

To fully comply with the ideas of the traditional CBA, it is necessary to forecast reliable future scenarios in order to calculate the NPV of the different ADFs. However, as the ADF technology in L3Pilot already is practically developed, it does not make sense to construct a future scenario without this technology. In addition, it is extremely challenging to construct reliable scenarios by forecasting how the traffic situation in Europe would develop with the automated driving functions in question for the next 10-30 years. Such forecasting should rely on assumptions with regard to the technological progress in the automotive industry, legislation, government policy, and consumer demand for ADFs, all of which are factors that will determine to what extent the technology in question is implemented, and when. Furthermore, another challenge is related to the parallel development in other areas which would affect people's mobility choices, such as sharing economy, new mobility concepts, electrification of vehicles, urbanisation, etc. Therefore, the impacts of these factors with and without the ADFs need to be predicted, which would be an impossible task. A further challenge is that even with the prediction of the deployment path for the ADFs, there are always high uncertainties involved when predicting the future market take-up of a technology which does not exist yet in market-ready form and of which user acceptance we do not know of. Thus, the real target year(s) for the future scenario(s) would include uncertainty anyhow.

The arguments above imply that the most common steps in conducting a cost-benefit analysis are not quite applicable for the socio-economic assessment in L3Pilot. This is because regardless of how the scenarios are constructed, the reliability of their content will be questionable. This will draw attention away from the essence of the cost-benefit analysis, which is to calculate the social net value of the ADFs.

Rather than trying to apply a traditional CBA approach with forecasting of how the world would develop over the coming decades with and without the automated driving functions, it is aimed to simplify this approach. Inspired by the slogan of keeping things simple, a "snapshot" of the world today is used as the basis for analysis. Hence, the baseline scenario is the world of today, which is without the technology in question. Alternative scenarios are then to be created by investigating how traffic impacts on safety, efficiency and the environment would have changed if a proportion of the vehicles in the world of today had been operated with ADFs. In this way, it will be possible to capture the pure impacts of implementing ADFs.

By using the simplified approach above, the aim is to investigate how much higher or lower the welfare would be if (a certain proportion of) today's vehicles had been operated with ADFs. This means that a context is created where nothing happens except for the introduction of cars with the relevant ADFs, assuming that today's infrastructure is adequate for ADFs to operate properly (e.g. road markings). Economists will call this approach a comparative static analysis, ceteris paribus. To interpret this literally, it implies that the society is in a steady-state, in an otherwise fixed and stable situation, meaning that nothing happens except for the introduction of vehicles with ADF technology in the current traffic situation.

The advantage of using such a snapshot approach is that official public statistics for the latest available year will form the basis for describing what the world would look like without the new technology. In L3Pilot, it will presumably be the year 2017 or 2018 depending on the availability of the relevant accident statistics and other statistics. This means that the baseline in our approach, reflecting the world of today without ADF technology implemented, can build on statistics regarding accident rates, accident severity, traffic flows, and so on.

Since it is chosen to focus on a snapshot of the net welfare effects in one year, it implies that the traditional NPV is to be replaced with the annual net benefits. Positive annual net benefits imply that implementation of ADFs is beneficial for the society and vice versa.

### 7.1.4 Operationalising the snapshot approach

Ideally, the penetration rate for the new technology in use should be endogenous i.e. determined by how potential users perceive the benefits of vehicles with the relevant ADFs compared to vehicles without and other ways of travelling than driving. It is challenging to determine the endogenous penetration rates at the EU-level regarding individual choice and effects on traffic patterns. Therefore, the simpler approach of experimenting with different exogenous penetration rates is chosen.

Exogenous penetration rates imply that the size of the fleet of vehicles eligible for the relevant ADF is constant. Each vehicle with the ADFs replaces exactly one without. This implies that apart from the fact that some drivers choose vehicles with relevant ADFs, all travellers continue to travel in the same way as before. The personal mobility impact assessment may reveal some effects in terms of route change (e.g. in favour of motorways that could be expected due to the use of motorway function). However, these will most likely have no major effects on travel behaviour and traffic patterns, and hence, there should be no serious objection to the exogenous penetration rates approach.

In order to conduct the analysis along the lines above, an assumption is needed on how vehicles in the world of today are replaced with vehicles equipped with the relevant ADF. The current stock of vehicles consists of different levels of automation: L0, L1 and L2. The cost-benefit analysis shall capture the impacts of vehicles equipped with the new technology.

It is reasonable to assume that the new vehicles that are introduced in the context of today replace the oldest ones in the current stock of the vehicles. This implies that we need information on the current distribution of vehicles across the different levels of automation, i.e. L0, L1 and L2. The next step is to elaborate on the magnitude of impacts by assuming different penetration rates for the new technology:

- What does it mean if the ADF is installed and activated during a trip in 5, 10 or 30 percent of vehicles without any ADF?
- What does it mean if the ADF is installed and activated in 100 percent of all vehicles?

The lower penetration rates indicated above reflect the most realistic future deployment of vehicles with ADFs, while the extreme case of 100 percent penetration rate is meant to capture the (theoretical) full potential impacts of the ADFs, as if the installation of the technology, as well as its active usage, were mandatory in all vehicles. In either case, the difference in net welfare impacts between the situations with and without ADFs will depend on the fraction of vehicles with activated ADFs (ADF in use within the ODD) on the roads.

### 7.1.5 Applicability of snapshot approach in CBA

The proposed snapshot approach above differs from the traditional CBA approach. However, it is not unique for L3Pilot. The euroFOT project also used a snapshot CBA approach for investigating the impacts of in-vehicle functions on traffic safety, traffic efficiency, and the environment (euroFOT, 2012). The in-vehicle functions in the CBA included FCW and ACC, which were grouped to one bundled function and scaled up at EU-27 level. Assuming that all cars were equipped with the relevant FWC/ACC technology, the expected annual impacts for the whole EU-27 given the traffic context of 2010 was estimated. The impacts were estimated for traffic safety, traffic efficiency, and the environment for a scenario where 100% of the vehicles were equipped with FWC/ACC technology. Impacts were also estimated for a penetration rate of 10%.

The snapshot approach in euroFOT has clearly some similarities with the one in L3Pilot. Neither constructs a future for the next 10 to 30 years with or without the technology. Both use the current situation as the baseline. Both manipulate the current situation to illustrate what it would have looked like if all or a fraction of the vehicles had been equipped with the technology in question. However, a snapshot is considered an unusual approach when it comes to CBA in general. That is why, in contrast to euroFOT, explicit arguments are provided for why this approach is preferable.

## 7.2 Analysis level

### 7.2.1 Dimension

The socio-economic impact assessment is to be carried out at EU level. Correct identification of all costs and benefits of ADFs across the EU countries and aggregation to EU-28 level is challenging. Simulation models in impact assessment partly rely on assumptions, data may not be available for all EU countries, contributing to challenges in scaling up and aggregating of the impacts at EU level. Therefore, it might be worthwhile to conduct a CBA at smaller scales than the EU level. In-depth studies of one or two countries with the most reliable information foundation could be useful in this regard. Sensitivity analysis is also a good way to take account of uncertainties in cost-benefit analysis. In addition, in-depth studies of travellers who represent important groups of travellers in these countries may provide important additional information, which is more detailed and easier to interpret. Here the results of the mobility impact assessment can be used.

### 7.2.2 Stakeholders

The welfare effect for a society is the difference between benefits and costs to all stakeholders in the society (i.e. individuals/households, producers and the government). In the context of L3Pilot, individuals are not only those who travel with ADFs, but also those who travel using conventional vehicles or other modes of transportation (e.g. bus, train, bicycle, etc.). These are travelling individuals. In a society, there are also individuals who do not use the above travel modes and hence are considered as non-travelling individuals. Producers are all manufacturers of vehicles and suppliers of ADF technology, while the government in this setting consists of the authorities in charge of road infrastructure and providing health care for the society.

In the CBA, it is convenient to distinguish between the following types of stakeholders: users of ADF equipped vehicles, other travellers, producers, the government and the rest of the society.

Travellers and non-travellers

When choosing how to travel from one place to another, travellers consider direct travel costs, travel comfort and travel time. Travellers may also consider the risk of possible accidents. As an example, travellers' expected welfare will increase if the expected accident cost decreases and/or its variance (or standard deviation) is reduced. Generalized travel cost (GTC) has often been used in transport economics for measuring travellers' costs (see e.g. Bruzelius, 1981). GTC consists of the sum of monetary and non-monetary costs of transport/trip, for example, costs of fuel, parking, tolls, value of travel time, etc. for travelling individuals. A decrease in expected GTC or its variance (or standard deviation) will imply higher welfare for travellers.

Drivers of vehicles with ADF technology may also experience that driving becomes more comfortable, and that time spent on the road may have some productive or recreational value because the ADF assist the driver during the trip. Such effects are taken into account as a reduction of GTC. Net welfare gains for these drivers depend on the extra monetary costs of ADFs (market price of purchasing ADFs, maintenance costs, etc.).

Furthermore, other travellers may also be affected as they are likely to experience that expected accident costs or travel costs will change. For these travellers, there are no extra monetary costs to pay, for example, costs of buying ADF equipment. Such indirect effects represent externalities. By externalities, it is meant that other travellers, both those who drive conventional cars, those who use other travel modes and pedestrians may gain from the benefits of ADF technology without having to pay for it directly. This is, in fact, a positive externality. In such situations, government intervention may be welfare improving. Intervention by the government can be in the form of subsidies provided for the drivers of ADF vehicles, e.g. reduction in or exemption from road charges and to have plans for making the equipment mandatory. A complete socio-economic analysis also needs to consider benefits and costs affecting other stakeholders than travellers, i.e. producers, the government and the rest of society.

Producers

Producers are manufacturers of vehicles with ADFs. If the ADF technology allows producers to increase their profit margins, the net gain of producer surplus should be included in the CBA. However, we do not expect that competition, and hence producers' profit margins, will be affected by the introduction of ADF technology, which means that this possible impact may be neglected. Therefore, producers' perspective is not part of the CBA in L3Pilot.

Government

In socio-economic impact assessment, it is necessary to keep track of the effect on the government's budget (called *budget effect*), not because the government in itself counts in the welfare calculations, but because a positive budget effect gives rise to extra public services and/or tax relief for taxpayers. A negative effect on the government budget has to be financed through reduced service production and/or tax increases. Since taxation has negative incentive effects, it is usual to say that an (extra) euro into/out of the government budget is worth more than an (extra) euro into/out of a private pocket.

In L3Pilot, relevant budget effects may be direct effects related to using vehicles with automated functions, but more importantly, budgetary consequences are also associated with necessary infrastructure investments. If infrastructure investments or adjustments to the existing road infrastructure are not required for the operation of vehicles with ADFs, then there would be no budgetary consequences for the government. In the snapshot approach, it is assumed that the existing infrastructure is capable of handling ADF equipped vehicles, and hence infrastructure-related costs do not need to be included in the CBA. However, if the functionality of ADFs (e.g. with extended ODD) depends on infrastructure adjustments or investments, then these costs should be taken into account in the analysis.

The government is also the main provider of healthcare services. A reduction in the number and severity of traffic accidents is likely to reduce public expenses for the handling of accidents and injuries such as costs related to the involvement of police and rescue teams along with healthcare costs for the injured. The CBA should, therefore, include these budgetary effects.

Rest of society

Within economics, it is well established that significant improvements in travel efficiency may enlarge labour markets and enhance productivity (Venables, 2007), which are referred to as wider impacts. There is, however, no reason to expect that vehicles with L3 ADFs will affect traffic efficiency in a way that such wider impacts can be expected. Thus, the potential for wider impacts regarding changes in the labour markets and productivity may be negligible. Realistically, notable impacts on traffic efficiency, and hence, effects on the labour markets and productivity as such may be expected to arise from higher automation levels than L3 ADFs. Therefore, the topics of wider impacts will most probably deserve to be addressed when investigating the impacts or L4 and L5 ADFs, where the vehicles handle all driving tasks (L4) and fully automated driving with no need for a driver (L5).

## 7.3 Assessment of costs and benefits

The core element of the socio-economic impact assessment relies on the outcome of all impact assessments of ADF, revealing the potential benefits of ADFs in terms of traffic safety (e.g. change in accidents), efficiency (e.g. change in travel time) and environmental effects (e.g. change in $CO_2$-emissions). All potential impacts of ADFs (see following sections) should in principle be captured in the socio-economic impact assessment, along with all relevant benefits and costs. Figure 7.1 illustrates an overview of the overall socio-economic impact assessment in L3Pilot.

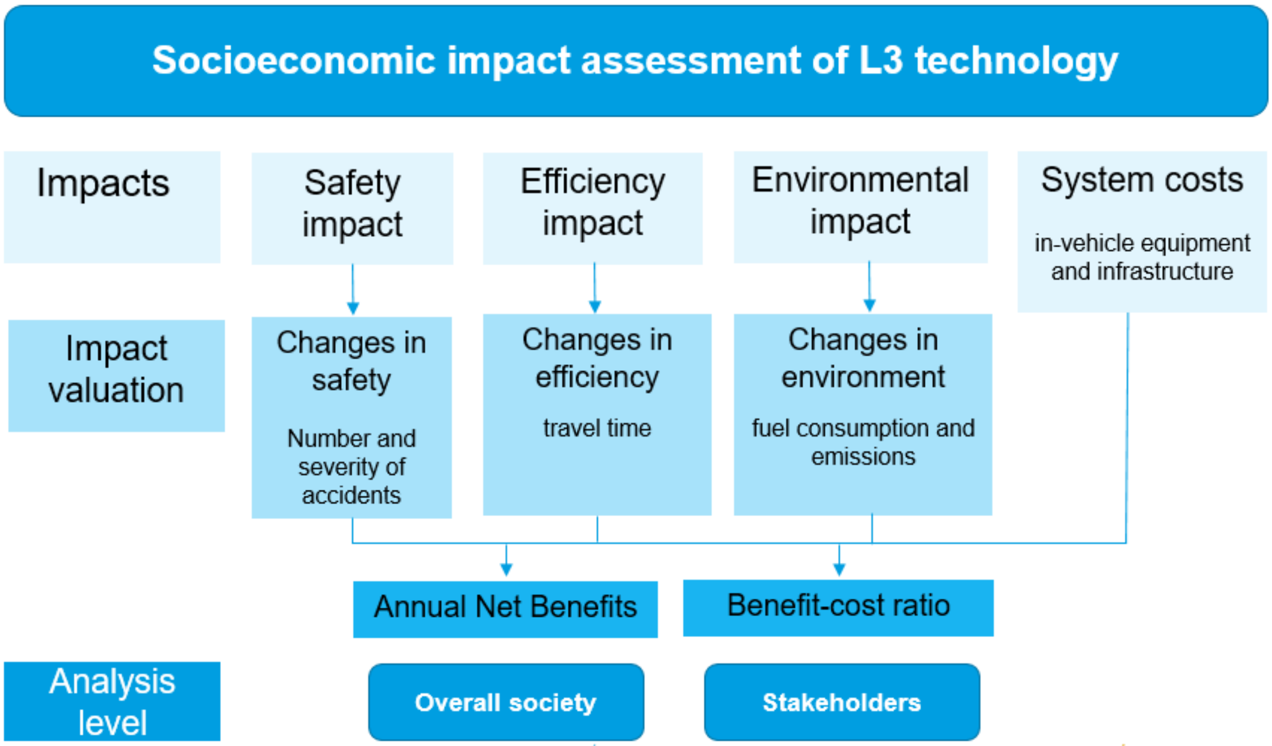



*Figure 7.1: Socio-economic impact assessment.*

### 7.3.1 System costs

System costs involve the costs of investing in AD research and advanced engineering, installing ADF systems, but also their operating and maintenance costs, if applicable. In addition, system costs are related to road infrastructure costs and road infrastructure-related costs, i.e. operating and maintenance costs. However, the impacts assessments on safety, efficiency and the environment assume no change in the existing infrastructure, i.e. the effects are estimated within the current ODD. Therefore, the CBA does not need to include other costs than those related to installing and maintaining in-vehicle ADF systems. However, the functionality of the ADFs on the roads may depend on adjustments in the existing road infrastructure such as traffic signs and road markings. In that case, the CBA may also investigate the economic value of ADF impacts if the road infrastructure investments are required, i.e. by enlarging the ODD for ADF technology. Then the additional costs related to investments and maintenance of the road infrastructure have to be included as well.

### 7.3.2 Expected impacts

Safety impacts

Potential safety impacts of ADFs are related to changes in the number of accidents, injuries (minor and severe) and material damage to vehicles. A further impact of the ADFs is the change in perception of safety due to the expected change in the number of accidents. Vehicles with ADFs are expected to provide safer driving by reducing the human error, and thereby reducing the frequency/likelihood and severity of accidents compared to conventional vehicles.

The parking ADF handles the actual parking manoeuvres and the final stages of driving to the parking spaces at private homes, dedicated parking areas or public parking. The potential benefits of automated parking are expected to arise mostly from increased safety, decreased driver stress and increased comfort.

Efficiency impacts

Efficiency impacts of ADFs consist of direct and indirect effects.

- Direct effects result from the impact on vehicle operations (e.g. car following, speed selection, etc.) and changes in traffic flow (e.g. where the ADF allows re-routing to avoid congestion, or where the ADF encourages safe car following behaviour).
- Indirect efficiency effects are expected to result from changes in accidents and resulting delays, and from changes in travel behaviour.

Traffic efficiency impacts of ADFs can also be expected in terms of changes in travel time due to changes in traffic flow and congestion costs. For instance, a reduction in accidents may indirectly lead to reduced travel time due to less accident-induced congestion. However, if people tend to drive with speeds clearly higher than the speed limits without ADFs, travel times may increase, as ADFs do not drive faster than their programmed speed limit. Thus, whether the overall impact on travel time is positive or negative is to be found out.

Time spent while driving conventional vehicles cannot be used to perform other activities. ADFs can facilitate the driving task, which makes it possible to spend parts of the travel time engaging in other activities. Travel time has a positive monetary value if it is possible to work while travelling. This is called *productive value of travel time*. Travel time has also a positive monetary value if it becomes possible to relax in the car while travelling, which is referred to as *recreational value of travel time*. Performing other activities while driving can be seen as time savings, which can be included in the CBA by monetising the value of time per hour depending on the type of activity. Time saved which is spent on work (productivity) has a higher value than time-saving for recreational activities (Henscher, 1977). Some measures for the value of time can be derived from the literature (see e.g. Wardman, Batley, Laird, Mackie, Fowkes, Lyons, Bates, & Eliasson, 2013).

Environmental impacts

Environmental impacts of ADFs are expected from changes in fuel consumption and $CO_2$-emissions. Potential benefits result in terms of reduced fuel consumption and $CO_2$-emissions. However, if drivers of vehicles with ADF tend to drive longer distances, or if other travellers and non-travellers find it attractive to buy automated vehicles, this could lead to increased traffic volume and thereby increased emissions.

The environmental impacts of the ADFs are mainly related to the mature urban, motorway and traffic jam ADFs. For parking ADF, there are no major effects expected on emissions or traffic flow. This is because the actual distance to the parking space might be limited and because the parking function operates at low-speed levels.

Summarized, the expected impacts of ADF are:

- Changes in traffic safety in terms of the number of accidents and their severity.
- Changes in traffic efficiency due to changes in traffic flow and congestion, which may affect the time spent travelling.
- Environmental impacts due to changes in fuel consumption and $CO_2$-emissions.

The above-mentioned impacts can be either positive or negative, depending on the characteristics of the ADF and potential secondary effects.

### 7.3.3 Monetary valuation of impacts

The socio-economic impact assessment of ADFs should include all costs and benefits related to safety, efficiency and environmental effects of the new technology. This is done by assigning monetary values to these effects. We acknowledge that all relevant costs and benefits are not reflected in market prices, for example, the monetary value of avoided fatality, $CO_2$ emission costs and so on. In order to calculate the overall economic values of the ADF impacts, the estimated changes in individual fatalities and injuries, travel time, fuel consumption and $CO_2$ emissions are to be multiplied with generally accepted cost unit rates.

Safety impacts of ADFs are related to changes in accidents. The economic value of changes in accidents can be derived from costs of personal injuries and property damage. Costs of personal injuries include health care costs for treating the injured and administrative costs related to injuries such as rescue services, police reports and even judiciary costs. Productivity loss because of injuries and reduction in quality of life (either temporarily or permanently) are also related to injury costs. For the property damage, costs to transport authorities (police, rescue teams, etc.) come in addition to repair costs or vehicle replacement costs. However, obtaining costs for all of these areas is practically not possible. Therefore, in practice, only the major components of costs are usually included in the cost-benefit analysis, e.g. health care costs and costs of property damage.

Further safety impacts due changes in accidents can be obtained by applying economic values to these changes, where there are no cost statistics available, e.g. fatalities. Avoiding fatality means saving human life. Therefore, by quantifying the value of a saved life, the benefits of avoiding a fatality could be measured. Value of statistical life (VSL) is a common measure for the valuation of a fatality avoided (Ashenfeller, 2006). VSL is based on estimating how much people are willing to pay to reduce the risk of death. VSL varies across countries as countries differ with respect to GDP per capita. The literature provides some statistics for VSL for some EU countries (e.g. Bickel, Friedrich, Burgess, Fagiani, Hunt, De Jong, et al., 2006).

Traffic efficiency impacts of ADFs are changes in travel time due to changes in traffic flow and the amount of congestion. Travel time costs refer to the amount of time spent on the road and its best alternative use. For example, any reduced travel time can be spent on performing activities such as work/business, personal, recreational or leisure activities. Travel time is usually valued as percentage of average wage based on the estimates of what people would be willing to pay to reduce travel time (Henscher, 1977). The monetary values of time savings vary depending on the type of activity. For instance, time-saving spent on business has a higher monetary value than time savings spent on personal travel (Wardman et al., 2013). To give another example, the unit prices for travel time and delays are higher for freight transport than for passenger transport. The monetary value of time savings in uncongested and congested traffic may also differ. The different unit values for time are reported for some countries in the literature. Environmental impacts are associated with changes in fuel consumption and hence changes in $CO_2$-emissions, which also have monetary values.

## 7.4 Data required for CBA in L3Pilot

The main task of the CBA is to find out whether ADFs are beneficial from society's point of view. To that end, data are needed for the baseline and treatment scenarios. The calculations will be done for each of the ADFs (motorway, traffic jam, urban and parking) within the current road infrastructure, based on different (exogenous) penetration rates of the activated ADFs (usage rate) of the new technology in each case. Input data requirements may vary between the different ADFs. We will also attempt to calculate the net benefits of enlarging the ODD for ADF technology, which means that also additional costs related to investments and maintenance of road infrastructure will have to be included.

The data required for the CBA will originate from the impact assessments on traffic safety, efficiency and environment, scaled up to EU-28 level. Also, some of the results from pilot site questionnaires and annual surveys will be used in the analysis, e.g. answers to questions on willingness to use and willingness to pay. Finally, other data sources such as official statistics are required to provide further data for the analysis, in particular concerning standard unit costs.

The analyses can be carried out at different levels of aggregation. At the top is the EU-28 treated as one entity. As standard unit costs are not well established at this level, it might be interesting to supplement these analyses with more in-depth studies of one or two countries with good data coverage (and perhaps representative travellers within specific traffic situations). Accordingly, input data are needed for different levels of aggregation, which also should guide the up-scaling of results from experiments and simulations.

### 7.4.1 Input from impact assessment

The impact assessment reveals the potential effects of ADF in terms of safety, efficiency and the environment. These data will be integrated into the CBA model.

The CBA analyses will use input at the EU-28 level for each of the four ADFs and for the in-depth analysis of specific countries (and for the representative traveller level in specific traffic situations). Countries and traffic situations will be specified later. It means that information is needed on how baseline variables are expected to change if different fractions of vehicles had been operated with the tested automated driving functions.

Details on specific input data will not be reported in this deliverable. In general, the following areas from impact assessment describing the expected difference between baseline and treatment conditions will be used in the CBA:

- Accidents and safety from the safety assessment,
- Travel time from the efficiency assessment,
- Environmental effects from the environmental assessment,
- Additional effects from the mobility assessment,
- Expected effects on comfort and performing secondary tasks,
- Uncertainty from the efficiency and safety assessments
  Effects on uncertainty related to travel time (reliability, punctuality) and perceived risk of accidents.

### 7.4.2 Input data from other sources

As mentioned above, the impacts of ADFs are derived from the changes in accidents, travel time savings, reductions in vehicle operating costs (fuel consumption) and $CO_2$ emissions. Given the results from the impact assessment, a major task in the CBA analysis is to assign monetary values to the impacts reported in some technical units. CBA should, however, include all safety, efficiency and environmental benefits and costs of ADFs, both in monetary and non-monetary terms and those which may be addressed qualitatively.

Monetary costs of accidents involve property/material costs and personal costs such as hospital costs due to accident injuries. The cost data for accidents should be based on available hospital treatment costs and insurance claims for property damage. Non-monetary costs of safety impacts are related to personal injuries, both fatal and injuries.

Changes in travel time also have a monetary value. The monetary value of time spent on productive or recreational activities, or depending on the trip purpose (work or leisure) can be found for some countries in the literature.

There are some studies in the literature, which provide estimates of the different unit values for some European countries (e.g. Bickel et al., 2006). These values can be applied in cost-benefit analysis for calculating unit values at EU-28. Input is needed at EU-28 level (averages), country-level (as well as representative traveller level) for the traffic situations to be considered. The following provides an overview of input is needed:

- Safety: Cost of accidents of different types per unit (same classification as above),
- Travel time: Value of time per unit (same classification as above),
- Emissions: Cost of $CO_2$-emissions per unit and fuel costs per unit, e.g. litre per 100 km driven,
- Uncertainty: Willingness to pay for reduced uncertainty (travel time and accidents).

In addition, the following cost components are included in CBA:

- System costs: These costs consist of costs of equipping vehicle with ADFs, operating costs and maintenance costs of ADFs. Benefits and costs of ADFs should be calculated so that they cover the same time period when it comes to system costs. It means that the cost of equipping the vehicles with ADFs should be annualised by discounting for the number of years, which the equipment is expected to last.

Other cost-benefit calculations include insurance premiums (with and without ADFs), and user charges if applied (subsidies for equipped vehicles: tolls/road charges, parking fees).

### 7.4.3 Input from L3Pilot surveys

In L3Pilot, two main types of surveys are conducted. One is the pilot site survey addressed to users of the ADF equipped vehicles, i.e. in real-life traffic (see chapter 5.2). The other type is an annual survey in seven European countries and two overseas countries (see chapter 5.5). The pilot site questionnaires are conducted once per participant and are to be answered by participating drivers (users) and accompanying passengers. The timeline for annual surveys is three years and they are to be conducted among the general public. Both pilot sites and annual surveys contain questions regarding travel behaviour and willing to use the ADFs, among others. The surveys also include questions regarding willingness to pay (WTP) for each ADF. WTP is a tool for measuring the price that respondents are willing to spend on a product. In L3Pilot, WTP aims at capturing the individuals' demand for equipping their vehicles with ADFs based on their preferences, i.e. according to what they are willing to pay for each ADF. In CBA, the benefits and costs of ADF technology can be assessed without asking potential users and others about their perceptions of this technology. However, a WTP study can provide supplementary information for the socio-economic impact assessment by revealing individuals' preferences for ADFs.

## 7.5 Summary

This chapter has provided the methodology framework for the socio-economic impact assessment of ADFs related to traffic safety, efficiency and environment. An important step in the methodology was to discuss to what extent the traditional and widely used CBA approach regarding constructing future scenarios and discounting was applicable in the case of L3Pilot. Therefore, we provided arguments for the choice of a snapshot approach for the socio-economic impact assessment in L3Pilot.

The main focus in the socio-economic impact assessment of ADFs lies on the net welfare effects for the society at EU-level, but country-specific or representative individuals' welfare may also be relevant in a CBA. Data input for the analysis are discussed in this chapter. A major part of input data arises from impact assessment on traffic safety, efficiency and environment along with some subjective data from surveys. Monetary valuation of all costs and benefits of ADFs are further discussed. Since data may not be available for all EU-countries, it is necessary to find appropriate methods for aggregating monetary values from national level to at EU-level.

Accurate identification of all costs and benefits of ADFs to the society is challenging. Uncertainty related to the identification of model parameters in the CBA may lead to overestimating or underestimating of the net welfare impacts for the society or its stakeholders. Conducting sensitivity analyses is essential for taking account of changes in model assumptions and uncertainties related to different parameters, e.g. uncertainty about unit costs. In this way, sensitivity analyses can contribute to improving the robustness of the main analysis.

# 8 Conclusions

The previous chapters describe the methods to be used in L3Pilot to investigate the various potential impacts of ADFs. The methods cover various levels of analysis, from the analysis of driving data logged in on-road tests to socio-economic impact assessment to quantify the potential impact of tested ADFs on general welfare. Experts from all addressed areas of analysis were involved in defining the various methods. For all areas, the proposed methods are grounded in the current scientific state-of-the-art and that have been used successfully by partners in previous research. To ensure that all planned levels of analysis will be feasible within L3Pilot and that overall meaningful results can be derived, the following steps have been taken:

- A common basic framework for all areas of analysis was discussed and agreed on amongst experts from various research areas (see chapters 2 and 3). Methods defined for the different areas described in chapter 4 to 7 build on that common framework.
- Where necessary, direct links between the different methods have been identified and defined in necessary detail. This relates for instance to PIs calculated by T&T evaluation that will be used to parameterise the models used in impact assessment (see chapter 4.7), or to items included in questionnaires or the annual survey that provide the information needed for impact assessment or socio-economic assessment (see chapter 5.2.5 or chapter 6.5).

Through close cooperation within the methodology subproject but also with other partners in L3Pilot, it was possible to define methods that are based on current scientific knowledge and to adapt them to the needs and circumstances in L3Pilot. From a methodological point of view, circumstances that might limit the generalisability of results are, for instance, that only prototype ADFs will be tested or that mostly safety drivers are either behind the wheel or at least in the car. In the process of method development, these circumstances were identified, and their potential impact on the different methods was discussed. Where possible, methods were chosen or adapted in a way that limitations unavoidable within L3Pilot on-road tests are addressed, and their impact is minimised. For instance, upscaling and impact assessment will not be done for prototype functions but for mature ADFs whose ODD was defined in cooperation with system developers and whose parameterisation will be based on the driving behaviour observed in the on-road tests.

Within the methodology subproject, it was also ensured that all research topics and RQs in L3Pilot are addressed with an appropriate method and that for all proposed methods data needs are expected to be fulfilled either through data from the on-road tests or from supplementary data sources. In conclusion, this deliverable proposes a complete and harmonised methodology that has been developed carefully to fulfil the needs of L3Pilot.

# 9 References


Adaptive (2017). Deliverable D1.0 Final project results. Deliverable in EU FP7 programme Adaptive http://www.adaptive-ip.eu/files/adaptive/content/downloads/AdaptIVe-SP1-v1-0-DL-D1-0-Final_Report.pdf

Alvarez, S. (2017) Safety benefit assessment, vehicle trial safety, and crash analysis of automated driving: a systems theoretic approach. PhD thesis. RENAULT and Université de recherche Paris Sciences et Lettres

Archer, J. (2005). *Indicators for traffic safety assessment and prediction and their application in micro-simulation modelling: A study of urban and suburban intersections*. PhD-Thesis, KTH.

Ashenfelter, O. (2006). Measuring the Value of a Statistical Life: Problems and Prospects. *The Economic Journal*, 116: C10-C23

Bärgman, J., Lisovskaja, V., Victor, T., Flannagan, C., & Dozza, M. (2015). How does glance behavior influence crash and injury risk? A 'what-if' counterfactual simulation using crashes and near-crashes from SHRP2. *Transp. Res. Part F Traffic Psychology Behaviour*, 35, 152–169.

Bärgman, J., Boda, C. N., & Dozza, M. (2017). Counterfactual simulations applied to SHRP2 crashes: The effect of driver behavior models on safety benefit estimations of intelligent safety systems. *Accid. Anal. Prev.*, vol. 102, pp. 165–180..

Bärgman, J., Van Nes, N., Christoph, M., Jansen,R., Heijne, V., Carsten, O., et al. (2017). *The UDRIVE dataset and key analysis results.* UDRIVE Deliverable 41.1. EU FP7 Project UDRIVE Consortium. https://doi.org/10.26323/UDRIVE_D41.1

Benmimoun, M., Fahrenkrog, F., Zlocki, A., & Eckstein, L. (2011). *Incident detection based on vehicle CAN-data within the large scale field operational test "euroFOT"*. Paper presented at the 22nd Enhanced Safety of Vehicles Conference (ESV 2011).

Bickel, P., Friedrich, R., Burgess, A., Fagiani, P., Hunt, A., De Jong, G. et al. (2006). HEATCO – Deliverable 5, *Proposal for Harmonised Guidelines*.

Bruzelius, N.A. (1981). Microeconomic theory and generalized cost. *Transportation*, 1o: 233-245.

Department for Transport (DfT) (2012) *Values of time and operating costs, TAG Unit 3.5.6 August 2012*. London: Department for Transport. http://www.dft.gov.uk/webtag

Dingus, T. A., Klauer, S. G., Neale, V. L., Petersen, A., Lee, S. E., Sudweeks, J., et al. (2006). *The 100-Car Naturalistic Driving Study Phase II – Results of the 100-Car Field Experiment.* Report No. DOT HS 810 593. Washington: National Highway Traffic Safety Admin. (NHTSA).

Draskóczy, M., Carsten, OMJ. & Kulmala, R. (1998). *Road Safety Guidelines*. CODE Project, Telematics Application Programme, Deliverable B5.2.

euroFOT (2012). *Overall Cost-Benefit Study, Deliverable D6.7*. Deliverable D6.7 of euroFOT project.

European Commission. (2019). Observatory. Available in: https://ec.europa.eu/transport/road_safety/specialist/observatory_en (Accessed 27th June, 2019).

Eurostat (2018). *New registrations of passenger cars, motor coaches, buses and trolley buses, by type of vehicle and alternative motor energy*. [Datafile]. Retrieved from: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqr_carmot&lang=en

Eurostat (2018). *Passenger cars, by age*. [Datafile]. Retrieved from: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=road_eqs_carage&lang=en

Faber, F., Jonkers, E., Aust, M. L., Benmimoun, M., Regan, M., Jamson, S., et al. (2012). *D6.2 Analysis methods for user related aspects and impact assessment*: euroFOT consortium. Retrieved from http://www.eurofot-ip.eu/en/library/deliverables/sp6_d62_analysis_methods_for_user_related_aspects_and_impact_assessment.htm.

Field, A.P. & Gillet, R. (2010). How to do a meta-analysis. *British Journal of Mathematical and Statistical Psychology*, 63, 665-694.

FOT-Net (2018). *FESTA Handbook. Version 7*. Retrieved from https://connectedautomateddriving.eu/wp-content/uploads/2019/01/FESTA-Handbook-Version-7.pdf

Frost & Sullivan (2018). European and North American ADAS L1 and L2 Market, 2018. *Industry Research Analysis, K25D, Automotive & Transportation*, 28 Dec 2018

Glass, G.V. (1976). Primary, secondary and meta-analysis. *Educational Researcher* 5(10): 3-8.

Griffon, T., Sauvaget, J.-L., Geronimi, S., Bolovinou, A. & Brouwer, R. (2019). *Deliverable D4.1 Description and taxonomy of automated driving functions.* Deliverabel D4.1 of L3Pilot project.

Gruschwitz, D., Hölscher, J., Raudszus, D., & Zlocki, A. (2017). *Marktdurchdringung von Fahrzeugsicherheitssystemen*, Berichte der Bundesanstalt für Straßenwesen, FE82.06625/2014, https://bast.opus.hbz-nrw.de/opus45-bast/frontdoor/deliver/index/docId/1766/file/M272_barrierefreies_Internet_PDF.pdf

Hargutt, V., Landau, A., Metz, B., & Neukum, A. (2014). Video validation of a maneuver classification algorithm for naturalistic driving data. Presentation at the Naturalistic Driving Research Symposium, Blacksburg, Virginia, 27.08.2014.

Helmer, T., Neubauer, M., Rauscher, S., Gruber, C., Kompass, K. & Kates, R. (2012). *Requirements and methods to ensure a representitive analysis of active safety systems*, presented at 11th International Symposium and Exhibition on Sophisticated Car Occupant Safety Systems.

Helmer, T. (2014). "*Development of a Methodology for the Evaluation of Active Safety using the Example of Preventive Pedestrian Protection*," Dissertation, TU Berlin.

Hensher, D.A. (1977). *Value of business travel time*. Permagon Press, London.

Hibberd, D., Louw, T., Aittoniemi, E., Brouwer, R., Dotzauer, M., Fahrenkrog, F., Innamaa, S., Kuisma, A., Merat, N., Metz, B., Neila, N., et al. (2018). *Deliverable D3.1 From research questions to logging requirements*. Deliverable D3.1 of L3Pilot project, https://l3pilot.eu/fileadmin/user_upload/Downloads/Deliverables/L3Pilot-SP3-D3.1-From_research_questions_to_logging_requirements-v2.0_DRAFT_for_website.pdf

Hickman, J. S., Hanowski, R. J., & Bocanegra, J. (2010). *Distraction in commercial trucks and buses: Assessing prevalence and risk in conjunction with crashes and near-crashes.* Report No. FMCSA-RRR-10-049. Washington D.C.: Federal Motor Carrier Safety Administration. Retrieved from http://www.fmcsa.dot.gov/facts-research/research-technology/report/Distraction-in-Commercial-Trucks-and-Buses-report.pdf.

Hiller J., Svanberg E., Koskinen, S., Bellotti F., & Osman, N. (2019) *THE L3PILOT COMMON DATA FORMAT – ENABLING EFFICIENT AUTOMATED DRIVING DATA ANALYSIS*, Paper presented at the 26th international technical conference on the enhanced safety of vehicles.

Hohm, A., Klejnowski, L., Skibinski, S., Bengler, K., Berger, S., Vetter, J. & Krug, S. (2018). *Ko-HAF – Cooperative Highly Automated Driving (Overall final report)*. Retrieved from https://www.ko-haf.de/fileadmin/user_upload/projekt/19S14002_Ko-HAF_partner%C3%BCbergreifender-Schlussbericht_final.pdf.

iCar (2015). *Implementation status survey by use of OEM data - results summary*.

Innamaa, S.; Axelson-Fisk, M.; Borgarello, L.; Brignolo, R.; Guidotti, L.; Martin Perez, O.; Morris, A.; Paglé, K.; Rämä, A.; Wallgren, P. & Will, D. (2013). *Impacts on Mobility – Results and Implications*. Large Scale Collaborative Project, 7th Framework Programme, INFSO-ICT 224067. European Commission 2013 No: Deliverable D4.4.3.

Innamaa S., Smith S., Barnard Y., Rainville L., Rakoff H., Horiguchi R., & Gellerman H., 2018. *Trilateral impact assessment framework for automation in road transportation, version 2.0.* Trilateral impact assessment sub-group for ART. www.connectedautomateddriving.eu

ISO (in prep). "*Road vehicles — Prospective safety performance assessment of pre-crash technology by virtual simulation -- Part 1: State-of-the-art and general method overview.* ISO/NP 21934-1.

Jonkers E., Wilmink I., Nellthorp J., Gühnemann A., & Olstam J. (2016). *Costs and benefits of green driving support systems*. EcoDriver deliverable D54.1.

Kates, R., Jung, O., Helmer, T., Ebner, A, Gruber, C. & Kompass, K. (2010). "Stochastic Simulation of Critical Traffic Situations for the Evaluation of Preventive Pedestrian Protection Systems," in *Erprobung und Simulation in der Fahrzeugentwicklung*.

Kessler, C., Etemad, A., Alessandretti, G., Heinig, K., Selpi, Brouwer, R., Cserpinszky, A., Hagleitner, W., & Benmimoun, M. (2012). *euroFOT Deliverable D11.3 – Final Report*.

Kolk, H., Kirschbichler, S., Tomsch, E.,Hoschopf,H., Luttenberger, P. & Sinz, W. (2016). Prospective Evaluation of the Collision Severity L7e Vehicles Considering a Collision Mitigation System, in *Transportation Research Procedia*, vol. 14, pp. 3877–3885.

Kolk, H., Tomasch, E., Sinz, W., Dobberstein, J. & Bakker, J. (2016). *Evaluation of a momentum based impact model and application in an effectivity study considering junction accidents* presented in ESAR - Expert Symposium on Accident Research.

Kuisma, S. (2017). *Towards a more comprehensive picture of mobility – Personal preferences, resources and constraints of daily travel*. Master's thesis. University of Helsinki, Helsinki.

Kulmala, R. (2010). Ex-ante assessment of the safety effects of intelligent transport systems. Accident Analysis and Prevention 42 (2010), pp. 1359–1369.

Kusano, K.D. & Gabler, H.C. (2012). Safety benefits of forward collision warning, brake assist, and autonomous braking systems in rear-end collisions. *IEEE Trans. Intell. Transportation Syst*. 13 (4), 1546–1555, http://dx.doi.org/10.1109/TITS. 2012.2191542.

Leveson, N. (2004). A New Accident Model for Engineering Safer Systems. *Safety Science* 42 (4): 237–270.

Leveson, N. (2012) *Engineering a Safer World: Systems Thinking Applied to Safety*. MIT Press

Leveson, N, Thomas, J (2018) *STPA handbook*https://psas.scripts.mit.edu/home/get_file.php?name=STPA_handbook.pdf

Lindman, M. & Tivesten, E. (2006). A method for estimating the benefit of autonomous braking systems using traffic accident data. In: *SAE Technical Paper*., http://dx.doi.org/10.4271/2006-01-0473.

Lindman, T., Ödblom, M., Bergvall, A., Eidehall, E., Svanberg, A., & Lukaszewicz, B. (2010). *Benefit Estimation Model for Pedestrian Auto Brake Functionality*. presented in ESAR - Expert Symposium on Accident Research.

Luttenberger, P., Tomasch, E., Willinger, R., Mayer, C., Bakker, J., Bourdet, N., Ewald, C., & Sinz, W. . (2014*). Method for future pedestrian accident scenario prediction.* presented at Transport Research Arena 2014, 14.-17. April 2014 in Paris, France.

L3Pilot (in prep.). *Deliverable D7.1 – Annual quantitative survey about user acceptance towards ADAS and vehicle automation.*

Malone, K., Rech, J., Hogema, J., Innamaa, S., Hausberger, S., Dippold, M., van Noort, M., de Feijter, E., Rämä, P., Aittoniemi, E., Benz, T., Burckert, A., Enigk, H., Giosan, I., Gotschol, C., Gustafsson, D., Heinig, I., Katsanos, K., Neef, D., Ojeda, L., Schindhelm, R., Sütterlin, C. & Visintainer, F. (2014). *Impact assessment and user perception of cooperative systems*. Deliverable D11.4 of DRIVEC2X project. Version 2.1.

Metz, B., Landau, A., Hargutt, V., & Neukum, A. (2013). *Naturalistic Driving Data - Re-Analyse von Daten aus dem EU-Projekt euroFOT* (FAT-Schriftenreihe Nr. 256). Berlin: Forschungsvereinigung Automobiltechnik e.V.

Metz, B., Wörle, J., Zerbe, A., Schindhelm, R. & Bonarens, F. (in prep.). *Deliverable D7.2 L3/L4 long-term study about user experiences.* Deliverable D7.2 of L3Pilot Project.

Mononen, P., Franzen, S., Pagle, K., Morris, A., Innamaa, S., Karlsson, M., Touliou, K., Montanari, R., & Fruttaldo, S. (2012). *Final Report. TeleFOT deliverable D1.15.*

Nagy, B., Hiller, J., Svanberg, E., Kremer, M., Luxen, M., Christen, F., Koskinen, S., Bellotti, F. & Osman, N. (2018). *Deliverable D5.1 Pilot tools for L3Pilot*. Deliverable D5.1 of L2Pilot project.

Naujoks, F., Wiedemann, K., Schömig, N., Jarosch, O., & Gold, C. (2018). Expert-based controllability assessment of control transitions from automated to manual driving. *MethodsX* 5: 579-592.

Neukum, A., Lübbeke, T., Krüger, H.-P., Mayser, C. & Steinle, J. (2008). ACC-Stop&Go: Fahrerverhalten an funktionalen Systemgrenzen. In M. Maurer & C. Stiller (Eds.), *5. Workshop Fahrerassistenzsysteme - FAS 2008*. pp. 141-150. Karlsruhe: fmrt.

NHTSA (2016). *National Automotive Sampling System (NASS) General Estimates System (GES): Analytical User's Manual 1988-2015*. Technical Report, National Highway Traffic Safety Administration.

Nilsson, G. (2004). Traffic Safety Dimensions and the Power Model to describe the effect of speed and safety. *Bulletin 221*. Department of Technology and Society. Lund University. Sweden.

Nordhoff, De Winter, Kyriakidis, Van Arem, & Happee (2018). Acceptance of driverless vehicles: Results from a large cross-national questionnaire study. *Journal of Advanced Transportation*, volume 2018.

Olson, R. L., Hanowski, R. J., Hickman, J. S., & Bocanegra, J. (2009). *Driver distraction in commercial vehicle operations, final report.*Report No. FMCSA-RRR-09-042. Washington, D.C.: Federal Motor Carrier Safety Administration. Retrieved from http://www.fmcsa.dot.gov/facts-research/research-technology/report/FMCSA-RRR-09-042.pdf.

Öorni (2016). *iMobility Support D3.1b Report on the deployment status of iMobility Priority systems and update of iMobility Effects Database*.

Penttinen, M., Rämä, P., Dotzauer, D., Hibberd, D., Innamaa, S., Louw, T., Streubel, T., Metz, B., Wörle, W., Brouwer, R., Rösener, C. & Weber, H. (2019). *Deliverable D3.2 Experimental Procedure*. Deliverable D3.2 of L3Pilot project. https://l3pilot.eu/fileadmin/user_upload/Downloads/Deliverables/L3Pilot-SP3-D3.2-Experimental_procedure-v1.0_DRAFT_for_website.pdf

Perdomo Lopez, D., Waldmann, R., Joerdens, C., & Rojas, R. (2017). Scenario Interpretation based on Primary Situations for Automatic Turning at Urban Intersections. In Gusikhin, O., Helfert, M., & Pascoal, A. (Eds.). *VEHITS 2017*. Pp. 15-23. SCITEPRESS - Science and Technology Publications Lda. Doi: 10.5220/0006150300150023

Pigott, T.D. (2012). *Advances in Meta-Analysis*. New York: Springer.

PTV (2019: http://vision-traffic.ptvgroup.com/en-us/products/ptv-vissim/. Accessed July 2019.

Rösener, C., Fahrenkrog, F., Uhlig, A., & Eckstein L, (2016). *A Scenario-based Assessment Approach for Automated Driving By using Time-Series Classification of Human Driving Behaviour*, presented at 19th International IEEE Conference on Intelligent Transportation Systems (ITSC), Rio de Janeiro, Brazil

Rösener, C., Sauerbier J., Várhelyi, A., & de Gelder, E. (2017). *AdaptIVe Deliverable D7.2 Application of AdaptIVe Evaluation Methodology*, AdaptIVe IP, 2017

Rösener, C, Hennecke, F., Sauerbier, J., Zlocki, A., Kemper, D., Eckstein, L., & Oeser, M. (2018). *A Traffic-based Method for Safety Impact Assessment of Road Vehicle Automation*, presented at Workshop Fahrerassistenzsysteme, Uni-DAS, Walting, Germany

SAE (2014). *Taxonomy and definitions for terms related to on-road motor vehicle automated driving systems* (Vol. J 3016, pp. 1-16): Society of Automotive Engineers.

SAE (2018). *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.* Society of Automotive Engineers.

Schulze M., Mäkinen T., Kessel T., Metzner S., & Stoyanov, H. (2014). *DRIVE C2X Final Report (DRIVing implementation and Evaluation of C2X technology in Europe).* Deliverable 11.6. EC 7th Framework Program.

Silla, A., Leden, L., Rämä, P., Scholliers, J., van Noort, M. & Bell, D. (2017). Can cyclists safety be improved with intelligent transport systems? Accident Analysis and Prevention 105 (2017), pp. 134–145.

Simmonds, M.C. & Higgins, J.P.T. (2007). Covariate heterogeneity in meta-analysis: Criteria for deciding between meta-regression and individual patient data. *Statistics in Medicine* 26, 2982-2999.

TNO (2019). https://www.tno.nl/en/focus-areas/traffic-transport/roadmaps/sustainable-traffic-and-transport/sustainable-mobility-and-logistics/improving-air-quality-by-monitoring-real-world-emissions/enviver-model-traffic-flow-and-emissions/. Accessed July 2019.

Tomasch, E., Kolk, H., Sinz, W., Hoschopf, H. & Kirschbichler, S. (2015). Prospektive Bewertung der Kollisionsschwere von L6e Fahrzeugen unter Berücksichtigung eines Kollisionsminderungssystems, in *10. VDI-Tagung Fahrzeugsicherheit - Sicherheit 2.0*, pp. 407–418.

Van Noort, M., Bakri, T., Fahrenkrog, F., & Dobberstein, J. (2015). SIMPATO - The Sfety Impact Assessment Tool of interactIVe, *IEEE Intell. Transp. Syst. Mag*., vol. 20, 2015.

Venables, A.J. (2007). Evaluating Urban Transport Improvements – Cost-Benefit Analysis in the Presence of Agglomeration and Income Taxation. *Journal of Transport Economic and Policy*, 41(2): 173-188.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly*, 27, 425–478.

Venkatesh, V., Thong, J. Y. L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the Unified Theory of Acceptance and Use of Technology. *MIS Quarterly*, 36, 157–178.

Wardman, M., Batley, R., Laird, J., Mackie, P., Fowkes, T., Lyons, G., Bates, J., & Eliasson, J. (2013). *Valuation of Travel Time Savings for Business Travellers: Main Report*. Institute for Transport Studies.

Wille, J. M. & Zatloukal, M. (2012). rateEFFECT: Effectiveness Evaluation of Active Safety Systems, in *5th International Conference on ESAR „Expert Symposium on Accident Research“*, pp. 1–41.

# Annex 1 List of Research questions

## Technical and traffic assessment

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| RQ-T1 | What is the ADF's technical performance? | How reliable is ADF performance in a given driving and traffic scenario? | How often is the function available in the driving and traffic scenarios of its ODD? |
| RQ-T2 | | How often and under which circumstances do the ADFs issue a takeover request? | Does the function initiate a take-over request if required by the boundaries of the ADF? |
| RQ-T5 | What is the impact on the driving behaviour of the ADF-vehicle? | How do take-over requests affect driving? | How do planned take-over situation affect the driving dynamics of the vehicle? |
| RQ-T6 | | What is the impact of ADF on the driving dynamics? | What is the impact of ADF on longitudinal acceleration in defined driving situations? |
| | | | What is the impact of ADF on lateral acceleration in defined driving situations? |
| RQ-T7 | | What is the impact of ADF on the accuracy of driving? | What is the impact of ADF on precision of manoeuvres? |
| | | | What is the impact of ADF on lane keeping performance in defined driving situations? |
| RQ-T8 | | What is the impact of ADF on the driven speed? | What is the impact of ADF on driven velocity in defined driving situations? |
| RQ-T9 | | What are the impacts of ADF on energy efficiency? | What is the impact of ADF on energy demand? |
| RQ-T10 | | What is the impact of ADF on the frequency of near-crashes / incidents? | What is the impact of ADF on the frequency of harsh brakings? |
| | | | What is the impact of ADF on the frequency of (unintended) lane departures? |
| RQ-T11 | | What is the impact of ADF on the frequency of certain events? | What is the impact of ADF on the frequency of defined driving scenarios? |
| RQ-T12 | What is the impact of ADF on the interaction with other road users | What is the impact of ADF on the interaction with other road users in a defined driving scenario? | What is the impact of ADF on lateral distances to other vehicles in defined driving scenarios? |
| | | | What is the impact of ADF on the behaviour of VRUs (cyclist, motorcyclist, pedestrians) in defined driving scenarios? |
| | | | What is the impact of ADF on the behaviour of approaching / crossing pedestrians? |
| | | | What is the impact of ADF on car following behaviour? |
| RQ-T13 | | What are the impacts of ADF on traffic efficiency? | What is the impact of ADF on traffic flow at intersections? |

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| RQ-T14 | | What is the impact of ADF on the number of near-crashes / incidents with other road users? | What is the impact of ADF on the frequency of near-crashes with other vehicles? |
| | | | What is the impact of ADF on near-crashes with VRUs? |
| RQ-T15 | What is the impact of ADF on the behaviour of other traffic participants? | How does the ADF influence the behaviour of subsequent vehicles? | What is the impact of ADF on following behaviour of subsequent vehicles? |
| RQ-T16 | | How does the ADF influence the behaviour of preceding vehicles? | What is the impact of ADF on the frequency of defined driving scenarios (e.g. cut-in manoeuvres) of the vehicles in front of the ego-vehicle? |
| | | | What is the impact of ADF on the behaviour of preceding vehicles? |
| RQ-T17 | | What is the impact of ADF on the number of near-crashes / incidents of other traffic participants? | What is the impact of ADF on the frequency of harsh brakings of the subsequent vehicle? |
| | | | What is the impact of ADF on the frequency of defined driving scenarios (e.g. very small distance) of the subsequent vehicle? |

## User and acceptance evaluation

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| RQ-U1 | What is the impact on user acceptance & awareness? | Are drivers willing to use an ADF? | Are drivers willing to use an ADF? |
| RQ-U2 | | How much are drivers willing to pay for the ADF? | How much are drivers willing to pay for the ADF? |
| RQ-U3 | | What is the user acceptance of the ADF? | What is the perceived safety of the ADF? |
| | | | What is the perceived comfort of the ADF? |
| | | | What is the perceived usefulness of the ADF? |
| | | | What is the perceived trust of the ADF? |
| | | | How does user acceptance differ between ADF types (urban, motorway, traffic jam, parking)? |
| RQ-U5 | | What is the impact of ADF on driver state? | What is the effect of ADF use on drivers' level of stress? |
| | | | What is drivers' level of fatigue while using the ADF? |
| | | | What is drivers' workload while using the ADF? |
| RQ-U6 | | What is the impact of ADF use on driver awareness? | What is the effect of ADF use on driver attention to the road/other road users? |

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| | | | What is drivers' risk perception while using the ADF? |
| RQ-U4 | | What are drivers' expectations regarding system features? | What is drivers' overall impression of the system? |
| RQ-U9 | What is the user experience? | What is drivers' secondary task engagement during ADF use? | What secondary tasks do or would drivers engage in during ADF use? |
| | | | What is the frequency and duration of drivers' secondary task engagement during ADF use? |
| RQ-U10 | | How do drivers respond when they are required to retake control? | How do drivers respond when they are required to retake control in planned take overs? |
| | | | How do drivers respond when they are required to retake control in unplanned take overs? |
| RQ-U11 | | How often and under which circumstances do drivers choose to activate/deactivate the ADF? | How often and under which circumstances do drivers choose to activate the ADF? |
| | | | How often and under which circumstances do drivers choose to deactivate the ADF? |
| RQ-U7 | | What is the impact of ADF use on motion sickness? | What is the impact of ADF use on motion sickness? |
| RQ-U8 | | What is the impact of motion sickness on ADF use? | What is the impact of motion sickness on ADF use? |

## Impact assessment

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| RQ-I1 | What is the impact of ADF on traffic safety? | What is the impact of ADF on the number of accidents in a certain driving scenario / for certain road users? | What is the impact of ADF on the number of accidents in a certain driving scenario? |
| | | | What is the impact of ADF on the number of accidents involving other road users such as pedestrians and bikers? |
| RQ-I2 | | What is the impact of ADF on accidents with a certain injuries level / damage in a certain driving scenario? | What is the impact of ADF on accidents with fatal injuries in a certain driving scenario? |
| | | | What is the impact of ADF on accidents with severe injuries in a certain driving scenario? |
| | | | What is the impact of ADF on accidents with slight injuries in a certain driving scenario? |
| | | | What is the impact of ADF on accidents with material damages in a certain driving scenario? |

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| | | | What is the impact of ADF on rescue chain in terms of preventing injuries? |
| RQ-I3 | What is the impact of ADF on traffic efficiency? | What is the impact on transport network efficiency (throughput) in a certain traffic scenario? | What is the impact of the ADF on throughput in a road section or intersection? |
| | | | What is the impact of the ADF on reliability of travel time? |
| | | | What is the impact of the ADF on travel times? |
| | | | What is the impact of the ADF on speed differences between vehicles? |
| | | | What is the impact of the ADF on network capacity? |
| RQ-I4 | What is impact of ADF on the environment ? | What is the impact of ADF on energy demand / pollution in a certain traffic scenario? | What is the effect of the ADF on fuel consumption? (in specific scenarios?) |
| | | | What is the effect of the ADF on energy demand? |
| | | | What is the impact of the ADF on CO2 emissions? |
| RQ-I5 | What is the impact of ADF on (personal) mobility? | What is the impact of ADF on amount of travel? | What is the impact of ADF on number of trips made? |
| | | | What is the impact of ADF on trip distance? |
| | | | What is the impact of ADF on trip duration? |
| RQ-I6 | | What is the impact of ADF on travel patterns? | What is the impact of ADF on mode choice? |
| | | | What is the impact of ADF on timing of trips? |
| | | | What is the impact of ADF on the frequency of road type usage? (urban, rural, motorway) |
| RQ-I7 | | What is the impact of ADF on quality of travel? | What is the impact of ADF on quality of travel? |

## Socio-economic impact assessment

| RQ-ID | RQ Level 1 | RQ Level 2 | RQ Level 3 |
|---|---|---|---|
| RQ-S1 | What is the overall socio-economic impact of L3 ADFs? | What is the net welfare gain in a certain societal scenario? | What is the impact of ADF with respect to direct welfare effects for the society? |
| | | | What is the impact of ADF with respect to indirect welfare effects for the society? |
| RQ-S2 | | What is the overall socio-economic impacts for different groups? | What is the welfare effect in terms of generalized travel costs? |
| | | | What are the welfare effects for travellers, no-travellers, producers and the government? |

## Annex 2 Links between RQs and questionnaire-items

### User and acceptance evaluation

Table A1: Questionnaire items to be used for answering RQs on user relates aspects. ID of questionnaire items is given per RQ, the corresponding items can be found in Annex 3 to Annex 5.

| RQ-ID | RQ Level 2 | RQ Level 3 | Questionnaire Items (Question code) used |
|---|---|---|---|
| RQ-U1 | Are drivers willing to use an ADF? | Are drivers willing to use an ADF? | TJM.32.a, U.32.a, P.27.a |
| RQ-U2 | How much are drivers willing to pay for the ADF? | How much are drivers willing to pay for the ADF? | TJM.32.d, TJM.32.e,TJM.32.f, U.32.d, U.32.e, U.32.f, P.27.e, P27.f, P.27g, TJM.37, U.37, P30 |
| RQ-U3 | What is the user acceptance of the ADF? | What is the perceived safety of the ADF? | TJM.28, TJM.32.c, TJM.32.z, U.32.c, P.25, P.27d |
| | | What is the perceived comfort of the ADF? | TJM.31, TJM.32q, U.31, U.32.q, P.25 |
| | | What is the perceived reliability of the ADF? | Not addressed in questionnaire |
| | | What is the perceived usefulness of the ADF? | TJM.30, TJM.32.g, TJM.32.p, U.32.g, U.32.p, P.26, P.27.n, P.27.q |
| | | What is the perceived trust of the ADF? | TJM.32.o, TJM.32.l, U.32.o, U.32.l, P,27.o, P.27.m |
| | | How is user acceptance influenced by system behaviour in different use cases? | TJM.32.b, TJM.32.k, TJM.32.m, U.32.b, U.32.k, U.32.m, P.27.c |
| RQ-U5 | What is the impact of ADF on driver state? | What is drivers' level of stress while using the ADF? | TJM.32.j, U.32.j, P.27.k |
| | | What is drivers' level of fatigue while using the ADF? | TJM.32.t, U.32.t |
| | | What is drivers' level of workload while using the ADF? | TJM.32.h, TJM.32.i, U.32.h, U.32.i, P.27.i, P.27.h |
| RQ-U6 | What is the impact of ADF use on driver awareness? | What is the effect of ADF use on driver attention to the road/other road users? | TJM.32.r, U.32.r, P.27.r |
| | | What is drivers' risk perception while using the ADF? | TJM.32.s, U.32.s, P.27.s |
| RQ-U4 | What are drivers' expectations regarding system features? | What are drivers' expectations regarding system features? | TJM.32.p, TJM.32.u, TJM.v, TJM.w, U.32.p, U.32u, U.32,v, P.27.q |
| RQ-U9 | What is drivers' secondary task | What secondary tasks do drivers engage in during ADF use? | TJM.32.n, (TJM.33& TJM.21), U.32.n, (U.33&U.21) |

| RQ-ID | RQ Level 2 | RQ Level 3 | Questionnaire Items (Question code) used |
|---|---|---|---|
| | engagement during ADF use? | What is the frequency and duration of drivers' secondary task engagement during ADF use? | TJM.33, U.33 |
| RQ-U10 | How do drivers respond when they are required to retake control? (Reaction time, success of takeover) | How do drivers respond when they are required to retake control in planned take overs? | TJM.32.x, TJM.32.α, TJM.32.β, U.32.w, U.32.z.U.32.α, TJM.38, TJM.39a-39.f, U.38, U.39a-39.f |
| | | How do drivers respond when they are required to retake control in unplanned take overs? | NA |
| RQ-U11 | How often and under which circumstances do drivers choose to activate/deactivate the ADF? | How often and under which circumstances do drivers choose to activate the ADF? | Not addressed in questionnaire |
| RQ-U7 | What is the impact of ADF use on motion sickness? | How often and under which circumstances do drivers choose to deactivate the ADF? | TJM.29.a, U.29.a |
| RQ-U8 | What is the impact of motion sickness on ADF use? | What is the impact of ADF use on motion sickness? | TJM.29.b, U.29.b |

| [a]LEGEND | TJM.i | Question number i from Traffic Jam/Motorway Pilot Questionnaire |
|---|---|---|
| | U.i | Question number i from Urban Pilot Questionnaire |
| | P.i | Question number i from Parking Functions Questionnaire |
| | NA | RQ not intended by the questionnaires |
| | MI | Missing item in the questionnaires |

## Mobility impact assessment

Table A2: Questionnaire items to be used for answering RQs for mobility impact assessment. ID of questionnaire items is given per RQ, the corresponding items can be found in Annex 2 to Annex 4.

| Research question | Methods | Data sources |
|---|---|---|
| What is the impact of ADF on number of trips made? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects (e.g. TeleFOT, euroFOT)<br>Impacts: pilot site surveys (TJM.33.v/U.33.u, background: TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.19, TJM/U.22, TJM/U.23, TJM/U.24, TJM/U.25), annual survey, focus groups |

| Research question | Methods | Data sources |
|---|---|---|
| What is the impact of ADF on trip distance? | Baseline definition, analysis of survey responses (per each user group), focus groups, alternative route analysis, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects (e.g. TeleFOT, euroFOT)<br>Impacts: pilot site surveys (TJM.33.w/U.33.v, TJM.35, background: TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.19, TJM/U.22, TJM/U.23, TJM/U.24), annual survey, focus groups |
| What is the impact of ADF on trip duration? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects (e.g. TeleFOT, euroFOT)<br>Impacts: pilot site surveys (TJM.33.w, U.33.v, TJM.35, U.35, TJM.36, background: TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.19, TJM/U.22, TJM/U.23, TJM/U.24), annual survey, focus groups |
| What is the impact of ADF on mode choice? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects (e.g. TeleFOT, euroFOT)<br>Impacts: pilot site surveys (U.36, TJM.33.p/U.33.p, background: TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.19, TJM/U.22, TJM/U.23, TJM/U.24, TJM/U.25), annual survey, focus groups |
| What is the impact of ADF on timing of trips? | Baseline definition, analysis of survey responses (per each user group), focus groups, scaling up of impacts | Baseline: national travel surveys, objective travel data from earlier projects (e.g. TeleFOT, euroFOT)<br>Impacts: pilot site surveys (U.35, TJM.36, background: TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.19, TJM/U.22, TJM/U.23, TJM/U.24), annual survey, focus groups |
| What is the impact of ADF on the frequency of road type usage? (urban, rural, motorway) | Baseline definition, analysis of survey responses (per each user group), focus groups, alternative route analysis, scaling up of impacts | Baseline: objective travel data from earlier projects (e.g. TeleFOT, euroFOT), national travel surveys<br>Impacts: pilot site surveys (TJM.35, background questions TJM/U.1, TJM/U.2, TJM/U.3, TJM/U.5, TJM/U.6, TJM/U.7, TJM/U.10, TJM/U.22, TJM/U.23, TJM/U.24, TJM/U.25) |
| What is the impact of ADF on quality of travel? | Interpretation of the results of user evaluation (impacts of ADF on user comfort, stress, reliability and perceived safety, possibly the use of travel time to other than driving activities), focus groups | User evaluation results, focus groups |

# Annex 3 Pilot Site Questionnaire – Traffic Jam/Motorway Pilot

## Before study/screening questions

➔ *Can be administered before the pilot test or already during driver recruitment e.g. together with pre-information regarding the experiment*

Traffic Jam/Motorway Pilot questionnaire question number ID inside box: TJM.i

Thank you for agreeing to take part in this study on vehicle automation. Please read the following information and answer these questions before the date of your test drive.

**A. Participant information**

A1. Sociodemographic information

TJM.1 What year were you born? (dropdown menu; 1900-2018)

TJM.2 What is your gender:

- **Male**
- **Female**
- **Other**
- **Prefer not to say**

TJM.3 Country of residency (dropdown menu):

- **Belgium**
- **France**
- **Germany**
- **United Kingdom**
- **Italy**
- **Sweden**
- **Other**

TJM.4 What is the highest level of education that you have completed (including ongoing education or studying at the moment)?

- **trade/technical/vocational training**
- **university degree**
- **none of those**

TJM.5 What is your employment status? (dropdown menu)

- **Employed full-time**
- **Employed part-time**
- **Self-employed**
- **Homemaker**

- **Unemployed**
- **Retired**
- **Student**

TJM.6 Could you do part of your job whilst on transportation e.g. travelling on a bus, train or plane?

- **Yes**
- **No**

TJM.7 Do you have a car available for your use?

- **yes, (nearly) always**
- **yes, sometimes**
- **no or hardly ever**

TJM.8 Please tick all of those that apply to you in your employment? (dropdown menu):

- **I am an employee of a vehicle manufacturer or supplier**
- **I work in the development of automated vehicle functions**
- **I test automated vehicle functions**
- **I have a professional driving qualification**
- **I am a qualified safety/test driver**
- **None of the above**

TJM.9 What category best describes your total household gross income for last year? (dropdown menu) (Edit this question to the currency of the country, ensuring that categories match closely)

- **below 20 000€**
- **20 000-40 000€**
- **40 000-60 000€**
- **60 000-80 000€**
- **80 000-100 000€**
- **more than 100 000€**

TJM.10 How many children under 19 years old live in your household? (dropdown menu)

- **none**
- **1**
- **2**
- **3**
- **4**
- **more than 4**

A2. Vehicle purchasing decisions

TJM.11 How often do you purchase / change your car? (dropdown menu)

- **Every year**
- **2-5 years**
- **6-10 years**
- **10 years**
- **Not sure, no clear habits**

TJM.12 Will your next car be a (dropdown menu):

- **Company car**
- **Leased car**
- **Own car**
- **I consider using a car sharing service**
- **I don't know yet**

TJM.13 When buying or leasing your next vehicle, would you select

- **a new car**
- **a pre-owned / used or**
- **I don't know**

TJM.14 Please estimate the price of the next vehicle you would buy: in currency of the country (open question, with 'I don't know' option)

TJM.15 How familiar are you with the make of the test vehicle? (dropdown menu)

- **I have owned one and/or used one frequently**
- **I have driven one a few times**
- **I have travelled in one but not driven**
- **Some other experience (e.g. read about them)**
- **No experience**

TJM.16 Today you will be operating with (add function name and brief description). How familiar are you with this type of systems you will be using today?

| **Highly familiar** | | | | **Highly unfamiliar** |
|---|---|---|---|---|

A3. Driving history

TJM.17 How many years of driving experience do you have?

- **less than one year**
- **1-2 years**
- **2-10 years**

- more than 10 years

TJM.18 On average, how often do you drive a car?

- (Nearly) Every day
- 3-5 days / week
- 1-2 days / week
- Less often or never

TJM.19 Approximately how many kilometres did you drive in the last 12 months? (dropdown menu)

- less than 2 000 km
- 2 000- 5 000 km
- 5 000- 10 000 km
- 10 000- 15 000 km
- 15 000- 20 000 km
- 20 000- 50 000 km
- more than 50 000 km

A4. In-vehicle system usage (baseline)

TJM.20 Please state if your current vehicle is equipped with the following systems:

| | I have it and I use it | I have it but I don' t use it | I don' t have it | Don' t know if I have it |
|---|---|---|---|---|
| **Parking Assist System:** (A system that provides a camera view and/or auditory beeps to indicate how close you are to an object, while you are parking). | | | | |
| **Self-parking Assist System** (A system that controls the vehicle for parallel parking or reverse parking. Some of these systems control both steering and the throttle; others only control the steering and the driver presses the brake and throttle). | | | | |
| **Cruise Control (CC) or Adaptive Cruise Control (ACC)** (A system that maintains vehicle speed while driving (CC), or also automatically slows down or speeds up to keep a safe distance from a vehicle ahead (ACC)). | | | | |

| | I have it and I use it | I have it but I don’ t use it | I don’ t have it | Don’ t know if I have it |
|---|---|---|---|---|
| **Blind spot monitoring** (A system that monitors the driver’s left and right blind spots for other vehicles. Often, drivers receive a visual or audio alert whenever a vehicle is present). | | | | |
| **Lane departure warning systems** (A system that provides assistance with lane-keeping, by sounding warnings when the vehicle travels outside of the lane markings/boundaries). | | | | |
| **Lane keeping assistance** (A system that helps motorists to avoid inadvertently moving out of the intended driving lane). | | | | |
| **Forward Collision Warning systems** (A system that provides warnings for potential collisions with the vehicle in front). | | | | |

TJM.21 While driving on the motorway, how often do you engage in the following activities:

| | Very frequently | Frequently | Every now and then | Infrequently | Very infrequently | Never |
|---|---|---|---|---|---|---|
| Texting | | | | | | |
| Music, radio, audiobooks | | | | | | |
| Interact with a passenger | | | | | | |
| Eating or drinking | | | | | | |
| Calling | | | | | | |
| Smoking | | | | | | |
| Personal hygiene/Cosmetics | | | | | | |
| Smart phone apps | | | | | | |
| Social media | | | | | | |
| Navigation | | | | | | |
| Browsing the internet | | | | | | |
| None | | | | | | |

A5. Trip choice

TJM.22 What mode of transport do you typically use for the following trip types? Choose 1-3 often used modes: 1 for the one most used, 2 for the second most used (if applicable), 3 for the third most used (if applicable). Exclude trips made by airplane.

| | Passenger car | Public transport | Taxi | Motorbike or scooter | Bicycle or walking | I don' t take such trips |
|---|---|---|---|---|---|---|
| Commuting | | | | | | |
| Business travel | | | | | | |
| Leisure/social | | | | | | |
| Errands (incl. groceries) | | | | | | |

TJM.23 Please state your agreement with the following statements:

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Lack of time greatly affects my daily travel choices. | | | | | |
| I tend to select the cheapest mode of transport, even if it would take more time. | | | | | |
| I tend to select the quickest mode of transport, even if it would cost me more. | | | | | |
| I would travel more in my daily life if travelling was easier. | | | | | |
| I tend to select the most comfortable mode of transport. | | | | | |
| Traffic jams affect my choice of mode. | | | | | |
| Traffic jams affect my choice of route in the car. | | | | | |
| Traffic jams affect the time that I choose to take my trips. | | | | | |
| Weather conditions affect my decision to drive. | | | | | |
| Darkness affects my decision to drive. | | | | | |
| Fatigue affects my decision to drive. | | | | | |

TJM.24 How often do you experience the following driving situations?

| | Everyday | Nearly every day | 3-5 days / week | 1-2 days / week | Less often or never |
|---|---|---|---|---|---|
| Driving on a motorway | | | | | |
| Driving on a congested motorway | | | | | |
| Driving on rural roads | | | | | |
| Driving on urban streets | | | | | |
| Driving at night | | | | | |
| Driving fatigued | | | | | |

TJM.25 Below is a list of statements on driving on motorways. Please indicate how strongly you agree or disagree with each statement:

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|
| Driving on motorways is stressful | | | | | | |
| Driving on motorways is difficult | | | | | | |
| Driving on motorways is demanding | | | | | | |
| Driving on motorways is fun | | | | | | |

TJM.26 Do you generally experience motion sickness when travelling as a passenger on the motorway?

- **Never or hardly ever**
- **Sometimes**
- **Often or always**

TJM.27 When it comes to trying a new technology product I am generally….

| | | |
|---|---|---|
| **among the last** | **in the middle** | **among the first** |

## Pilot site questionnaire (post drive)

Thank you for taking part in this study. The test today has provided you with an experience of a particular type of partly self-driving vehicle. Please answer all questions imagining that you were now able to use this vehicle on a day-to-day basis. Please be honest in your responses. All contributions will be anonymized and cannot be used to identify you as an individual.

TJM.28 What is your immediate reaction / first impression after completing your journey with the vehicle? *(Free association)*

[ ] ________________________________________

TJM.29 Did something happen during the drive that made you feel unsafe or uncomfortable? If yes, please explain briefly:

[ ] ________________________________________

TJM.30a-30.b Did you experience motion sickness during your test drive with the function active?
a. 30.a During the driving with the function active, I felt:

- **No signs of motion sickness**
- **Slightly nauseated**
- **Severely nauseated**

b. 30.b If you answered “slightly” or “severely nauseated” in the previous question, did it impact your use of the system? If yes, please explain briefly:

[ ] ________________________________________

TJM.31 I think that the tested motorway pilot system was …

(Translations for this in German, Swedish, French, Italian here: https://www.hfes-europe.org/accept/accept.htm)

| | | | | | | |
|---|---|---|---|---|---|---|
| Useful | | | | | | Useless |
| Pleasant | | | | | | Unpleasant |
| Bad | | | | | | Good |
| Nice | | | | | | Annoying |
| Effective | | | | | | Superfluous |
| Irritating | | | | | | Likeable |
| Assisting | | | | | | Worthless |
| Undesirable | | | | | | Desirable |
| Raising alertness | | | | | | Sleep-inducing |

TJM.32 How comfortable or uncomfortable did the behaviour of the vehicle with the activated system make you feel? Please answer regarding the following topics:

| | Very comfortable | | | | Very uncomfortable | Don' t know |
|---|---|---|---|---|---|---|
| Distance kept to the vehicle in front | | | | | | |
| Smoothness of driving | | | | | | |
| Acceleration behaviour of vehicle | | | | | | |
| Braking behaviour of vehicle | | | | | | |
| Behaviour in curves | | | | | | |
| Behaviour in motorway junction areas | | | | | | |
| Lane change behaviour | | | | | | |
| Distance kept to road markings | | | | | | |

TJM.33.a-33.β Below is a list of statements on the system you used today. Please indicate how strongly you agree or disagree with each statement:

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|---|
| 33.a | I would use this system if it was in my car. | | | | | | |
| 33.b | Sometimes the system behaved unexpectedly. | | | | | | |
| 33.c | I felt safe when driving with the system active. | | | | | | |
| 33.d | I would buy the system. | | | | | | |
| 33.e | The cost of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 33.f | The benefits of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 33.g | I would recommend the system to others. | | | | | | |
| 33.h | Driving with this system was difficult. | | | | | | |
| 33.i | Driving with this system was demanding. | | | | | | |

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|---|
| 33.j | Driving with the system was stressful. | | | | | | |
| 33.k | The system worked as it should work. | | | | | | |
| 33.l | I would want to monitor the system's performance. | | | | | | |
| 33.m | The system acted appropriately in all situations. | | | | | | |
| 33.n | I would use the time the system was active to do other activities. | | | | | | |
| 33.o | I trust the system to drive. | | | | | | |
| 33.p | I would use the system during my everyday trips. | | | | | | |
| 33.q | Driving with the system active was comfortable. | | | | | | |
| 33.r | During driving with the system active, I monitored the surrounding environment more than in manual driving. | | | | | | |
| 33.s | During driving with the system active, I was more aware of hazards in the surrounding environment than in manual driving. | | | | | | |
| 33.t | Driving with the function on long journeys would make me tired. | | | | | | |
| 33.u | Using the system on motorways was fun. | | | | | | |
| 33.v | I would make MORE trips if I had the function in my car. | | | | | | |
| 33.w | I would select destinations further away if I had the function in my car | | | | | | |
| | *Items on take-over requests* | | | | | | |
| 33.x | It was obvious to me why takeover requests occurred. | | | | | | |
| 33.y | I would have liked more information about why a takeover request was triggered. | | | | | | |
| 33.z | During the takeover I always felt safe. | | | | | | |
| 33.α | When the system asks me to retake control, I am warned in an appropriate way. | | | | | | |
| 33.β | When the system asks me to retake control, I am warned with sufficient time to do so safely. | | | | | | |

TJM.34 Imagine your vehicle was equipped with the function you experienced today, how often would you engage in the following activities while the system is active?

| | Very frequently | Frequently | Every now and then | Infrequently | Very infrequently | Never |
|---|---|---|---|---|---|---|
| Texting | | | | | | |
| Music, radio, audiobooks | | | | | | |
| Interact with a passenger | | | | | | |
| Eating or drinking | | | | | | |
| Calling | | | | | | |
| Smoking | | | | | | |
| Personal hygiene/Cosmetics | | | | | | |
| Smart phone apps | | | | | | |
| Social Media | | | | | | |
| Navigation | | | | | | |
| Browsing the internet | | | | | | |
| Sleeping | | | | | | |
| Watching movies | | | | | | |
| Office/work tasks | | | | | | |
| None | | | | | | |

TJM.35 Imagine that you have a partly self-driving car which is able to drive by itself on motorway. While the car is driving by itself, you can focus on other activities (reading news or email, watching videos, eating, etc.). You have a flexible schedule and you can plan when to leave.

You have a trip that takes 30 minutes of driving. There is an alternative route, which is somewhat longer but in which this self-driving system would be available. How much additional time would you be willing to accept for this alternative route, where the car could drive by itself and you could engage in other activities?

________minutes

TJM.36 Imagine that you have a partly self-driving car which is able to drive by itself in congestion. You have a trip that takes 30 minutes of driving. You have scheduled it to avoid the peak of congestion. How much additional time would you be willing to accept for the duration of this trip if the car could drive by itself and you could engage in other activities?

________minutes

TJM.37 Do you have any other comments on the test drive?

**Willingness to pay**

TJM.38 How much extra would you be willing to pay for including this partially self-driving system in your car? (Change to currency of the country)

**Motorway chauffeur system:**

| | | | | |
|---|---|---|---|---|
| 0 € | less than 3000 € | 3000- 4999 € | 5000- 6999 € | ≥ 7000 € |

**Traffic jam chauffeur system for motorways:**

| | | | | |
|---|---|---|---|---|
| 0 € | less than 2499 € | 2500- 3499 € | 3500- 4499 € | ≥ 4500 € |

## Optional: Questioning during drive after Take-over requests

Take-over situations are evaluated in a two-step process. First, the driver decides on one of the five verbal categories. Second, a more fine-grained evaluation is conducted by choosing one of the corresponding numbers for the three intermediate categories.

*To do this, please take the whole situation into account, including the behaviour of the system, your reaction, the surrounding traffic etc. Please think about how you would evaluate this situation if it would happen to you on one of your daily trips.*

*The categories are defined as follows:*

- Not at all: no reaction was needed to continue driving safely.
- Harmless (rating 1-3): you needed no or only little effort to resolve the situation and take vehicle control back.
- Unpleasant (rating 4-6): retaining control was demanding and required immediate reaction, but the required effort was still manageable.
- Dangerous (rating 7-9): the situations was highly demanding. Considerable or intense corrections/response was required to retain control. In everyday traffic, the situation would be too critical to be acceptable.
- Uncontrollable: Situation let to an accident / leaving of the road. Accident could only be prevented because safety driver intervened with an emergency reaction.

TJM.39 How dangerous was the previous take-over situation?

*(Please take into account the situations as a whole including the behaviour of the function as well as your reaction to it).*

| | |
|---|---|
| uncontrollable | 10 |
| dangerous | 9 |
| | 8 |
| | 7 |
| unpleasant | 6 |
| | 5 |
| | 4 |
| harmless | 3 |
| | 2 |
| | 1 |
| not at all | 0 |

TJM.40.a-40.f Please indicate to what extent you agree or disagree with the following statements on take-over requests:

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don’ t know |
|---|---|---|---|---|---|---|---|
| 40.a | It was obvious to me why all takeover requests occurred. | | | | | | |
| 40.b | I would have liked more information about why a takeover request was triggered. | | | | | | |
| 40.c | During the takeover I always felt safe. | | | | | | |
| 40.d | I would like to know more about the system limits. | | | | | | |
| 40.e | When the system asked me to retake control, I was warned in an appropriate way. | | | | | | |
| 40.f | When the system asked me to retake control, I was warned with sufficient time to do so safely. | | | | | | |

# Annex 4 Pilot Site Questionnaire - Urban Pilot

## Before study/screening questions

➔ *Can be administered before the pilot test or already during driver recruitment e.g. together with pre-information regarding the experiment*

Urban Pilot questionnaire question number ID inside box: U.i

Thank you for agreeing to take part in this study on vehicle automation. Please read the following information and answer these questions before the date of your test drive.

**A. Participant information**

A1. Sociodemographic information

U.1 What year were you born? (dropdown menu; 1900-2018)

U.2 What is your gender

- **Male**
- **Female**
- **Other**
- **Prefer not to say**

U.3 Country of residency (dropdown menu):

- **Belgium**
- **France**
- **Germany**
- **United Kingdom**
- **Italy**
- **Sweden**
- **Other**

U.4 What is the highest level of education that you have completed (including ongoing education or studying at the moment)?

- **trade/technical/vocational training**
- **university degree**
- **none of those**

U.5 What is your employment status (dropdown menu):

- **Employed full-time**
- **Employed part-time**
- **Self-employed**
- **Homemaker**

- **Unemployed**
- **Retired**
- **Student**

U.6 Could you do part of your job whilst on transportation e.g. travelling on a bus, train or plane?

- **Yes**
- **No**

U.7 Do you have a car available for your use?

- **yes, (nearly) always**
- **yes, sometimes**
- **no or hardly ever**

U.8 Please tick all of those that apply to you in your employment (dropdown menu)

- **I am an employee of a vehicle manufacturer or supplier**
- **I work in the development of automated vehicle functions**
- **I test automated vehicle functions**
- **I have a professional driving qualification**
- **I am a qualified safety/test driver**
- **None of the above**

U.9 What category best describes your total household gross income for last year? (dropdown menu) (Edit this question to the currency of the country, ensuring that categories match closely)

- **below 20 000€**
- **20 000- 40 000€**
- **40 000- 60 000€**
- **60 000- 80 000€**
- **80 000- 100 000€**
- **more than 100 000€**

U.10 How many children under 19 years old live in your household? (dropdown menu)

- **none**
- **1**
- **2**
- **3**
- **4**
- **more than 4**

A2. Vehicle purchasing decisions

U.11 How often do you purchase / change your car? (dropdown menu)

- **Every year**

- 2-5 years
- 6-10 years
- 10 years
- Not sure, no clear habits

U.12 Will your next car be a (dropdown menu):

- Company car
- Leased car
- Own car
- I consider using a car sharing service
- I don't know yet

U.13 When buying or leasing your next vehicle, would you select

- a new car
- a pre-owned / used or
- I don't know

U.14 Please estimate the price of the next vehicle you would buy: in currency of the country (open question, with 'I don't know' option)

U.15 How familiar are you with the make of the test vehicle? (dropdown menu)

- I have owned one and/or used one frequently
- I have driven one a few times
- I have travelled in one but not driven
- Some other experience (e.g. read about them)
- No experience

U.16 Today you will be operating with (add function name and brief description). How familiar are you with this type of systems you will be using today? (5 point scale)

| | | | | |
|---|---|---|---|---|
| Highly familiar | | | | Highly unfamiliar |

A3. Driving history

U.17 How many years of driving experience do you have?

- less than one year
- 1-2 years
- 2-10 years
- more than 10 years

U.18 On average, how often do you drive a car?

- (Nearly) Every day
- 3-5 days / week

- **1-2 days / week**
- **Less often or never**

U.19 Approximately how many kilometres did you drive in the last 12 months? (dropdown menu)

- **less than 2000 km**
- **2 000- 5 000 km**
- **5 000- 10 000 km**
- **10 000- 15 000 km**
- **15 000- 20 000 km**
- **20 000- 50 000 km**
- **more than 50 000 km**

A4. In-vehicle system usage (baseline)

U.20 Please state if your current vehicle is equipped with the following systems:

| | I have it and I use it | I have it but I don' t use it | I don' t have it | Don' t know if I have it |
|---|---|---|---|---|
| **Parking Assist System:** (A system that provides a camera view and/or auditory beeps to indicate how close you are to an object, while you are parking). | | | | |
| **Self-parking Assist System** (A system that controls the vehicle for parallel parking or reverse parking. Some of these systems control both steering and the throttle; others only control the steering and the driver presses the brake and throttle). | | | | |
| **Cruise Control (CC) or Adaptive Cruise Control (ACC)** (A system that maintains vehicle speed while driving (CC), or also automatically slows down or speeds up to keep a safe distance from a vehicle ahead (ACC)). | | | | |
| **Blind spot monitoring** (A system that monitors the driver's left and right blind spots for other vehicles. Often, drivers receive a visual or audio alert whenever a vehicle is present). | | | | |
| **Lane departure warning systems** (A system that provides assistance with lane-keeping, by sounding warnings when the vehicle travels outside of the lane markings/boundaries). | | | | |
| **Lane keeping assistance** (A system that helps motorists to avoid inadvertently moving out of the intended driving lane). | | | | |
| **Forward Collision Warning systems** (A system that provides warnings for potential collisions with the vehicle in front). | | | | |

U.21 While driving in urban environments, how often do you engage in the following activities:

| | Very frequently | Frequently | Every now and then | Infrequently | Very infrequently | Never |
|---|---|---|---|---|---|---|
| Texting | | | | | | |
| Music, radio, audiobooks | | | | | | |
| Interact with a passenger | | | | | | |
| Eating or drinking | | | | | | |
| Calling | | | | | | |
| Smoking | | | | | | |
| Personal hygiene/Cosmetics | | | | | | |
| Smart phone apps | | | | | | |
| Social media | | | | | | |
| Navigation | | | | | | |
| Browsing the internet | | | | | | |
| None | | | | | | |

A5. Trip choice

U.22 What mode of transport do you typically use for the following trip types? Choose 1-3 often used modes: 1 for the one most used, 2 for the second most used (if applicable), 3 for the third most used (if applicable). Exclude trips made by airplane.

| | Passenger car | Public transport | Taxi | Motorbike or scooter | Bicycle or walking | I don’ t take such trips |
|---|---|---|---|---|---|---|
| Commuting | | | | | | |
| Business travel | | | | | | |
| Leisure/social | | | | | | |
| Errands (incl. groceries) | | | | | | |

U.23 Please state your agreement with the following statements:

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| Lack of time greatly affects my daily travel choices. | | | | | |
| I tend to select the cheapest mode of transport, even if it would take more time. | | | | | |
| I tend to select the quickest mode of transport, even if it would cost me more. | | | | | |
| I would travel more in my daily life if travelling was easier. | | | | | |
| I tend to select the most comfortable mode of transport. | | | | | |
| Traffic jams affect my choice of mode. | | | | | |
| Traffic jams affect my choice of route in the car. | | | | | |
| Traffic jams affect the time that I choose to take my trips. | | | | | |
| Weather conditions affect my decision to drive. | | | | | |
| Darkness affects my decision to drive. | | | | | |
| Fatigue affects my decision to drive. | | | | | |

U.24 How often do you experience the following driving situations?

| | Everyday | Nearly every day | 3-5 days / week | 1-2 days / week | Less often or never |
|---|---|---|---|---|---|
| Driving on a motorway | | | | | |
| Driving on rural roads | | | | | |
| Driving on urban streets | | | | | |
| Driving at night | | | | | |
| Driving fatigued | | | | | |

U.25 Below is a list of statements on driving in urban areas. Please indicate how strongly you agree or disagree with each statement:

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|
| Driving in urban areas is stressful | | | | | | |
| Driving in urban areas is difficult | | | | | | |
| Driving in urban areas is demanding | | | | | | |
| Driving in urban areas is fun | | | | | | |

U.26 Do you generally experience motion sickness when travelling as a passenger on urban street network?

- **Never or hardly ever**
- **Sometimes**
- **Often or always**

U.27 When it comes to trying a new technology product I am generally….

| | | |
|---|---|---|
| **among the last** | **in the middle** | **among the first** |

## Pilot site questionnaire (post drive)

Thank you for taking part in this study. The test today has provided you with an experience of a particular type of partly self-driving vehicle. Please answer all questions imagining that you were now able to use this vehicle on a day-to-day basis. Please be honest in your responses. All contributions will be anonymized and cannot be used to identify you as an individual.

U.28 What is your immediate reaction / first impression after completing your journey with the vehicle? *(Free association)*

[ ] ______________________________________________

U.29 Did something happen during the drive that made you feel unsafe or uncomfortable? If yes, please explain briefly:

[ ] ______________________________________________

U.30.a-30.b Did you experience motion sickness during your test drive when the car was driving by itself?

a. 30.a During the driving with the function active, I felt:

- **No signs of motion sickness**
- **Slightly nauseated**
- **Severely nauseated**

b. 30.b If you answered “slightly” or “severely nauseated” in the previous question, did it impact your use of the system? If yes, please explain briefly:

[ ] ______________________________________________

U.31 I think that the tested partly self-driving system was …

| | | | | | | |
|---|---|---|---|---|---|---|
| Useful | | | | | | Useless |
| Pleasant | | | | | | Unpleasant |
| Bad | | | | | | Good |
| Nice | | | | | | Annoying |
| Effective | | | | | | Superfluous |
| Irritating | | | | | | Likeable |
| Assisting | | | | | | Worthless |
| Undesirable | | | | | | Desirable |
| Raising alertness | | | | | | Sleep-inducing |

U.32 How comfortable or uncomfortable did the behaviour of the vehicle with the activated system make you feel? Please answer regarding the following topics:

| | Very comfortable | | | | Very uncomfortable | Don' t know |
|---|---|---|---|---|---|---|
| Distance kept to the vehicle in front | | | | | | |
| Smoothness of driving | | | | | | |
| Behaviour when approaching pedestrians at intersection | | | | | | |
| Acceleration behaviour of vehicle | | | | | | |
| Braking behaviour of vehicle | | | | | | |
| Turning behaviour (intersections, curves) | | | | | | |
| Distance kept to road markings | | | | | | |
| Distance kept to obstacles | | | | | | |
| Distance kept to pedestrians and cyclists when overtaking | | | | | | |

U.33.a-33.α Below is a list of statements on the system you use today. Please imagine how strongly you would agree or disagree with each statement from the point of view of a driver:

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|---|
| 33.a | I would use this system if it was in my car. | | | | | | |
| 33.b | Sometimes the system behaved unexpectedly. | | | | | | |
| 33.c | I felt safe when driving with the system active. | | | | | | |
| 33.d | I would buy the system. | | | | | | |
| 33.e | The cost of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 33.f | The benefits of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 33.g | I would recommend the system to others. | | | | | | |

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don’ t know |
|---|---|---|---|---|---|---|---|
| 33.h | Driving with this system was difficult. | | | | | | |
| 33.i | Driving with the system was demanding. | | | | | | |
| 33.j | Driving with the system was stressful. | | | | | | |
| 33.k | The system worked as it should work. | | | | | | |
| 33.l | I would want to monitor the system’s performance. | | | | | | |
| 33.m | The system acted appropriately in all situations. | | | | | | |
| 33.n | I would use the time the system was active to do other activities. | | | | | | |
| 33.o | I trust the system to drive. | | | | | | |
| 33.p | I would use the system during my everyday trips. | | | | | | |
| 33.q | Driving with the system was comfortable. | | | | | | |
| 33.r | During driving with the system active, I monitored the surrounding environment more than in manual driving. | | | | | | |
| 33.s | During driving with the system active, I was more aware of hazards in the surrounding environment than in manual driving. | | | | | | |
| 33.t | Driving with the function on longer journeys would make me tired. | | | | | | |
| 33.u | I would make MORE trips if I had the function in my car. | | | | | | |
| 33.v | I would select destinations further away if I had the function in my car. | | | | | | |
| | ***Items on take-over requests*** | | | | | | |
| 33.w | It was obvious to me why takeover requests occurred. | | | | | | |
| 33.x | I would have liked more information about why a takeover request was triggered. | | | | | | |
| 33.y | During the takeover I always felt safe. | | | | | | |
| 33.z | When the system asked me to retake control, I was warned in an appropriate way. | | | | | | |
| 33.α | When the system asked me to retake control, I was warned with sufficient time to do so safely. | | | | | | |

U.34 Imagine your vehicle was equipped with the urban pilot system you experienced today, how often would you engage in the following activities while the system is active?

| | Very frequently | Frequently | Every now and then | Infrequently | Very infrequently | Never |
|---|---|---|---|---|---|---|
| Texting | | | | | | |
| Music, radio, audiobooks | | | | | | |
| Interact with a passenger | | | | | | |
| Eating or drinking | | | | | | |
| Calling | | | | | | |
| Smoking | | | | | | |
| Personal hygiene/Cosmetics | | | | | | |
| Smart phone apps | | | | | | |
| Social Media | | | | | | |
| Navigation | | | | | | |
| Browsing the internet | | | | | | |
| Sleeping | | | | | | |
| Watching movies | | | | | | |
| Office/work tasks | | | | | | |
| None | | | | | | |

U.35 Imagine that you have a partly self-driving car which is able to drive by itself in urban areas. You have a trip that takes 30 minutes of driving. You have scheduled it to avoid the peak of congestion. How much additional time would you be willing to accept for the duration of this trip if the car could drive by itself and you could engage in other activities?

________minutes

U.36 If a partly self-driving car was available to you, how do you think it would affect your choice of travel mode?

| | … less often | | | | … as often as today |
|---|---|---|---|---|---|
| I would use public transport …. | | | | | |
| I would use a motorbike/scooter | | | | | |
| I would walk or use a bicycle …. | | | | | |
| I would use a taxi service …. | | | | | |

U.37 Do you have any other comments on the test drive?

**Willingness to pay**

U.38 How much extra would you be willing to pay for including this partially self-driving system in your car? _____ (currency of the country)

| | | | | |
|---|---|---|---|---|
| **0 €** | **less than 3000 €** | **3000- 4999 €** | **5000- 6999 €** | **≥ 7000 €** |

## Optional: Questioning during drive after Take-over requests

Take-over situations are evaluated in a two-step process. First, the driver decides on one of the five verbal categories. Second, a more fine-grained evaluation is conducted by choosing one of the corresponding numbers for the three intermediate categories.

*To do this, please take the whole situation into account, including the behaviour of the system, your reaction, the surrounding traffic etc. Please think about how you would evaluate this situation if it would happen to you on one of your daily trips.*

*The categories are defined as follows:*

- Not at all: no reaction was needed to continue driving safely.
- Harmless (rating 1-3): you needed no or only little effort to resolve the situation and take vehicle control back.
- Unpleasant (rating 4-6): retaining control was demanding and required immediate reaction, but the required effort was still manageable.
- Dangerous (rating 7-9): the situations was highly demanding. Considerable or intense corrections/response was required to retain control. In everyday traffic, the situation would be too critical to be acceptable.
- Uncontrollable: Situation let to an accident / leaving of the road. Accident could only be prevented because safety driver intervened with an emergency reaction.

U.39 How dangerous was the previous take-over situation?

(Please take into account the situations as a whole including the behaviour of the function as well as your reaction to it).

| | |
|---|---|
| uncontrollable | 10 |
| dangerous | 9 |
| | 8 |
| | 7 |
| unpleasant | 6 |
| | 5 |
| | 4 |
| harmless | 3 |
| | 2 |
| | 1 |
| not at all | 0 |

U.40.a-40.f Please indicate how strongly you agree or disagree with the following statements on take-over requests:

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don’ t know |
|---|---|---|---|---|---|---|---|
| 40.a | It was obvious to me why all takeover requests occurred. | | | | | | |
| 40.b | I would have liked more information about why a takeover request was triggered. | | | | | | |
| 40.c | During the takeover I always felt safe. | | | | | | |
| 40.d | I would like to know more about the system limits. | | | | | | |
| 40.e | When the system asked me to retake control, I was warned in an appropriate way. | | | | | | |
| 40.f | When the system asked me to retake control, I was warned with sufficient time to do so safely. | | | | | | |

# Annex 5 Pilot Site Questionnaires – Parking Functions

## Before study/screening questions

➔ *Can be administered before the pilot test or already during driver recruitment e.g. together with pre-information regarding the experiment*

Parking Functions questionnaire question number ID inside box: P.i

Thank you for agreeing to take part in this study on vehicle automation. Please read the following information and answer these questions before the date of your test drive.

**A. Participant information**

A1. Sociodemographic information

P.1 What year were you born? (dropdown menu; 1900-2018)

P.2 What is your gender

- **Male**
- **Female**
- **Other**
- **Prefer not to say**

P.3 Country of residency (dropdown menu)

- **Belgium**
- **France**
- **Germany**
- **Great Britain**
- **Italy**
- **Sweden**
- **Other**

P.4 What is the highest level of education that you have completed (including ongoing education or studying at the moment)?

- **trade/technical/vocational training**
- **university degree**
- **none of those**

P.5 What is your employment status (dropdown menu):

- **Employed full-time**
- **Employed part-time**
- **Self-employed**
- **Homemaker**
- **Unemployed**
- **Retired**
- **Student**

P.6 Could you do part of your job whilst on transportation e.g. travelling on a bus, train or plane?

- **Yes**
- **No**

P.7 Do you have a car available for your use?

- **yes, (nearly) always**
- **yes, sometimes**
- **no or hardly ever**

P.8 Please tick all of those that apply to you in your employment (dropdown menu)

- **I am an employee of a vehicle manufacturer or supplier**
- **I work in the development of automated vehicle functions**
- **I test automated vehicle functions**
- **I have a professional driving qualification**
- **I am a qualified safety/test driver**
- **None of the above**

P.9 What category best describes your total household gross income for last year?

(Edit this question to the currency of the country, ensuring that categories match closely)
(dropdown menu)

- **below 20 000€**
- **20 000- 40 000€**
- **40 000- 60 000€**
- **60 000- 80 000€**
- **80 000- 100 000€**
- **more than 100000€**

P.10 How many children under 19 years old live in your household? (dropdown menu)

- **none**
- **1**
- **2**
- **3**
- **4**
- **more than 4**

A2. Vehicle purchasing decisions

P.11 How often do you purchase / change your car? (dropdown menu)

- **Every year**
- **2-5 years**
- **6-10 years**

- 10 years
- Not sure, no clear habits

P.12 Will your next car be a: (dropdown menu)

- Company car
- Leased car
- Own car
- I consider using a car sharing service
- I don't know yet

P.13 When buying or leasing your next vehicle, would you select

- a new car
- a pre-owned / used or
- I don't know

P.14 Please estimate the price of the next vehicle you would buy: ________ in currency of the country (open question, with 'I don't know' option).

P.15 How familiar are you with the make of the test vehicle? (dropdown menu)

- I have owned one and/or used one frequently
- I have driven one a few times
- I have travelled in one but not driven
- Some other experience (e.g. read about them)
- No experience

P.16 Today you will be operating with (add function name and brief description). How familiar are you with this type of systems you will be using today? (5 point scale)

| | | | | |
|---|---|---|---|---|
| Highly familiar | | | | Highly unfamiliar |

A3. Driving history

P.17 How many years of driving experience do you have?

- less than one year
- 1-2 years
- 2-10 years
- more than 10 years

P.18 On average, how often do you drive a car?

- (Nearly) Every day
- 3-5 days / week
- 1-2 days / week
- Less often or never

P.19 Approximately how many kilometres did you drive in the last 12 months? (dropdown menu)

- **less than 2000 km**
- **2 000- 5 000 km**
- **5 000- 10000 km**
- **10000- 15 000 km**
- **15 000- 20 000 km**
- **20 000- 50 000 km**
- **more than 50 000 km**

A4. In-vehicle system usage (baseline)

P.20 Please state if your current vehicle is equipped with the following systems:

| | I have it and I use it | I have it but I don' t use it | I don' t have it | Don' t know if I have it |
|---|---|---|---|---|
| **Parking Assist System:** (A system that provides a camera view and/or auditory beeps to indicate how close you are to an object, while you are parking). | | | | |
| **Self-parking Assist System** (A system that controls the vehicle for parallel parking or reverse parking. Some of these systems control both steering and the throttle; others only control the steering and the driver presses the brake and throttle). | | | | |
| **Cruise Control (CC) or Adaptive Cruise Control (ACC)** (A system that maintains vehicle speed while driving (CC), or also automatically slows down or speeds up to keep a safe distance from a vehicle ahead (ACC)). | | | | |
| **Blind spot monitoring** (A system that monitors the driver's left and right blind spots for other vehicles. Often, drivers receive a visual or audio alert whenever a vehicle is present). | | | | |
| **Lane departure warning systems** (A system that provides assistance with lane-keeping, by sounding warnings when the vehicle travels outside of the lane markings/boundaries). | | | | |
| **Lane keeping assistance** (A system that helps motorists to avoid inadvertently moving out of the intended driving lane). | | | | |
| **Forward Collision Warning systems** (A system that provides warnings for potential collisions with the vehicle in front). | | | | |

A5. Trip choice

P.21 Do you have a personal parking space that you can use? Please tick all options that apply.

- **At home**

- **At work**
- **Somewhere else**
- **Nowhere**

P.22 How often do you park in the described ways?

| | Everyday | (nearly) every day | 3-5 days / week | 1-2 days / week | Less often or never |
|---|---|---|---|---|---|
| In a private parking garage | | | | | |
| In a private parking lot | | | | | |
| On a company car park | | | | | |
| Along public roads | | | | | |
| Parallel parking | | | | | |
| Perpendicular parking | | | | | |
| In a large parking lot e.g. at the airport | | | | | |

P.23 Please state your agreement with the following statements:

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|
| Having to search for a parking space at the end of the trip affects my decision about where to drive. | | | | | | |
| The expectation of a demanding parking maneuverer at the end of a trip affects my decision about where to drive. | | | | | | |
| I accept longer searches for a parking space or longer walking distances to find a good parking space. | | | | | | |
| Parking in is a stressful experience. | | | | | | |
| Parking out is a stressful experience. | | | | | | |
| Parking is difficult. | | | | | | |
| Parking is demanding. | | | | | | |

P.24 When it comes to trying a new technology product I am generally….

| | | |
|---|---|---|
| **among the last** | **in the middle** | **among the last** |

## Pilot site questionnaire (post drive)

Thank you for taking part in this study. The test today has provided you with an experience of a particular type of partly self-driving vehicle. Please answer all questions imagining that you were now able to use this vehicle on a day-to-day basis. Please be honest in your responses. All contributions will be anonymized and cannot be used to identify you as an individual.

P.25 What is your immediate reaction / first impression after completing the parking test with the vehicle? *(Free association)*

[ ] ______________________________________

P.26 Did something happen during the test that made you feel unsafe or uncomfortable? If yes, please explain briefly:

[ ] ______________________________________

P.27 I think that the tested self-parking system was …

| | | | | | | |
|---|---|---|---|---|---|---|
| Useful | | | | | | Useless |
| Pleasant | | | | | | Unpleasant |
| Bad | | | | | | Good |
| Nice | | | | | | Annoying |
| Effective | | | | | | Superfluous |
| Irritating | | | | | | Likeable |
| Assisting | | | | | | Worthless |
| Undesirable | | | | | | Desirable |
| Raising alertness | | | | | | Sleep-inducing |

P.28.a-P.28.r Below is a list of statements on the function that you tested. Please indicate how strongly you agree or disagree with each statement:

| | | Strongly disagree | Disagree | Neutral | Agree | Strongly agree | Don' t know |
|---|---|---|---|---|---|---|---|
| 28.a | I would use this system if it was in my car. | | | | | | |
| 28.b | I liked parking with the system. | | | | | | |
| 28.c | Sometimes the system behaved unexpectedly. | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28.d | I felt safe when parking with the system. | | | | | | |
| 28.e | I would buy the system. | | | | | | |
| 28.f | The cost of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 28.g | The benefits of the system would be the most important thing I would consider before purchasing one. | | | | | | |
| 28.h | I would recommend the system to others. | | | | | | |
| 28.i | Parking with the system was difficult. | | | | | | |
| 28.j | Parking with the system was demanding. | | | | | | |
| 28.k | Parking with the system was stressful. | | | | | | |
| 28.l | The system worked as it should work. | | | | | | |
| 28.m | I would want to constantly monitor the system's performance. | | | | | | |
| 28.n | The system was useful. | | | | | | |
| 28.o | I trust the system to park for me. | | | | | | |
| 28.p | The system acts appropriately in all situations. | | | | | | |
| 28.q | I would use the system every day. | | | | | | |
| 28.r | I was more aware of the surrounding environment than in manual parking. | | | | | | |

P.29 How beneficial would the parking system be for you in the following situations? (5 point scale between not beneficial and very beneficial – do not include text or numbers in between)

| | Not beneficial (1) | 2 | 3 | 4 | Very beneficial (5) | Not relevant to me |
|---|---|---|---|---|---|---|
| Parking in a home garage/space | | | | | | |
| Parking on a fixed space on a company car park/parking lot | | | | | | |
| Others:__________________ | | | | | | |

P.30 Do you have any other comments on the system you experienced?

**Willingness to pay**

P.31 How much extra would you be willing to pay for including this partly self-driving system in your car?

| | | | | |
|---|---|---|---|---|
| **0 €** | **less than 1000 €** | **1000- 1499 €** | **1500- 1999 €** | **≥ 2000 €** |

# Annex 6 CBA approach in FESTA Handbook and L3Pilot

Field Operational Tests (FOT) aim to identify real-world impacts of new vehicle technology, in real road traffic environments. Guidance to facilitate the successful delivery of FOTs is given in a handbook, *originally* developed by FESTA (Field operational test support action, 2007-2008). The FESTA Handbook, which also gives guidance on socio-economic CBA, is updated and revised over time to present best practices in light of experience and knowledge (latest version FOT-Net, 2018).

The FESTA Handbook provides recommendations and guidelines for scaling up effects from the experiments to socio-economic impacts. The results of this process are the key input for the CBA in L3Pilot. The scaling up of effects from the experiments to impacts at EU-level and obtaining the unit values in economic terms, which can be ascribed to these impacts, are not easy to estimate. Therefore, these factors have to be taken into account when interpreting the calculated economic values at the societal level. Overall, the CBA approach in L3Pilot complies well with the guidelines and recommendations given in the latest FESTA Handbook. The following table provides an overview of the CBA approach in L3Pilot as compared with the guidelines in FESTA Handbook.

*CBA approaches in FESTA Handbook and L3Pilot.*

| CBA in FESTA Handbook | CBA in L3Pilot |
|---|---|
| The basic choice is a CBA to summarize benefits and costs at a societal level | Same |
| May also consider stakeholder-specific benefits, costs and financial analyses | Does not consider stakeholder perspectives |
| EU-level analysis is preferred | Same |
| Use the costs incurred and the main expected benefit(s) | Same |
| Other direct and indirect impacts can also be included | Discuss the possibility of other impacts |
| Willingness to pay and use data can be used to supplement the analysis above | Same |
| System cost estimation is an element within FOTs which is quite often neglected – in-vehicle equipment, infrastructure equipment | Includes costs for in-vehicle equipment.<br>Road and public infrastructure to be included, if applicable |
| Use the price paid for by the manufacturer to the supplier plus a mark-up | Development costs should not be considered at the societal level when the technology exists |
| Cost estimations may be carried out by an expert group (project staff and industry experts). Market prices may be used to estimate the cost price: In the automotive industry market prices for ICT systems differ from the cost prices by a factor of 3 | Same |
| FOTs should be designed to be as complete as possible, both in terms of impacts and stakeholder views | Same |
| Willingness to pay studies (WTP) is a way of getting evidence on the users' likely demand for the products. | WTP will be used to complement the ex post -based value of economic impacts |

| CBA in FESTA Handbook | CBA in L3Pilot |
|---|---|
| A discount rate of 3% (real) is recommenced | According to recommended discount rate (e.g. for discounting ADF costs to annual costs) |
| Impact measurements represent an essential input to the CBA and will normally feed through from the experiments to the scaling-up procedure to the CBA inputs | It is expect this to be the case in L3Pilot and have to be explicit as to the kinds of data we need |
| Data needs, data sources, relevant generic and unit values | Same |
| Reporting: Safety benefit | Safety key performance indicators |
| Reporting: Other benefits to road users – time savings, operating cost savings and reliability gains | Efficiency key performance indicators<br>Also by calculating generalized travel costs |
| Reporting: Environmental benefits – climate change, regional and local air quality, noise etc. | Environmental key performance indicators |
| Reporting: Costs to operators | Costs of infrastructure, if relevant |
| Reporting: Revenue to operators | No |
| Reporting: Costs and revenues for original equipment manufacturers | Does not plan to present Benefit/Cost-ratios for manufacturers, and assumes sufficient competition to avoid that ADFs will create additional producer surplus.<br>Does not include manufacturers' perspectives, and assumes competition which ensures normal profits |
| Reporting: Costs and revenues for government | Same and assuming that the net value for society exceeds the direct monetary effect because society also has taken the cost of funding (taxation) into account |
| Reporting: No explicit recommendation to report impacts for the rest of society | Mentions the potential for such impacts, but that these cannot be expected for ADF technology |