Defining the future of passenger car transport

Deliverable D6.1 – WP6 – PU

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Work package 6, Deliverable D6.1

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Legal Disclaimer

List of abbreviations

ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
AV	Automated Vehicle
CACC	Cooperative Adaptive Cruise Control
CAFE	Corporate Average Fuel Economy
CATS	Connected and Automated Transport Systems
C-ITS	Cooperative Intelligent Transport Systems
CV	Connected Vehicle
DisA	Distraction Alert
DrowA	Drowsiness Alert
ERTRAC	European Road Transport Research Advisory Council
EU	European Union
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FORS	Fleet Operation Recognition Scheme
GDPR	General Data Protection Regulation
IMA	Intersection Movement Assist
ISA	Intelligent Speed Assist
IVS	In-vehicle Signage
LCA	Lane Change Assist
LDW	Lane Departure Warning
LKA	Lane Keeping Assist
NHTSA	National Highway Traffic Safety Administration
NRC	National Research Council
PST	Policy Support Tool
SAE	Society of Automotive Engineers
SRG	Stakeholder Reference Group
TA	Turn Assist
TTC	Time to Collision
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to everything
VKT	Vehicle Kilometers Travelled

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Executive summary

The aim of the LEVITATE project is to prepare a new impact assessment framework to enable policymakers to manage the introduction of connected and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives. As part of this work, LEVITATE seeks to forecast societal level impacts of connected and automated transport systems (CATS). These impacts include impacts on safety, environment, economy and society. This report specifically focuses on passenger cars as part of CATS. Urban transport and Freight transport are considered in deliverable 5.1 and 7.1, respectively. The aim of this report is to provide a working framework under which the future of automated passenger cars and resulting impacts can be defined as is relevant for the future work of LEVITATE project. This includes defining expected penetration rates as influenced by market forces and technology adoption, possible use cases of automated passenger cars, their impacts and associated timeframe. A comprehensive list of impacts has been discussed and provided in deliverable 3.1 of LEVITATE and therefore not included in this report.

Forecasts of ADAS penetration made in 2005 compared to actual penetration of ADAS technologies in present days, clearly showed overestimation. By comparison, it is probable that current estimations of technology adoption of SAE level 3 – 5 may be overestimates as there are several affecting factors including user trust, willingness to pay, market forces and costs and, policies and regulations. Most studies and organisations have predicted market penetration of SAE level 3 – 5 CATS between 8% and 30% by year 2030 and SAE level 5 close to saturation (100%) after year 2060. It is worth noting that a connected vehicles future is closer and market penetration is expected to be close to 100% within the coming decade (i.e. by 2030). Initial information on forecasted market penetration will inform the subsequent work (tasks 6.2, 6.3 and 6.4) to look at short-, medium- and long-term impacts of passenger cars, respectively. The findings presented in this report were obtained in two ways, through literature review and a stakeholder workshop. An extensive literature review of the impacts on urban transport for the short, medium and long-term future will be provided as an outcome of the corresponding subsequent tasks 5.2, 5.3, 5.4, therefore it is out of the scope of this report. Literature review on ADAS (SAE level 1/2 technologies) showed clear impacts on traffic, safety, environment, mobility and society, albeit small percentages. It is expected that level 3 – 5 technologies will also have major impacts on traffic, safety, environment, economy and mobility.

A stakeholder reference group workshop was conducted to gather views from city administrators and industry on the future of CATS and possible uses (i.e. use cases) of automated passenger cars, named, sub-use cases. The outcome of this was expected to inform the future work in terms of prioritisation on interventions and sub-use cases to analyse within WP6 of LEVITATE. It emerged that while planning processes extend to year 2040 for level 5 technology, no formal definitions of exactly what to expect are in place. Overall, workshop participants stated that CATS were mainly expected to supplement public transport functions. According to the participants, there are many opportunities that would emerge through these new technologies and cities would need to prepare to take full advantage of them.

The widespread use of automated passenger cars for personal use is more likely to be distant than their use as mobility services (such as taxis) simply due to prohibitive initial costs. Also, various forecasting studies show that the claimed (by CATS industry) benefits will only be achieved if we move from privately owned to a shared-ownership model. A list of sub-use cases of possible interest for use cases of passenger cars from a CATS perspective has been developed, informed by the literature and stakeholder workshop. This list will be prioritised and refined within subsequent tasks in the project to inform the interventions and scenarios related to passenger cars which will be included in the LEVITATE policy support tool (PST).

Looking further ahead within work package 6, task 6.2, 6.3 and 6.4 will focus on forecasting short-, medium- and long-term impacts. These impacts (from task 3.1) will be forecasted with prioritised sub-use cases and interventions (mentioned in this report) using appropriate methods developed in task 3.2. Appropriate market penetration will be considered as part of forecasts and the obtained quantitative relationship between level of penetration of automation (or intervention) and impacts will be used in WP8 for PST.

1 Introduction

1.1 LEVITATE

Societal **Lev**el **I**mpacts of Connec**t**ed and **A**utoma**t**ed Vehicl**e**s (LEVITATE) is a European Commission supported Horizon 2020 project with the objective to prepare a new impact assessment framework to enable policymakers to manage the introduction of connected and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives.

Specifically LEVITATE has four key objectives:

1. To incorporate the methods (those come from objective 3) within a **new web-based policy support tool** to enable city and other authorities to forecast impacts of CATS on urban areas. The methods developed within LEVITATE will be available within a toolbox allowing the impact of measures to be assessed individually. A Decision Support System will enable users to apply backcasting methods to identify the sequences of CATS measures that will result in their desired policy objectives.
2. To develop a range of **forecasting and backcasting** scenarios and baseline conditions relating to the deployment of one or more mobility technologies that will be used as the basis of impact assessments and forecasts. These will cover three primary use cases – automated urban shuttle, passenger cars and freight services.
3. To establish **a multi-disciplinary methodology** to assess the short, medium and long-term impacts of CATS on mobility, safety, environment, society and other impact areas. Several quantitative indicators will be identified for each impact type
4. To apply the methods and **forecast the impact of CATS** over the short, medium and long term for a range of use cases, operational design domains and environments and an **extensive range of mobility, environmental, safety, economic and societal indicators**. A series of case studies will be conducted to validate the methodologies and to demonstrate the system.

1.2 Work package 6 and Deliverable 6.1 within LEVITATE

Work Package (WP) 6 considers the specific case of passenger cars which are used across the transport system, mainly urban but extending to rural and highways. Work undertaken in WP6 is based on the methodology developed in WP3 and the scenarios developed in WP4 to identify and test specific scenarios regarding the impacts of CATS on passenger cars. Findings will complement those of WP5 (Urban transport) and WP7 (Freight) and feed into the developing of the LEVITATE Policy Support Tool (PST) in WP8. More specifically, the purpose of work package 6 is:

- To identify how each area of impact (safety, environment, economy and society) will be affected by the transition of passenger cars into connected and automated transport systems (CATS). Impacts on traffic will be cosidered cross-cutting across the other dimensions.

- To assess the short-, medium- and long-term impacts, benefits and costs of cooperative and automated driving systems for passenger cars.
- To test interactions of the examined impacts in passenger cars, and
- To prioritise considerations for a public policy support tool to help authority decisions.

The purpose of Deliverable 6.1 is to summarise the literature and workshop findings in relation to defining expectations of the short-, medium- and long-term future of automated passenger cars and their impacts on society, economy, environment and safety. This will pave the way for choosing the most suitable and realistic sub-use cases which may be used in forecasting the impacts of CATS. The document complements the corresponding reports of 5.1 on urban transport and 7.1 on freight.

2 Methods

Before assessing impact, benefits and costs of CATS it is necessary to define what are the short-, medium- and long-term futures. This document identifies aspects relevant to this specific use cases by employing:

a) A targeted review of recent literature (worldwide) on the future of automated vehicles on car transport. The deliverables of relevant European Union (EU) projects (to promote cross-fertilisation) were also considered.

b) A dedicated stakeholder consultation, with relevant stakeholders (related to passenger cars) and LEVITATE partners. The workshop gathered opinions on what is expected for connected and automated passenger cars and provided insights from experience of stakeholders. Structured discussions considered the situation/problem from the current standpoint (what is currently being done well/badly), described an ideal future and identified the major steps to be achieved/hurdles to be overcome to reach the desired future.

2.1 Literature review strategy

Literature informing about the future of passenger cars, including those on forecasts, within CATS domain was considered. In terms of level of automation, the definition provided by SAE (2018) was adopted as it is now considered to be practice standard. Literature on Advanced Driver Assistance Systems (ADAS) were included because those seem to be closely related to autonomous driving or self-driving. There are some parallels between ADAS and automated cars that can be drawn on to inform the work on impact assessment. A focused research on ADAS technologies was carried out. Relevant systems were determined before investigating predicted and actual impacts of each system. Previous European projects, such as iCar and eSafety, provided information that was further complimented with journal papers and government reports. In addition, following libraries were consulted, including:

- The ITS Library: https://ertico.assetbank-server.com/assetbank-ertico/action/viewHome
- RASAP (Repository & Open Science Access Portal): https://rosap.ntl.bts.gov/welcome

2.2 Workshop details and planning

A single workshop was planned with the goal to gain the input of experts on the three use cases. Therefore, this section is identical among all three deliverables: D5.1 - Defining the future of urban transport, D6.1 - Defining the future of passenger cars, and D7.1 - Defining the future of freight transport. For completeness and readability, the text is included in all three documents. The workshop agenda can be found in the appendix (section 6.3).

2.2.1 Background

The LEVITATE project is supported by a reference group of core stakeholders comprising of international / twinning partners, key international organisations, road user groups (i.e. pedestrians, cyclists, professional drivers), industry, insurances and health sector representing the more influential organisations that can affect mobility, environment, road safety and help improve casualty reduction among travellers. The main role of the Stakeholder Reference Group (SRG) is to support the project team in ensuring the research continues to address the key issues as well as providing a major route to implementation of the results and consequent impact on mobility and road safety of all travellers. SRG members include:

- **Cities and Regions:** City of Vienna (partner), Transport for Greater Manchester (partner), Transport of London, Madrid, Aarhus, Stuttgart region, KiM Dutch Ministry of Transport, ETSC, Rijkswaterstaat, Provincie Gelderland, City of Paris, Berlin, Catalonia, Amsterdam, Gothenberg and, City of Wels.
- **OEMs, Suppliers and, Infrastructure Providers & Operators:** DigiTrans consortium incl. associated partners: ASFINAG (Austrian infrastructure operator), BOSCH, Blue Danube Airport, AVL, DB Schenker, Magna, Rotax and, MAN.

2.2.2 Date of workshop and Desired outcomes

The SRG workshop was held in Gothenburg on 28th of May and the intended outcomes were to inform and provide:

- Project definitions of the future of CATS with respect to the short-, medium- and long-term (WP5,6,7)
- Goal dimensions and indicators of the desired future city (WP4)
- Identification of which sub-use cases are of most interest and if any are missing. (WP5,6,7)
- Initial feedback on the Policy Support Tool (PST) (WP8)

2.2.3 Workshop participants

Those members from SRG that were relevant to Task 4.1, 5.1, 6.1 and 7.1 in project LEVITATE were invited to the workshop and below is the list of type of organisations whom the participants belong to.

- Representatives of European cities
- Representatives of the European Commission, European decision makers
- Local/regional and national authorities and policy makers
- Automobile manufacturers
- Researchers in automotive industry or CATS sector in general, and Consultants
- Researchers from previous European projects about CATS

In overall, there were 40 participants at the workshop. Figure 2.1 shows participants by organisation. Majority of participants (53%) were from local and national authority organisations. Whereas, rest of the participants were from specialist groups (association related to car, cycles, pedestrian), research organisations and, R&D departments within commercial organisations.

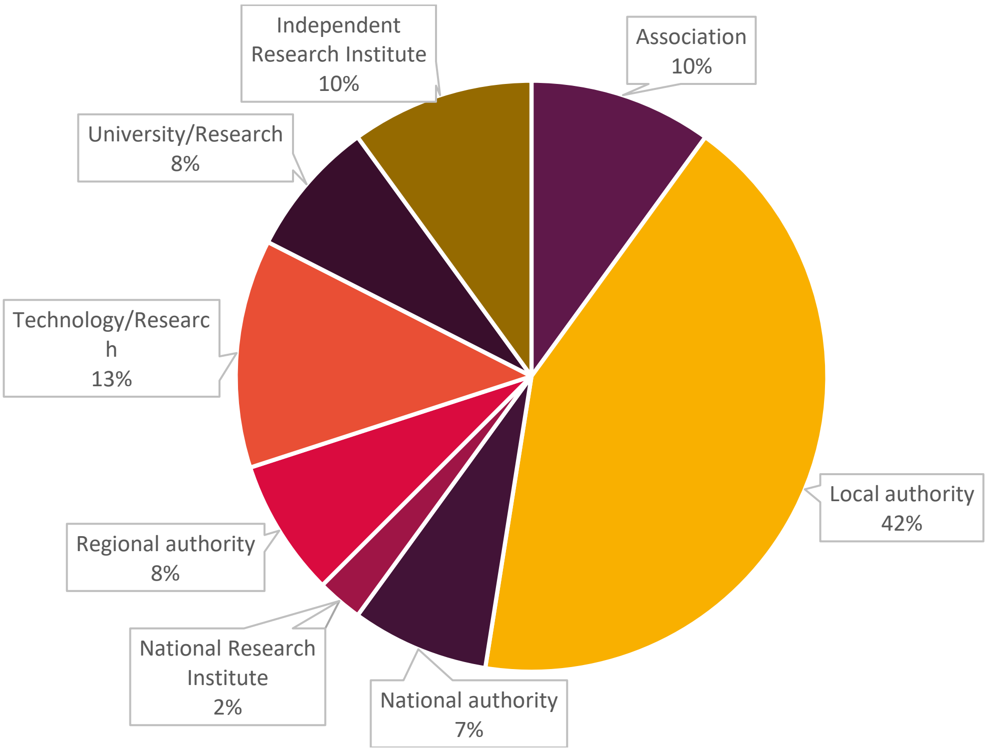


Figure 2.1 Participants by type of organisation.

Figure 2.2 shows participants by country. There was a good mix of partners from Europe. However, the majority were from western Europe possibly due to convenience of location of the Workshop.

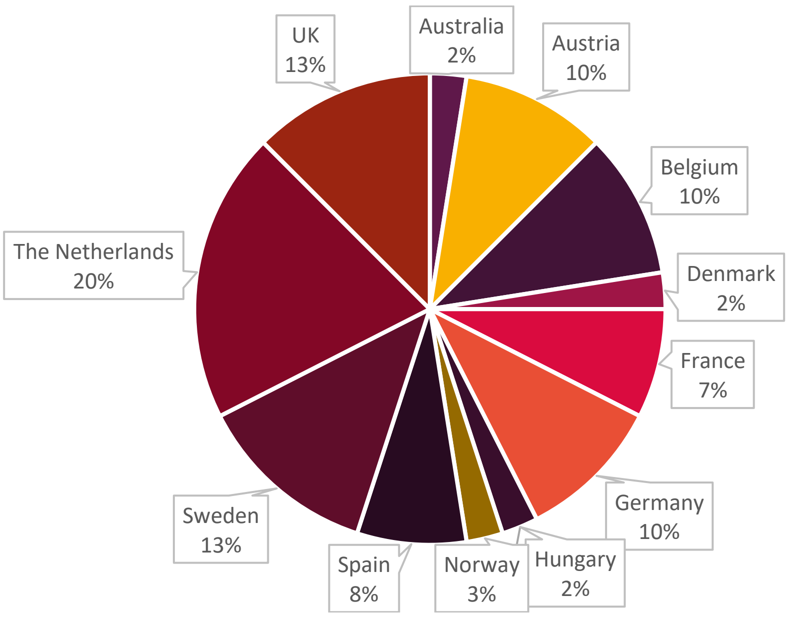


Figure 2.2 Workshop participants by country.

Figure 2.3 shows participants by their job functions. It can be ascertained that all participants were involved in jobs that were highly influential in decision-making within their own organisations. There were a few exceptions whose job titles were either missed to collect or were not provided. However, it was certain that they are involved in jobs that is influential in future directions of CATS.

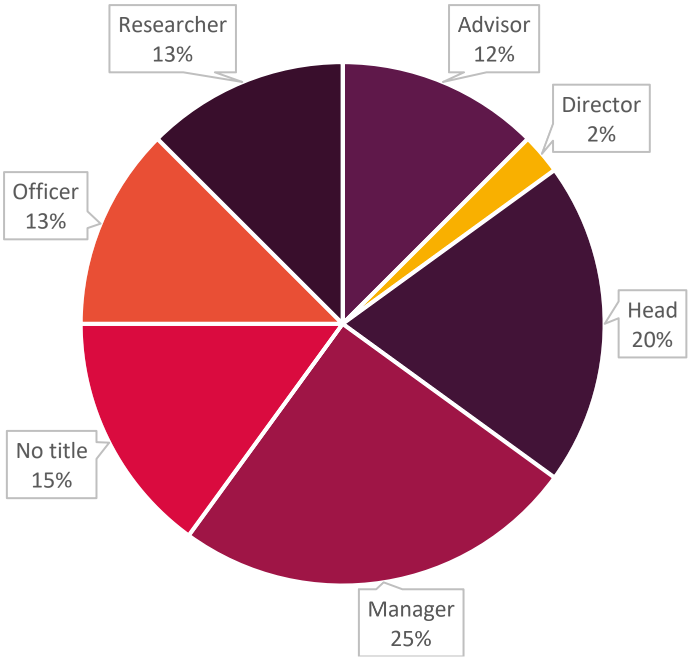


Figure 2.3 Participants by their job function.

Participants were further divided into smaller groups to discuss futures of automated urban transport (22 participants), passenger cars (11 participants), and freight transport (7 participants).

2.2.4 Ethics

Whenever data is being collected within the LEVITATE project all relevant data protection rules are followed. LEVITATE complies with the General Data Protection Regulation (GDPR) and provides confidentiality of any personal information collected within the project (e.g. no transfer of personal information between partners i.e. personal information is processed and anonymised within the organisation that collected the data, dataset is cleared of personal data as soon as possible after collection, only personal data that is really necessary is collected, asked for informed consent).

Ethics approval was granted by Loughborough University. A survey was conducted between partners to aid in understanding the ethics issues that are likely to be faced and simultaneously, to provide the basis for a public statement on the way GDPR requirements are managed within the project. All appropriate measures are taken within LEVITATE to assure that ethical requirements are addressed appropriately.

2.2.5 Pre-workshop pilot interviews

Before the workshop, three interviews were conducted as a scoping exercise to improve the understanding of the sub-use cases that are of most interest to city administrations and ensure the project is addressing the most important mobility interventions. Two representatives from Transport for Greater Manchester and one from Transport for

London were interviewed. The interviews were designed according to the workshop structure, lasted 30 minutes each and the aim was to define the short, medium & long term future of passenger car, urban and freight transport. The interview questions can be found in section 6.1 in Appendix. The main points for the discussion were sent to the participants 2 hours before the interview and were structured into the following parts:

Part 1: First thoughts on future cities and CATS
Part 2: What is currently being done for future planning and is it working?
Part 3: Specific future vision
Part 4: Sub-use cases
Part 5: The Policy Support Tool

Below a summary of stakeholders' comments on the future of passenger cars is provided.

- For the next 5 years there will not be much of an impact as, compared to conventional vehicles, automated cars will occupy a small percentage of the vehicles fleet.
- In 5-10 years, CATS could affect the connectivity and efficiency of the network with cost effective shuttle solutions offering more responsive transport for alternative routes.
- There will be different penetration rates and different levels of automation on the road and there is a danger for CATS to become an elite mode of transport.
- Commercial services such as automated taxis should be carefully regulated to avoid unsustainable passenger uptake and avoid congestion.
- Sustainability and shared mobility should be promoted to ensure a healthy city region.

2.2.6 Pre-workshop online survey

SRG members who registered for the workshop were also asked to complete an online survey to obtain a general assessment of the proposed indicators and to allow using the survey results as an impulse for inspiring discussions during the workshop. The questions were focused on identifying importance of their goals and way of measuring (i.e. indicators) them when planning for the future, as well as on ongoing and planned activities on sub-use cases (of automated passenger cars) and interventions. The survey questionnaire can be found in section 6.2 in the appendix and their results in section 4.1.

2.2.7 Workshop structure

A full-day workshop took place in Gothenburg, Sweden, in the Lindholmen Conference Centre on 28th May 2019. Besides project introduction and impulse presentations (i.e. intended to induce lively discussions), the main discussion was split into four sessions, and each session was further split into thematic groups. The overall structure was as follows:

- Project introduction
- Session 1: Visions of CATS Futures (discussion about the role of CATS in the short- medium- and long-term future)
  - Group 1: Automated Urban Transport
  - Group 2: Passenger Cars
  - Group 3: Freight Transport & Logistics
- Impulse presentation on the City of the future
- Session 2: Ideal Futures (discussion about goal dimensions and indicators of the desired future city)
  - Group 1: Environment

    - Group 2: Society
    - Group 3: Economy
    - Group 4: Safety
- Session 3: Selecting Interventions & Activities (identification and prioritisation of sub-use cases)
    - Group 1: Automated Urban Transport
    - Group 2: Passenger Cars
    - Group 3: Freight Transport & Logistics
- Round 4: Expectations and Needs regarding the PST
- Closing

In session 1 and 3, participants were split into self-selecting groups based on their expertise/subject area for cars, urban transport and freight. Since the group for urban transport was large, it was split into further two, creating four groups overall. In session 2, the participants were randomly split based on the coloured dots that were provided on their name badges. The coloured dots represented impact dimensions – safety, environment, economy and society.

The whole workshop was planned and organised by LEVITATE project team members.
- Moderator: Alexandra Millonig (AIT)
- Group facilitators: Ashleigh Filtness (LOUGH), Bin Hu (AIT), Alexandra Millonig (AIT), Julia Roussou (NTUA)
- Registration and organisation: Dagmar Köhler, Suzanne Hoadley, Balázs Németh (all POLIS)

3 Literature review findings

3.1 Introduction (Background and Research Problems):

Published literature was reviewed to understand possible futures of automated passenger cars. Since Advanced Driver Assistance Systems (ADAS) technologies are considered as SAE level 1/level 2 technologies, they were reviewed to inform what may be expected from SAE level 3 – 5 automation of passenger cars and to identify what can be learnt from ADAS. Therefore, this chapter is presented into three parts in following way: (1) Advanced Driver Assistance Systems (ADAS) technologies, (2) expected future of CATS and (3) identification of uses of automated passenger cars.

This literature review on ADAS included an introduction to the types of ADAS technologies and their functionalities and their impacts on traffic, society, environment, safety and, economy. The influencing factors in adoption of ADAS and their forecasted and actual market penetration were also reviewed. Extending this to CATS, the literature was reviewed in brief to see what impacts from CATS may be expected and the level of market penetration of SAE level 3 – 5 technologies. Furthermore, different use cases of automated passenger cars were identified from literature and workshop which would provide input for forecasting of impacts that will be used in PST.

3.2 Current ADAS Technologies

In this section, current ADAS technologies, i.e., SAE level 1 and 2 systems, and their impacts are discussed. As these systems are the closest existing comparison to future CATS, information in this section can be used as a basis for prediction of impacts and penetration rate evolution of future CATS. Since there is overlap between systems for freight transport, urban transport and personal cars, section 3.2 of this deliverable has similarities to the corresponding sections in deliverables 5.1 and 7.1.

3.2.1 Which technologies are already out there?

ADAS can be grouped in different ways. Systems can for example be grouped by their operational domain: lateral control, longitudinal control, a combination of both, systems concerned with the state of the driver, and systems designed for special manoeuvres. Another way to group the systems is to look at the level of guidance they provide, viz., systems can inform or warn the driver, may take over part of the driving task or can intervene when necessary (Vlakveld, 2019). Table 3.1 provides an overview of the available ADAS in different groups.

There are many different driver-assist systems on the market. Most relevant to future CATS (Level 3-5) are those that influence lateral and/or longitudinal movements by either warning, performing autonomously, intervening, or a combination of these. As such the current review focuses on these. Systems that do not translate to future CATS, such as Seatbelt Reminders and Adaptive Headlights, will not be discussed in more detail. Assistance systems that are only in use during special manoeuvres or monitor driver state are also not discussed. These include Back-up Cameras, Back-up Warning, Rear Traffic Warning, Drowsiness Alert (DrowA), Distraction Alert (DisA), and Alcohol Interlock systems.

ADAS that influence lateral movement are Lane Departure Warning (LDW), Lane Keeping Assist (LKA), and Lane Change Assist (LCA). LDW is a system that warns the driver when the car moves too close to the edge of the lane, LKA uses the same technique but steers the car back towards the centre of the lane when necessary. LCA systems warn the driver when another vehicle is present in the blind spot of the car during lane changes.

Systems involved with longitudinal movement inform the driver about the speed of the car and adjust when necessary. Intelligent Speed Assist (ISA) helps drivers by displaying the current speed limit. Some versions of this system warn the user when they surpass the speed limit or even prevent cars from speeding. Curve Speed Warning warns the driver when the current speed is inappropriate for the upcoming curve. Forward Collision Warning (FCW) detects a slower moving vehicle in front of the car and warns the driver when a collision is likely to occur. Autonomous Emergency Braking (AEB) is similar to FCW but intervenes when a collision would otherwise occur. Adaptive Cruise Control (ACC) allows the driver to set a desired speed and distance to the forward vehicle. The car automatically adjusts its speed, applies brake and accelerates within limits when needed.

Bicycle and Pedestrian Detection systems assist the driver by issuing a warning when trajectories of the car and person intersect. More advanced versions intervene by braking when a collision is deemed likely. Intersection Movement Assist (IMA) and Turn Assist (TA) have similar functions that warn the driver when vehicles would intercept the current path of the car at an intersection (IMA) or when making a turn across an opposing lane (TA). More advanced versions will also intervene when necessary.

Table 3.1. Overview of effective areas from different ADAS. The '+' sign indicates more advanced versions of a system

	Inform	**Warn**	**Automate**	**Intervene**
Lateral		LCA, LDW	LKA	LKA
Longitudinal	ISA	Curve speed warning, FCW, ISA	ACC, ISA	AEB, ISA
Combined		Bike and ped. detection, IMA, TA		Bike and ped. detection, IMA, TA
Driver State		DrowA, DisA		DisA$^+$, alcohol interlock
Special Manoeuvres	Back-up cameras	Back-up warning, Rear traffic warning		Back-up warning$^+$, Rear traffic warning$^+$
Other		Seatbelt reminders	Adaptive headlights	

3.2.2 Examples of societal level impacts of these systems

This section focuses on the systems that are more closely related to AVs. These systems influence lateral and/or longitudinal movements and are capable of warning, performing autonomously and/or intervening. Only those systems that influence specific impacts are discussed in each paragraph.

3.2.2.1 Safety impacts

The expected results of the different systems are most often estimated by using historic crash data and determining what percentage of these crashes would not occur if the systems were present. This can be done by comparing crash details to known effective scenarios of systems, for example, (Farmer, 2008), or by running a simulation of the same scenario with different systems equipped (Kusano & Gabler, 2012). Actual impacts of the systems are determined by comparing data from vehicles equipped with the system to similar vehicles without the system (Fildes et al., 2015), or by data gathered from a Field Operational Trial (Rakha, Hankey, Patterson, & Van Aerde, 2001). Comparing the difference between the historical expected predictions with the actual impacts, provides an indication of what might be expected of the accuracy of current forecasted impacts of future level 3-5 technologies.

Lane Change Assist (LCA) influences possible lane changing crashes. These crashes account for around 5% of all reported crashes (Hynd et al., 2015). The system was expected to prevent 25% of relevant crashes, 9% of relevant fatal crashes and 11% of injuries per year (Farmer, 2008; Jermakian, 2011). The overall actual effects on crash involvements shows a reduction of 14% in relevant crashes and 23% reduction in relevant crashes with injuries (Highway Loss Data Institute, 2019).

Lane Departure Warning (LDW) and **Lane Keep Assist (LKA)** influence unintended lane departure crashes, accounting for around 2% of all crashes. LDW was expected to reduce all injury crashes by 6% and fatal crashes by 10% (Hummel, Kühn, Bende, Lang, & Research, 2011). LKA shows higher expectations with 5% of all injury crashes and 19% of fatal crashes prevented (Jermakian, 2011). Actual effects of LDW show reduced relevant injury crashes by 21% (Highway Loss Data Institute, 2019). LKA reduced injury crashes by 30% (Sternlund, Strandroth, Rizzi, Lie, & Tingvall, 2017). However, other studies considering all crashes show no significant improvement for both LDW (Moore & Zuby, 2013) and LKA (Highway Loss Data Institute, 2012).

Curve speed warning systems influence crashes that happen due to unsafe speeds in curves. These crashes make up around 4% of all crashes but close to 30% of all fatal crashes (Davis, Morris, Achtemeier, & Patzer, 2018). Studies on expected safety impacts of curve speed warning systems were not found. Actual effects of a curve speed warning system show a decrease of speed by 10% on rural curves on a test track (Davis et al., 2018). A warning system shows similar results to traditional transverse bars on the road, decreasing speed by 6km/h, while a speed limiter shows a decrease of 10km/h in a driving simulator (Comte & Jamson, 2000).

Forward Collision Warning (FCW) and **Autonomous Emergency Braking (AEB)** systems influence rear-end crashes, accounting for close to 30% of all crashes (Jermakian, 2011). FCW expectation range from 3% reduction in rear-end collisions (Kusano & Gabler, 2012) to a reduction of 67%, dependent on the exact system and simulation settings used (Kusano & Gabler, 2015). Actual effects show an average of 33% reduction in collision (Cicchino, 2017; Rizzi, Kullgren, & Tingvall, 2014). AEB was expected to reduce overall crashes by 11% (Hynd et al., 2015). Actual effects show an average 41% reduction in rear-end striking crashes (Cicchino, 2017; Fildes et al., 2015). A combination of FCW and AEB was expected to prevent 50% of rear-end crashes with injuries (Kusano & Gabler, 2012) and 23% of all injury crashes (Farmer, 2008; Jermakian, 2011). These reduction match the actual findings of 50% rear-end injuries (Cicchino, 2017; Highway Loss Data Institute, 2016) and 23% reduction of all injury crashes (Moore & Zuby, 2013).

Adaptive Cruise Control (ACC) influences crashes related to vehicle headway and speed. Expectations range between 3% and 13% reduction of all crashes with injuries, with an average of 7% (Alkim, Bootsma, & Looman, 2007; Chira-Chavala & Yoo, 1994; Vaa, Assum, & Elvik, 2014). However, actual results are unclear. ACC can result in both higher and lower mean speed (Morskink et al., 2007), and shows no significant impact on crashes (Rakha et al., 2001).

Intelligent Speed Assist (ISA) impacts on crashes related to speed. ISA was expected to reduce overall crashes with injuries between 6 and 27% (AVV, 2001; Regan et al., 2006). Actual effects on number of crashes are not known. ISA is reported to reduce average speed by 2-7km/h (AVV, 2001; Morskink et al., 2007), which is expected to result in a reduction of crashes.

Bike and Pedestrian Detection influence crash rates with pedestrians and cyclists, accounting for around 1% of all crashes but more than 10% of fatal crashes (Yanagisawa, Swanson, & Najim, 2014). These systems were expected to reduce relevant injury crashes between 4% and 24% for pedestrians and 44% for cyclists (Hummel et al., 2011; Van der Zweep et al., 2014). Actual effects show 35% injury mitigation for pedestrians on a test-track (Yanagisawa et al., 2014). No relevant data for cyclist crash reduction was found.

Intersection Movement Assist (IMA) and **Turn Assist (TA)** systems influence crossing path crash rates on intersections and crossings, covering around 26% of all crashes (Pierowicz, Jocoy, Lloyd, Bittner, & Pirson, 2000). The systems were expected to reduce relevant crashes between 0% and 64% with warning only (Pierowicz et al., 2000; Scanlon, Sherony, & Gabler, 2017), and 25% to 59% with AEB combined (Scanlon et al., 2017). Actual effects range from 0% reduction to 26% reduction of relevant crashes (Wu, Ardiansyah, & Ye, 2018). This range is dependent on the TTC. No reduction is found for TTC below 3 seconds, while 26% reduction is found for a TTC of 5 seconds.

3.2.2.2 Traffic flow impacts

ACC is expected to influence the capacity of roads. The amount and direction of this change is not evident from the current research. Advanced ACC systems might allow for smaller headway, increasing traffic flow according to simulations (Chira-Chavala & Yoo, 1994). However, when headway preferences higher than 1 second are maintained during field tests or simulations, a decrease in capacity occurs (Alkim et al., 2007; Chira-Chavala & Yoo, 1994; Morskink et al., 2007).

A slight increase in travel time when **ISA** is present, 2.5% averaged, is found in different simulation studies (Carsten & Tate, 2000; Morskink et al., 2007; Vaa et al., 2014). An increase in travel time of up to 5.6% is estimated for strict adherence to speed limits (Vaa et al., 2014). Field trials show no significant increase in travel time for urban areas (Biding & Lind, 2002).

3.2.2.3 Economic impacts

With the many different types of ADAS considered within the literature, no clear cost implications can be determined. However, it is clear that vehicles that have these systems implemented cost more to produce and to buy. The installation, maintenance and possible repair costs of ADAS equipped vehicles are higher than comparable vehicles without these systems. The reduction in crashes due to these systems result in lower costs long term, ultimately benefitting both individuals and society.

Field tests give insight in the impacts of **ACC** and **ISA** on fuel consumption, with ACC resulting in lower fuel consumption due to lower speed deviations and smoother traffic flow, saving 3% of fuel overall (Alkim et al., 2007; Kessler et al., 2012). These results match those found in earlier simulations (Bose & Ioannou, 2003). ISA also shows a reduction in fuel consumption, 1.5% on motorways and 5% on urban roads (Kessler et al., 2012). However, (Regan et al., 2006) found no significant change during similar tests.

3.2.2.4 Environmental impacts

Reductions in fuel consumption translate into reductions in emissions. Further effects on emissions are found in field tests and simulations, **ACC** is found to reduce emissions by 10% on motorways (Alkim et al., 2007; Bose & Ioannou, 2003). This is due to changes in speed variations. However, the increase of average speed with ACC increases regular emissions by 1-2% (Kessler et al., 2012). Due to the decrease of average speed when **ISA** is present, significant reductions in emissions are achieved (Kessler et al., 2012; Regan et al., 2006). Combining ACC with ISA allows for a decrease in speed variations due to ACC, without the accompanying increase in average speed by limiting maximum speed with ISA.

3.2.2.5 Societal/mobility impacts

Because many of the current systems are optional and not widely implemented, no discernible impacts on society are currently present. Many of the systems reduce driver stress during vehicle operation, potentially allowing more individuals to drive. This effect might be strongest for older drivers, enabling them higher mobility. This is particularly relevant for the systems involved with backing up and parking assistance, such as rear-view cameras. Questionnaires on these systems show a higher willingness to use parking spaces and prevent avoidance of backing up (Jenness, Lerner, Mazor, Osberg, & Tefft, 2007).

Results from ISA field trials show that while the system is accepted by the driver of the vehicle, other drivers become more irritated (AVV, 2001). This is a result of the strict adherence to speed limits, which forces other drivers to either adjust their speed accordingly or overtake the equipped car. On average 2 out of 3 drivers experienced negative interactions with other drivers, of which 17% were aggressive interactions (AVV, 2001). These interactions with irritated drivers were one of the main reasons the ISA system was found disabled by the driver, accounting for 14% of all emergency interruptions of the system (AVV, 2001).

Table 3.2 summarizes how the actual impacts of the various systems relate to the estimated impacts. It can be seen that for all systems but FCW and AEB, road safety impacts were either under or overestimated. It should *be noted that while the actual reduction in all relevant crashes for LCA, LDW and LKA was below expectation, the* *reduction in injury crashes for these systems turned out to be higher than expected. For ACC, ISA and bike detection, either the evidence was not clear, or data was not available for their full assessment. The impacts on traffic flow are currently not clear due to variances in time headway used in the different studies. ISA estimates appear on the lower side, suggesting an increase in travel time that is not found in field studies. Economic and Environmental impact estimates match the actual findings for ACC but were not found for ISA systems. No clear societal impacts can be determined as of now.*

Table 3.2. Estimate comparison to actual effects

Impact type	Not clear	Low estimate	Good estimate	High estimate
Safety: All relevant crashes			FCW, AEB	LCA, LDW, LKA
Safety: Relevant injury crashes	ACC, ISA, Bike detection	LCA, LDW, LKA, Ped. detection	FCW, AEB	
Traffic flow	ACC	ISA		
Economic	ISA		ACC	
Environmental	ISA			
Societal	All			

3.2.3 Which factors influenced the adoption of these systems?

Adoption of new systems is influenced by many different factors. Awareness of the existence of advanced driver assistance systems is necessary to even consider installation or usage. Studies show that awareness of ADAS and their areas of application is severely lacking, both among novice drivers and more experienced professional drivers (Harms & Dekker, 2017; Tsapi, 2015). Knowledge about the function of ACC was missing in over 60% of novice drivers (Tsapi, 2015). Even when the vehicle was equipped with the system, only 15% of the Dutch drivers were aware that they had access to the system (Harms & Dekker, 2017). It should be noted that when drivers were aware that their vehicle was equipped with ADAS, usage was close to 100%. Similar results were found in Germany, with only 12-32% of drivers were aware of ACC, FCW and LDW (German Road Safety Council, 2010).

The cost of an ADAS equipped vehicle is higher than a vehicle without. The size of this prize difference influences the adoption rate. The most common reason (34% of responses) to put off buying a vehicle with ADAS equipped is the increased cost (Zwijnenberg et al., 2007). As technology improves, the costs of the assistance systems is likely to decrease (Abele, Kerlen, & Krueger, 2005). This effect can be amplified with policy changes. The mandatory installation of LDW/LKA in heavy trucks starting from 2015 in the EU, will likely result in decreased system costs.

Trust that the systems perform as expected is another factor that influences adoption rates. Fear for unreliable systems, excessive warnings or an annoying user experience can prevent system adoption and use. The fear for unreliable systems is decreasing, from 20% of respondents in 2007 (Zwijnenberg et al., 2007) to only 3% (Harms & Dekker, 2017). Annoyance with the system is still present and originates in part from a lack of understanding. Unexpected interference by a system or unclear and excessive warnings are reasons to avoid the system (Harms & Dekker, 2017; Tsapi, 2015; Viktorová & Sucha, 2018; Zwijnenberg et al., 2007).

3.2.4 What was the penetration rate evolution of these systems?

Pure safety systems such as AEB, LDW/LKA and LCA are slowly becoming more commonplace. In 2010 these systems were installed in less than 1% of new cars (Öörni, 2016). 2011 shows a slight increase with around 1% of new cars equipped. In 2012 the penetration rates increase further to 3% of new cars equipped with AEB or LCA, and 4% with LDW/LKA. In 2013 similar increase is present for LDW/LKA and LCA, increasing to 6% and 5% respectively. AEB is installed in 9% of new cars in 2013 (Öörni, 2016; Van Calker & Flemming, 2012).

Systems with greater focus on driver comfort have higher penetration rates. ACC with FCW is already present in 2% of new cars in 2010, increasing to 3%, 4% in 2011 and 2012. In 2013 a total 13% of new cars are equipped with these systems (Öörni, 2016).

Eco-driving systems such as start-stop assist show even higher penetration rates. 5% of new cars were equipped with the system in 2010, 16% in 2011, 24% in 2012 and 34% in 2013 (Öörni, 2016).

If these penetration rates are compared to predicted values from 2005, a consistent overestimation becomes apparent. The above mentioned systems were predicted to be equipped in at least 5% of new cars in 2010, with LCA even estimated to be present in close to 20% of all new cars (eSafety Forum, 2005).

Information about Dutch cars manufactured between 2012 and 2016 show 7% penetration of LDW/LKA, 5% for AEB, 4% for LCA, and 2% for ACC (Harms & Dekker, 2017).

Figure 3.1 gives an overview of what percentage of new cars is equipped with an assistance system across Europe based on the above-mentioned data.

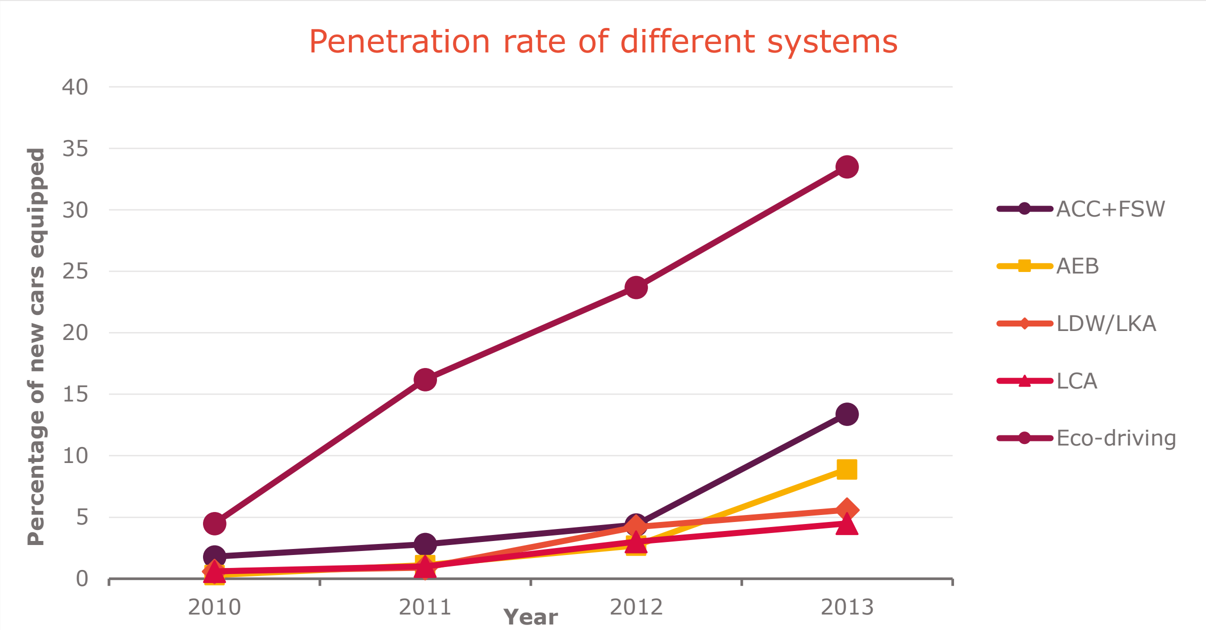


Figure 3.1 Penetration rate of different systems in new cars.

Estimates for the total penetration rate across all active cars are made for 2015. AEB is estimated to be equipped in around 1% of all cars, ACC in between 1-5%, and LDW/LKA and LCA in less than 1% (Öörni, 2016).

3.3 The expected future of passenger cars

This section offers a structured overview of what a future with CATS could evolve towards, through a review of recent literature on impacts. Additionally, factors such as technological developments, policy related to CATS and social demand (acceptance/trust), as well as the interrelations and feedback effects between different impacts, are discussed, given the fact that the impacts of CATS depend on these unknown factors. Due to the large uncertainties in many factors influencing the future of CATS, the scope of possible futures to be analysed in the LEVITATE project will be limited. A choice is therefore made to describe the future in terms of sub-use cases and penetration rates of SAE level 3-5 passenger cars.

3.3.1 How will CATS technology evolve?

Automated driving includes a wide range of different technologies (OECD/ITF, 2015). According to SAE (2018), CATS are divided in five levels of automation additional to baseline unautomated driving. Automated levels 1 and 2 are used by the driver to provide support with dynamic driving tasks and driver can activate, deactivate and override them at their will, as s/he remains engaged in the dynamic driving task (UNECE, 2017). These systems called ADAS (Automated Driver Assistance Systems) encompass different functions such as, Adaptive Cruise Control (ACC), Lane keeping Assistance Systems, Remote Control Parking, etc. These functions are available in most modern cars of today. In contrast to levels 1 and 2, automation levels 3, 4 and 5 perform the dynamic driving task. However, level 3 and 4 may require the driver to monitor the driving environment, retake control or perform the strategic driving task. More specifically, Automated Vehicles (AVs) of level 3 perform the dynamic driving task in specific use cases and the driver is asked to retake control at any time when system encounter an unknown situation. The level 4 AV system performs the dynamic driving task in some environmental conditions, even if the driver does not respond appropriately to a request to intervene. However, not all environmental conditions are expected to be covered by level 4 AV system. Finally, in automation level 5 the vehicle performs all dynamic driving tasks during its entire journey and the driver can perform other non-driving related activities.

In order to attain full automation, there are two incremental paths, something everywhere and everything somewhere. The first path described as "something everywhere", involves adding gradually more automation features in conventional vehicles, giving the possibility for drivers to transfer more of the dynamic driving tasks to these systems. The traditional car manufacturers generally adopt this strategy for automation levels 1 and 2. Inclusion of ADAS in most of today's vehicles in production indicates this. The transition between automation level 2 (partial automation) and level 3 (conditional automation) remains the most concerning issue for experts, as the transition of control requires the resolution of multiple human-machine interaction issues (OECD/ITF, 2015).

The second path, described as "everything somewhere", begins in high automation of level 4. This strategy involves deploying vehicles that are fully automated in specific use cases and gradually expanding their use in a wider range of contexts. Based on this strategy, the European project CityMobil 2 introduced fully automated shuttles that operated under specific circumstances in particular routes and low speeds in 7 different EU cities (Alessandrini, Cattivera, Holguin, & Stam, 2014). Additionally, other projects have deployed such fully automated vehicles, in restricted contexts for freight transport tasks, such as NEDO's (Japan's New Energy and Industrial Technology Development Organization) automated trucks aiming at a fuel consumption reduction (Sugimachi et al., 2010).

Regardless the deployment path that is followed in order to attain full automation, according to Van Nes & Duivenvoorden (2017), there are two main technological groups that will lead towards full automation. The first technological group can be described as "sensor-based" that involves developing devices that are capable of observing the road environment in order to take over control and perform dynamic driving tasks. The second technological group known as "connectivity based" focuses on the use of wireless networks to allow communication between vehicle to vehicle (V2V) and vehicle to infrastructure (V2I). The "sensor-based" is only used for AVs and the "connectivity-based" is used by both Connected Vehicles (CVs) and AVs. The exploitation of both systems is crucial in order to develop fully safe and independent AVs, as these systems will replace human perceptions and communication.

3.3.2 How do societal level impacts of these new systems emerge?

In order to provide a structure to develop an understanding on how CATS impacts will emerge in the short, medium and long-term, a preliminary taxonomy of the potential impacts of CATS was developed in Elvik et al. (2019). This process involved identifying an extensive range of potential impacts which may occur from the future expansion of CATS. A wide range of potential impacts were considered for example, those that would be directly noticed by each road user, direct impacts, those which influence the wider transport system, systemic impacts and more broadly those occurring outside of the transport system, such as changes to employment, wider impacts. Subsequently, a taxonomy was created by classifying the extensive list of impacts into appropriate categories. Over the future phase of this project, the draft taxonomy will be systematically evaluated and become more extensive during structured workshops, where stakeholders will be asked to prioritise and indicate missing topics. Additionally, in order to facilitate analysis, all impacts are divided in four wider categories, safety, environment, society and economy.

3.3.2.1 Impacts on safety

One of the most promising benefits of the penetration of automated vehicles is the reduction of accidents. According to Elvik et al. (2019) road safety is included in the wider impacts. The impacts identified by Elvik et al. (2019) with potential relevance to safety are presented in Table 3.3:

Table 3.3 Impacts related to road safety.

Impact	Description of impact
Systemic impacts	
Amount of travel	Vehicle kilometres or person kilometres of travel per year in an area
Modal split of travel	The distribution of trips between modes of transport
Vehicle utilisation rate	Share of time a vehicle is in motion (not parked); cabin factor (share of seats in use)
Infrastructure wear	The rate per unit of time at which a road is worn down
Infrastructure design	Equipping roads with technology for vehicle-to-infrastructure communication
Road capacity	The maximum number of vehicles that can pass a section of road per unit of time
Wider impacts	
Public health	Incidence of morbidity and mortality; subjectively rated health state

The DriveC2X project provide some estimates of accidents reduction due to the use of Cooperative Intelligent Transport System (C-ITS) services. The project conducted field demonstrations at several test sites across Europe and then held a safety and efficiency assessment of C-ITS services. These services include: In-vehicle Signage speed limits and other signs, Obstacle Warning, Road Works Warning, Car Breakdown Warning, Traffic Jam Ahead Warning, Green Light Optimal Speed Advisory Weather Warning, Rain and Slippery road/Ice&Snow, Approaching Emergency Vehicle and Emergency Electronic Brake Light. The safety impact assessment of the aforementioned C-ITS applications was carried out in both fatal accidents and injuries for the years 2020 and 2030 (Malone et al., 2014). The most effective service in terms of accidents reduction was speed limit warning through In-vehicle signage (IVS), preventing 16% of fatalities and 8.9% of injuries. The other C-ITS services resulted in a reduction of 0.1%-3.4% of fatalities and a reduction of 0.2%-3.3% of injuries.

The introduction of automated driving of levels 3, 4 and 5 is expected to bring significant safety benefits, especially as the level of automation increases. According to Logan et al. (2017), the US Federal Highway Administration predicted that 50-80% of highway crashes could be eliminated with the adoption of Automated Highway Systems. AEB for example, has been found to reduce all rear-end crashes by 35% to 41%. A more general assessment is provided by Fagnant and Kockelman (2015) who suggested based on the fact that more than 40% of fatal accidents in the US are due to alcohol, distraction, medication and/or fatigue, CATS not affected by these factors could have the potential to contribute at a reduction of at least 40% in fatalities. A report by the NSW State Insurance Regulatory Authority (Finity Consulting, 2016) estimated that the wide adoption of automated vehicles in Australia would reduce the chance of injuries for drivers and passengers by 80%, of cyclists by 70%, of motorcyclists by 40% and pedestrians by 45%.

3.3.2.2 Impacts on the environment

According to Elvik et al. (2019) environment related impacts of CATS are presented in Table 3.4.

Table 3.4 Impacts related to environment.

Impact	Description of impact
Direct impacts	
Travel time	Duration of a trip between a given origin and a given destination
Vehicle operating cost	Direct outlays for operating a vehicle per kilometre of travel
Systemic impacts	
Amount of travel	Vehicle kilometres or person kilometres of travel per year in an area
Modal split of travel	The distribution of trips between modes of transport
Vehicle utilisation rate	Share of time a vehicle is in motion (not parked); cabin factor (share of seats in use)
Wider impacts	
Public health	Incidence of morbidity and mortality; subjectively rated health state
Air pollution	Concentration of pollutants per cubic metre of air
Noise pollution	Number of individuals exposed to noise above a certain threshold
Vehicle emissions	Emissions micrograms per kilometre per vehicle (by chemical)
Energy efficiency	Rate at which propulsion energy is converted to movement; rate of loss due to conversion of energy to heat or noise rather than movement
Propulsion energy	Source of energy used to move vehicles (fossil fuel or electric)

In 2012, the average vehicle fuel consumption was 8.63l/100km (Hula, Bunker, & Alson, 2015). Corporate Average Fuel Economy standards (CAFE) have aimed for increased fuel economy from the new light-duty vehicles to reach an average of 4.32l/100km in 2025 (Anderson et al., 2016). The National Research Council in the US (NRC) estimated that fuel consumption improvements on conventional vehicles from today to 2050 will range from 130% to 250% (i.e. 2.70 to 2.14l/100km) (National Research Council, 2013). These reductions in fuel consumption are due to engine improvements as well as vehicle weight reductions and smooth rolling resistance. Hybrid vehicles, which are already more efficient than traditional engines, will have even more potential to improve fuel economy by achieving up to 1.62l/100km.

Using the automation technologies of levels 2 – 5 (eco-driving – for example, speed control, smooth and gradual acceleration and deceleration) are expected to further improve fuel economy. Eco-driving can improve fuel economy by 4% to 10% (National Research Council, 2013). In addition, since connected systems can optimize traffic flow and reduce the distance required for safety between vehicles, there may be an increase in the capacity of travel lanes and a reduction in congestion fuel consumption. Folsom (2012) estimated that a fleet of automated vehicles could lead to fuel consumption up to 0.47 to 0.235l/100km.

3.3.2.3 Impacts on mobility (society)

The wide adoption of CATS is expected to have various impacts on the society. The impacts that are more likely to be relevant to mobility (society), among those identified by Elvik et al. (2019) are included in Table 3.5:

Table 3.5 Impacts related to mobility (society)

Impact	Description of impact
Direct impacts	
Travel time	Duration of a trip between a given origin and a given destination
Access to travel	The opportunity of taking a trip whenever and wherever wanted
Systemic impacts	
Amount of travel	Vehicle kilometres or person kilometres of travel per year in an area
Modal split of travel	The distribution of trips between modes of transport
Vehicle ownership rate	Percent of households owning 0,1,2 etc. vehicles
Shared mobility	Sharing a vehicle with others on a trip-by-trip basis
Wider impacts	
Public health	Incidence of morbidity and mortality; subjectively rated health state
Geographic accessibility	Time used to reach a given destination from different origins
Inequality in transport	Statistics indicating skewness in the distribution of travel behaviour between groups according to social status, functional limitations or place of residence
Employment	Changes in number of people employed in given occupations

The implementation of CATS is expected to lead to lower travel costs, higher user comfort and increased accessibility to different groups, resulting in an increase of vehicle kilometres travelled per day. The increased accessibility due to the wider adoption of automated vehicles, especially given the fact that AVs may allow disabled people to travel the same distance and do same number of car journeys, it could lead to an increase of the average kilometres covered per day by more than 50% (Meyer & Deix, 2014). Brown et al. (2014) used data from the NHTS 2009 (National Household Travel Survey, conducted by the Federal Highway Administration (FHWA)) and the 2003 Freedom to Travel project to estimate the increase in travel for young people, the elderly and the disabled. There was a total increase of 40% of vehicle kilometres travelled (VKT) per vehicle due to automated driving. Milakis et al. (2017) reported a potential increase of VKT of 3% to 27% for various automated vehicle deployment scenarios in the Netherlands.

The wide adoption of automated passenger vehicles is expected to have a profound and prolonged impact on land use (Bagloee, Tavana, Asadi, & Oliver, 2016). More specifically, literature suggests that there are two leading theories for potential impacts, either the implementation of CATS will contribute to a more dispersed and low-density land-use, due to the improved geographic accessibility and the reduced travel time, or the reduced need for parking spaces, will stimulate urban growth in central districts (Heinrichs, 2016). Additionally, the potential congestion in major cities in the short term, due to the increase of VKT and to the increased accessibility, could lead to higher energy consumption. In order to promote more efficient land use and use of resources, achieving environmental sustainability, it is suggested to implement road use pricing, where prices are applied into different segments offering traffic load balancing.

Most studies report that CATS could increase travel demand by 3% to 27% due to changes in destination choices (for example, longer journeys), changes in transport mode (shift from public transport) and the introduction of new users. According to the outcomes of hypothetical and realistic simulations in the city of Zurich, one shared automated vehicle could replace about 10 to 14 conventional vehicles (Boesch, Ciari, & Axhausen, 2016; Zhang, Guhathakurta, Fang, & Zhang, 2015). The International Transport Forum (2015), simulated different scenarios of automated transport systems, penetration rates and availability of high-capacity public transport. This report stated that shared automated vehicles could replace all conventional vehicles, offering equal levels of mobility with up to 89.6% (65% during rush hour) fewer vehicles on the roads.

Concerning social sustainability, in the short- and medium-term future the high cost of owning a private automated vehicle could lead to social inequality for the low-income groups (Milakis et al., 2017). The concept of Mobility as a Service could be a solution to this problem. In the long term, full penetration of AVs, as well as investment in automated public transport could ensure social equity and accessibility for all social groups. Additionally, public health is an important factor taken into account when designing the future for AVs. Given the fact that AVs offer the possibility of comfortable door-to-door travel, other modes of transport, such as walking and cycling, could be abandoned leading to a decrease of public health due to a sedentary way of life (Cohen, Jones, & Cavoli, 2017). A medium or long-term policy, when penetration rates of AVs will be higher, could be to delimit AVs access to certain zones, promoting other healthier modes of transport.

3.3.2.4 Impacts on economy

The impacts that are more likely to be relevant to economy (society), among those identified by Elvik et al. (2019) are included in Table 3.6:

Table 3.6 Impacts related to economy.

Impact	Description of impact
Direct impacts	
Vehicle operating cost	Direct outlays for operating a vehicle per kilometre of travel
Vehicle ownership cost	The cost of buying and keeping a vehicle
Systemic impacts	
Amount of travel	Vehicle kilometres or person kilometres of travel per year in an area
Vehicle utilisation rate	Share of time a vehicle is in motion (not parked); cabin factor (seats in use)
Vehicle ownership rate	Percent of households owning 0,1,2 etc. vehicles
Shared mobility	Sharing a vehicle with others on a trip-by-trip basis
Modal split of travel	The distribution of trips between modes of transport
Wider impacts	
Public finances	Income and expenses of the public sector
Employment	Changes in number of people employed in given occupations

Concerning the impact on the economy of the deployment of CATS, the estimated overall economic benefits due to reduction in accidents and in travel time, fuel savings and parking facility, could amount from 2000$ to 4000$ per vehicle per year (Fagnant & Kockelman, 2015). According to a US Department of Transportation investigation (U.S. Department of Transportation, 2017) the wide adoption of CATS can lead to a reduction of fuel consumption of up to 50%, reduction of emissions from 12% to 50%, reduction of travel time from 12% to 48%, reduction of journey delays up to 85% and save significant number of lives every year.

3.3.3 Which factors influence the adoption of these systems?

The potential impact of CATS which might be expected in the future will be hugely influenced by the extent to which automated systems are adopted. The review of literature relevant to CATS indicated that various factors influence the wide adoption and public acceptance of connected and automated vehicles of level 3 or higher. The most commonly reported influencing factors are trust and willingness to pay.

According to Casley et al. (2013), who conducted a survey to study public acceptance, there are six influences on public perception about CATS. These influences were divided in two categories, primary and secondary. More specifically, the primary influences studied included the perceived safety of automated vehicles, their expected cost and people’s opinion on the current legal structure regarding development, sale and use of automated technology. The secondary influences included the perceived change in people’s productivity using automated vehicles, the automated vehicles efficiency as well as their environmental impact effect on their decision to buy one. CATS were not desirable by the majority of the survey participants, due to their expected high cost, safety issues and the deficient current legal state related to automated vehicles. On the contrary, the survey indicated that public opinion was rather positive regarding the secondary influences such as the vehicle and road efficiency, the reduced environmental impact and the increased in-vehicle productivity.

There are also other influencing factors which could affect adoption such as policy and regulation, road use pricing, parking fee, dedicated lanes, price of owning and operating car and many more inter-linked factors.

3.3.3.1 Trust

A study by Liu et al. (2019) focusing on public perceptions and acceptance of automated vehicles of levels 4 and 5, regarding three acceptance measures; general acceptance, behavioural intention to use and willingness to pay, concluded that respondents were more optimistic about benefits from fully automated vehicles (level 4) instead of highly AVs (level 5). Furthermore, the three acceptance measures were influenced by trust in AVs as well as by the perceived benefit. Similar studies on user acceptance are also presenting a rather positive public opinion on fully automated driving (Begg, 2014; Howard & Dai, 2014). However, participants also demonstrated a certain level of reluctance concerning safety, legal issues and cyber security influencing the adoption of AVs (KPMG, 2013).

Du et al. (2019) studied the impact of explanations given to AV users on their adoption, through a simulation-based experiment. 32 participants were asked to use a driving simulator under four different conditions. These conditions were: (1) no explanation, (2) explanation given before or (3) after the AV acted and (4) the option for the driver to approve or disapprove the AV’s action after hearing the explanation. The results in terms of trust and preference for AVs, indicated that explanations provided before an AV action correlated with an increase in trust and preference for the AV, leading to an easier adoption of these systems. However, there was no difference in anxiety and mental workload. It is evident that trust in this new technology is crucial for user acceptance, leading to the overall adoption of automation, as well as to an increase of the intention to use AVs (Choi & Ji, 2015).

Another international survey (Sommer, 2013) concerning the adoption of AVs, indicated that even though participants considered automated driving a useful technological development, they were scared of this new technology and reluctant about the reliability of fully automated vehicles. Concerning the expected penetration of AVs, participants predicted that automated vehicles will be on public roads until 2030, as for their adoption, respondents claimed that they would use this technology on long highway journeys as well as in traffic jams.

Direct experience of an automated vehicle is also influencing users trust and acceptance (Xu et al., 2018). More precisely, after a field experiment during which 300 participants operated an automation level 3 vehicle, a psychological model was developed. The outcomes of the model indicated that users trust, perceived usefulness of AVs and perceived ease of use were increased after the experience with the AV. Additionally, the model suggested that trust and perceived safety have a direct influence in user acceptance and adoption of this technology.

3.3.3.2 Willingness to pay

User acceptance, concerns and willingness to buy automated vehicles of levels 3 to 5, were studied through an international survey of 5000 participants (Kyriakidis, Happee, & de Winter, 2015). Respondents were generally reluctant to the overall adoption of AVs, as manual driving is considered more enjoyable. Additionally, due to concerns related to the AVs increased cost, cybersecurity, legal issues and safety, the majority of participants estimated that automated vehicles of level 5 will reach a 50% penetration rate until 2050. Similarly, neutral or negative public opinion regarding AVs was proved by different studies (Clark, Parkhurst, & Ricci, 2016; Haboucha, Ishaq, & Shiftan, 2017).

Willingness to pay is another important factor that influences adoption of the new CATS technology. According to the survey conducted by the global market research company Power and Associates (2012), 37% of the participants (17400 vehicle owners), would purchase an automated driving mode. However, this percentage dropped to 20% when they were informed that the estimated market price would be 3000$. Another study describing the adoption of CATS, suggests that unless there is rise in people’s willingness to pay, appropriate policies promoting CATS and rapid reduction in technology costs, the US fleet distribution won’t be homogeneous by 2045 (Bansal & Kockelman, 2017). According to Bansal & Kockelman (2017), willingness to pay has huge influence in market penetration, along with price drop. Their simulation showed that annual 5% price drop and constant willingness to pay would result in 24.8% light-duty vehicles (level 4) in US vehicle fleet. However, this changes to 87.2% if they assume 10% annual rise in willingness to pay along with 10% decrease in vehicle price annually. Motorists’ and the general public’s opinion on automated vehicles in UK, the US and Australia is rather positive (Schoettle & Sivak, 2014), considering that they are optimistic about AVs benefits and they would desire to use this technology once available on urban roads, even though they expressed some safety concerns. However, the majority of the 1533 participants of the survey was not willing to pay extra for the automated vehicles technology.

Based on the above, it is evident that various factors influence the adoption of automated vehicles of levels 3 to 5. The most crucial factors that delays adoption was found to be perceived safety and trust in this new technology, as well as concerns related to cybersecurity and legal issues. A first action in order to increase desirability of automated passenger vehicles could be proving their safety. On the other hand, perceived benefits can lead to an increase of acceptance in the near future, for this reason advertising the benefits of AVs could lead to a further rise of desirability. Additionally, willingness to pay is also influencing adoption, so another measure to increase popularity of AVs could be for car industry to reduce the market price of AVs. Finally, public education about this new technology could reduce fear of the unknown and lead to a wider adoption.

3.3.4 Market penetration of CATS technologies

The penetration rates of different CATS automation levels for the short-, medium- and long-term future depend, according to literature, on various factors, such as the available technologies, acceptance by general public and trust on CATS, etc.

There are many studies concerning the availability of new technologies throughout different automation levels. There seems to be consensus that automation level 3 vehicles will be available in the next 3 years. However, there seem to be different timelines for levels 4 and 5. The International Transport Forum 2015, states that Tesla is fully committed to bring fully automated vehicle on public roads. They have ambitious programs to achieve fully automated vehicles in very short time span. This could drive market competition more aggressive leading to faster AV penetration in the market. The European Road Transport Research Advisory Council (ERTRAC, 2015) presents a more optimistic prediction concerning the timelines of the automated vehicles technologies. More specifically, they have estimated that level 3 technologies will be available by 2020, level 4 technologies by 2022 and level 5 after 2028. Austroads after extensive discussions with vehicle manufacturers and large automakers, have concluded to the timetable that is considered to be the most probable and realistic, concerning the introduction of automated vehicle technologies of each level, with level 5 full penetration being expected after 2050.

Ford's estimates for AV uptake, indicated that limited automation would be available sometime between 2012 and 2017, semi-automated vehicles were expected between 2017 and 2025 and fully automated vehicles deployment would take place between 2025 and 2030 (Lakhani, Iansiti, & Fisher, 2014). Other vehicle manufacturers estimates are similar, with General Motors, Nissan and Continental AG predicting that automation level 4 and 5 technologies are expected to be deployed between 2025 and 2030 (Trimble, Bishop, Morgan, & Blanco, 2014). It must be emphasised here that most technological development roadmaps indicate when the technology will be available rather than what will be the share of AVs on the road (in terms of market penetration). So, based on this, it can be argued that the market penetration will begin after those indicated years.

Dokic, Müller, & Meyer (2015) have concluded to three main milestones for the penetration of different AVs levels. More specifically, automation level 3 technologies, such as traffic jam chauffeur, will be deployed by 2020, automation level 4 vehicles will be available in highways by 2025 and in cities by 2030. According to Levinson (2015) automation level 3 technologies, such as truck platooning, will be available on 2020, and those of level 4 will be available in new vehicles after 2030 and in all vehicles by 2040.

The members of the Institute of Electrical and Electronics Engineers estimated that by 2040 75% of vehicles will be automated and special lanes will be dedicated to CATS (Tardo & Stickel, 2012). As happens with all new vehicle technologies, AVs may need from 1 to 3 decades in order to dominate in vehicle sales and from 1 to 2 decades to achieve full penetration of public roads. According to Litman (2015), AVs could represent 15% of the vehicles fleet by 2030 and 45% by 2050. Litman's predictions (2015) on level 4 and 5 AVs penetration rates, concluded to the coexistence of conventional and automated vehicles of different levels of automation for at least 30 years and maybe forever. Moreover, Litman (2015) argues that the market penetration of AVs will follow the S-curve given by the theory of 'diffusion of innovations'. According to this, the market penetration is initially slow due to domination of development and testing, followed by commercial expansion and rapid growth, eventually slowing down and coming to saturation. However, the time taken by each of these phases can only be an estimate.

A preliminary model showing the time it takes for each new level of automated vehicles technology to fully penetrate the vehicles fleet, has reached to the conclusion that, each level takes about 15 years to achieve 100% of new car sales. This model estimates that sales of 100% of new fully automated cars will not occur until around 2040 (Miller, 2015). According to a research conducted in 2016, most vehicles on the roads of USA was of level 1. More precisely, 16% of the vehicles were level 0, 72% of the vehicles level 1, 12% level 2 and no vehicles of automation level 3 or higher (Kelly Blue Book, 2016). IHS Automotive planned to achieve level 3 functionality by 2020, level 4 by 2025 and level 5 by 2030, with AVs reaching 9% of sales in 2035 and 90% of vehicle fleet by 2055 (Stocker & Shaheen, 2016). Navigant Consulting expected automated vehicle to represent 75% of light vehicle sales by 2035, while the Insurance Information institute claimed that all vehicles will be automated by 2030 (Stocker & Shasheen,2017).

The Centre for Connected and Autonomous Vehicles (CCAV) of Department for Transport and Department for Business, Energy & Industrial Strategy have forecasted global uptake of CATS up to 2035. They have assumed three different cases, progressive, central and obstructed (Transport Systems Catapult, 2017). According to their forecast, global sales penetration of level 3-5 will be 85%, 25% and 10% for progressive, central and obstructed scenarios, respectively, by 2035.

Based on the reviewed literature (Figure 3.2), it appears that there is no agreement on the accuracy of market penetration (of level 3/4/5 automated vehicles). However, the general trend is clear, and all reports agree that market penetration will be below 50% by year 2030. Also, according to Litman (2015), it seems that the market penetration of level 4-5 automated vehicles may only be close to 100% after 2050. According to Frost and Sullivan (2019), penetration of connected vehicles will be close to 100% within next decade (2030). It should be noted that these forecasts were done for different regions and so like-for-like comparison should be avoided. Also, Figure 3.2 shows only best cases.

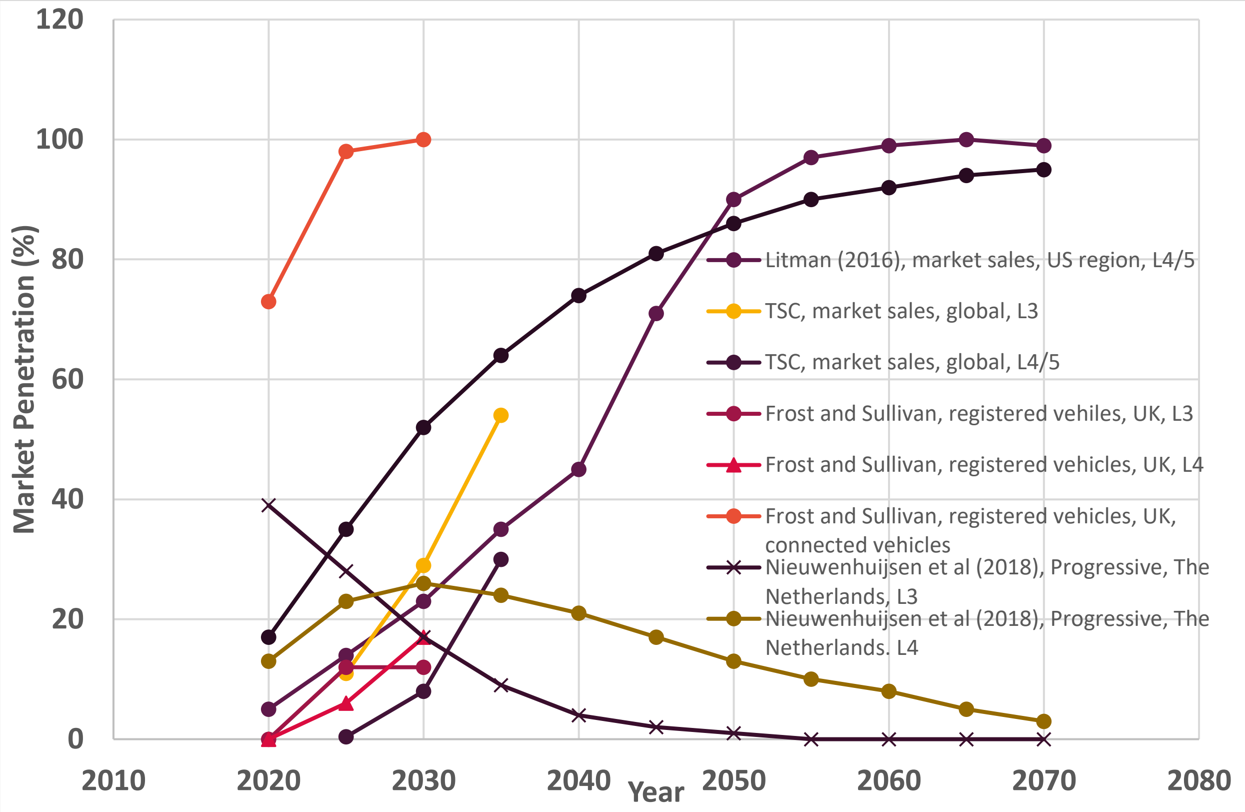


Figure 3.2 Forecast of market penetration of CATS as per literature (Frost and Sullivan, 2019; Litman, 2015; Nieuwenhuijsen, de Almeida Correia, Milakis, van Arem, & van Daalen, 2018; Transport Systems Catapult, 2017).

3.3.5 Definitions of short-, medium- and long-term future

In order to plan for the future, policy makers focus on various features of the cities of tomorrow. The most important features taken into consideration in defining the short-, medium- and long-term futures are safety, social and environmental sustainability, accessibility and economy (González-González, Nogués, & Stead, 2019).

Regarding safety, during the transition phase towards fully automated vehicles, conventional vehicles will share the roads with automated vehicles of different levels of automation, this could lead to an increase in accidents in the short- and medium-term (Van Nes & Duivenvoorden, 2017). In order to ensure safety, policy makers will have to adjust regulations and infrastructure, such as designing dedicated lanes for AVs. Later on, once AVs have reached high penetration, in the long term, leading to a reduction of accidents rates, the segregated lanes could be eliminated, liberating space for pedestrians and cyclists.

It is evident that automated transport can contribute to urban sustainability, but available and future technologies must be adapted to the specific location, time and space to achieve successful implementation. The LEVITATE project will take into account all the aforementioned features of the short-, medium- and long-term future in order to provide a complete impact assessment. Additionally, different policies related to the short-, medium- and long-term future of AVs will be simulated for different cities, in order to provide valid results for guidance in the long-term policy planning.

Although most roadmaps have technological readiness/implementation plans, they do not provide a workable definition of short-, medium- and long-term future. For the purpose of analysing short-, medium- and long-term impacts of CATS, in this project, we are considering those defined by the types of impacts as identified in deliverable D3.1 (Elvik et al., (2019) of LEVITATE. A range of impacts were classified into three categories, direct impacts, systemic impacts and wider impacts. Direct impacts are changes that are noticed by each road user on each trip. These impacts are relatively short-term in nature and can be measured directly after the introduction of intervention or technology. Systemic impacts are system-wide impacts within the transport system. These are measured indirectly from direct impacts and are considered medium-term. Wider impacts are changes occurring outside the transport system, such as changes in land use and employment. These are inferred impacts measured at a larger scale and are result of direct and system wide impacts. They are considered to be long-term impacts. This definition is applicable to work packages 5, 6 and 7 and therefore will not necessarily inform classification of impacts over time in the PST. This is simply because from the PST user's viewpoint, this classification may encounter some confusion for the impacts that lie within the fuzzy boundary of either short-, medium- or long-term. So, this definition is adopted in this work package in order to progress with the tasks in next phase of the project.

3.4 First Identification of sub-use cases

The Policy Support Tool (PST) which will be developed in LEVITATE will support policy makers by allowing consideration of the potential impacts of interventions and scenarios relevant to each of the key use cases (freight transport, passenger cars and urban transport). Regarding passenger cars, a set of sub-use cases and interventions will be developed to inform on the predicted impacts of CATS. The final sub-use cases to be used in the PST will be developed and refined over multiple steps of which, the first 3 are presented in the current report. These steps are,

1. Initial generation of sub-use cases (section 3.4)
2. Definition and categorisation of sub-use cases (section 3.4)
3. Consultation with stakeholders (section 4.3)
4. Predictability assessment (Tasks 6.2, 6.3, 6.3)
5. Refinement and clustering (Tasks 6.2, 6.3, 6.3)
6. Prioritisation (Tasks 6.2, 6.3, 6.3)

As a first step to develop sub-use cases, an overall list was developed from the existing expertise of the project partnership and existing knowledge from scientific literature. This was subsequently refined; their descriptions were clarified, and they were classified into logical categories. Also, impact indicators and assessment methodologies for those sub-use cases are currently being identified in separate work packages in this project (WP4 and WP3, respectively). Some sub-use cases were renamed to remove field specific words and jargons so that it is more understandable for broader audience such as city administrators or SRG members (e.g. "System-aware route optimization" renamed to "Centralized traffic management").

Furthermore, three categories have been used for the classification:

- Interventions: An intervention is an action undertaken by a policymaker or governmental or local authority to achieve a desired objective. Interventions may include educational programs, new or stronger regulations, infrastructure improvements or a promotion campaign.
- Applications: The term application refers to the operational aspect of CATS. Compared to interventions, applications are market / business driven.
- Technology: These are (sub) systems for certain CATS functionalities and therefore enable other technologies or applications.

In terms of predictability (step 4), each sub-use case will be visited (first glance) to examine whether it would be possible to predict quantifiable impacts using methods that are developing in task 3.2 of this project.

Regarding step 5, the refinement of sub-use cases is an ongoing work and will continue in the tasks 6.2, 6.3 and 6.4 (Assessing the short-, medium- and long-term impact, cost and benefits) within WP6 of this project. The work includes the following:

- Prioritisation of the sub-use cases to enable their inclusion in pilot version of the PST.
- Clustering of sub-use cases to facilitate the assessment methodologies (T6.2, 6.3 and 6.4) and the inclusion into PST (WP8).
- Extend the list of interventions specific to passenger cars.

Finally, in step 6, the prioritisation of the sub-use cases will mainly take these three input directions into account:

- Scientific literature indicates the state of the art and the available assessment methodologies for the sub-use cases. However, this might not be more linked with their methodological feasibility rather than their importance / relevance for practice.
- Roadmaps indicate the relevance of sub-use cases from the industrial/political point of view, independent of available scientific methodologies.
- The SRG Workshop provides first hand feedback for the sub-use cases, but might only reflect the opinions of organisations and people who participated.

Table 3.7 and Table 3.8, present the sub-use cases which are relevant for all three use cases and those which are specific for passenger cars.

Table 3.7: General sub-use cases that are applicable for all Use Cases. Please note that this list also includes suggestions from SRG workshop. Indicator column indicates whether the sub-use case was discussed in literature, roadmap and workshop.

Sub-Use Case	**Description**	**Category**	**Indicator** Literature (L) Roadmap (#) Workshop (@)
Geo-fencing based powertrain use	Different powertrains on hybrid vehicles are used according to defined zones (e.g. low-emission zone in the city centre).	Application	L
Green light optimized speed advisory	Vehicles approach traffic lights with optimal speed to avoid stopping at red, hence increasing energy efficiency.	Application	LR

Sub-Use Case	Description	Category	Indicator Literature (L) Roadmap (#) Workshop (@)
C-ITS day 1 services	Hazardous location notifications (slow or stationary vehicle, road works warning, emergency brake light, …) Signage applications (in-vehicle signage, in-vehicle speed limits, signal violation / intersection safety, …)	Application	LR
C-ITS day 1.5 services	Charging stations info, vulnerable road user protection, on street parking management, off street parking info, park & ride info, connected & cooperative navigation, traffic info & smart routing	Application	LR
Road use pricing	Prices are applied on certain road (segments) with the goal to achieve load-balancing. Can be dynamic depending on area, traffic load, and time.	Intervention	LRW
Centralized traffic management	Routing / navigation of vehicles is managed by a centralized system with access to traffic loads. The goal is to balance the traffic load across the road network. Even though this exists in multiple cities worldwide the latest advancement will include the use of CATS technology in the centralized traffic management decision making.	Intervention	LR
Urban platooning	Vehicles dynamically join and leave platoons in the city. The goal of urban platooning is to increase traffic throughput, especially in the bottlenecks of the urban road system i.e. intersections.	Application	WL
Segregated and dedicated pathway operations	A policy measure where automated vehicles operate on dedicated or segregated roads/ lanes, for example a dedicated CATS lane or an elevated automated urban transport lane accordingly	Intervention	LR
Option to select route by motivation	An integrated (into the car) multiple choice of routes available to users based on motivations. The motivations being, fastest, shortest, most environment friendly, safest, etc.	Application	W
Street re-design	Redesigning of streets would need to be considered for automated vehicles. For example, automated vehicles can make precise manoeuvres and so streets could be made narrower.	Intervention	LRW
Cluster-wise cooperative	Strategically coordinate CATS' manoeuvres to form clusters with following methodologies: initial vehicle clustering,	Application	L

Sub-Use Case	Description	Category	**Indicator** Literature (L) Roadmap (#) Workshop (@)
eco-approach and departure	intra-cluster sequence optimization, and cluster formation control. This could increase traffic throughput by 50% and reduce emissions by 20%		

Table 3.8: Passenger Cars sub-use cases - Descriptions and categorizations. Please note that this list also includes suggestions from SRG workshop. Indicator column indicates whether the sub-use case was discussed in literature, roadmap and workshop.

Sub-Use Case	Description	Category	**Indicator** Literature (*) Roadmap () Workshop ()
SAE L2/3/4 automation	Different levels of vehicle automation according to SAE definitions. The main difference across levels is the degree of human involvement in the driving task.	Technology	LRW
SAE L5 automation	Level 5 vehicle automation (and also level 5 penetration rate) poses a significant difference to levels 2,3,4 since level 5 means full automation (all functions under all conditions).	Technology	LRW
Highway pilot	A highly intelligent system consisting of assistance and connectivity sub-systems which enable the automated driving on the highway	Technology	LR
Autopark	An automated car-manoeuvring system that moves the vehicle from a traffic lane into a parking spot to perform parallel, perpendicular or angle parking	Application	LRW
(Cooperative) Adaptive Cruise Control	A cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.	Technology	LRW
Stop and Go (Traffic jam pilot)	A currently existing cruise control system that takes over the driving task in traffic jams and slow-moving traffic up to 60 km/h	Application	LRW
Multi-modal transport in single journey	User can use multi-modal transport in making a single journey	Application	LRW
In-vehicle signage	For example, to direct the user to appropriate parking slot or provide advices	Technology	W

A preliminary list of sub-use cases will be taken forward for further refinement in future tasks bases on indications from workshop and in terms of how feasible it is to predict impact for those sub-use cases. Furthermore, these sub-use cases will be clustered to add more clarity in the workflow and when designing the PST.

3.5 Key outcomes

Market penetration is a primary input for forecasting impacts, but it is hard to predict. Using the example of ADAS it is clear that factors related to technology adoption influenced market penetration. In particular, trust and reliability of ADAS were major factors for technology adoption. According to the literature, only a small percentage (around 10%) of cars were installed with ADAS features up to year 2015, much lower than might have been expected based on earlier predictors. The analysis of the impacts of ADAS functions has demonstrated the difficulty of forecasting penetration rate and has identified the role of regulation in either preventing adoption of a technology or requiring it as a standard. The introduction of safety technology schemes by local authorities, such as the Fleet Operation Recognition (FORS) scheme operated by Transport for London, also demonstrates the value of direct and indirect financial incentives to promote new systems.

It appears that there is no agreement on the accuracy of forecasts of market penetration of level 3/4/5 automated vehicles. However, general trend is clear, and all reports agree that market penetration will be below 50% by year 2030. Also, according to Litman (2015), it seems that the market penetration of level 4-5 automated vehicles may be achieved close to 100% after year 2050. According to Frost and Sullivan (2019), penetration of connected vehicles will be close to 100% within next decade (2030). It should be noted that these forecasts were done for different regions and so like-for-like comparison should be avoided. Also, Figure 3.2 shows only best cases.

In terms of futures of level 3-5 CATS technologies, studies show that in general there will be positive impacts on safety, mobility and, environment but there were some concerns about society and equality within society. Land use impacts will be dependent on how CATS are introduced. These in turn affect the economics and so on. These are interlinked affecting parameters which need to be studied to manage introduction of CATS into Europe's cities.

Within WP6, short-, medium- and long-term impacts are considered to be those defined by deliverable 3.1 in this project (Elvik et al., 2019) as direct, systemic and wider impacts, respectively. This definition is adopted in this work package which will allow organisation of work in task 6.2, 6.3 and 6.4, for short-, medium- and long-term impacts, respectively.

Furthermore, to practically develop a PST to aid with future planning, it is necessary to define specific actions and interventions which may wish to be known about. For passenger cars, many sub-use cases may be of interest. An initial list has been identified that will need to be investigated within the next phase of this project to see how they will impact on society, economy, environment and safety. These sub-use cases will be prioritised within tasks 6.2, 6.3 and 6.4 according to their relevance within those tasks.

4 Workshop outcomes

A workshop was conducted to gather stakeholders' view on future of passenger cars within CATS. This workshop was held at Gothenburg on 28th May 2019 and further details can be found in section 2.2. The attendees were mix of backgrounds and participated in a facilitated group discussion. Participants were asked to self-identify and separate out into passenger cars, urban transport and freight transport. Furthermore, Workshop participants who self-identified as passenger cars experts were asked following questions and collective response to those questions is summarised as below.

In the following section we cover the outcomes of the pre-workshop online survey and sessions 1 and 3, since the other two are not within the scope of this deliverable (session 2 contributes to WP4 and session 4 contributes to WP8).

4.1 Pre-workshop online survey

The online survey was sent to all registered participants prior to the workshop to obtain a general assessment of the proposed indicators and to allow using the survey results as an impulse for inspiring discussions during the workshop. The details of the setting and outcome can be found in deliverable D4.1. Here we provide a summary on:

- the number and organisation type of the participants (Figure 4.1)
- their indicated importance of the goal dimensions (Figure 4.2)
- the number of ongoing and planned activities on the sub-use cases (presented in Figure 4.9 in later section 4.3.4) and broken down to organisation types:
    - governmental organisations (Figure 4.3)
    - municipalities (Figure 4.4)
    - research and developmental organisations (Figure 4.5)

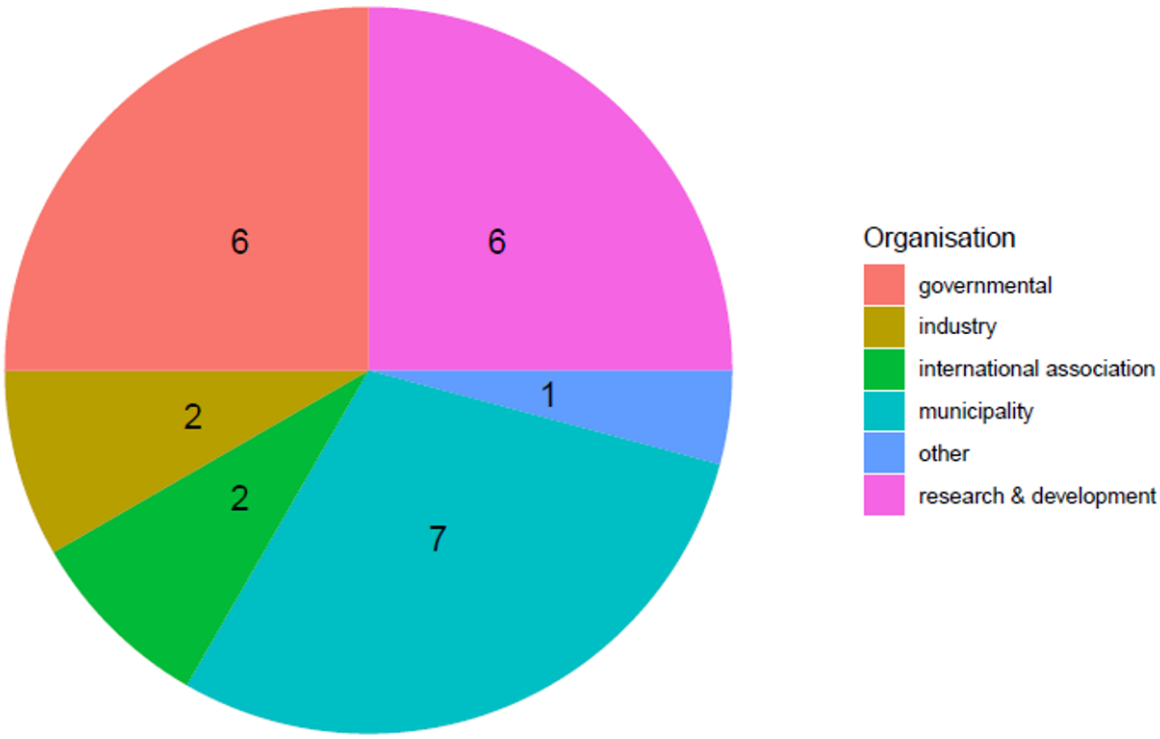


Figure 4.1 Number of participants for each organisation type. N=24.

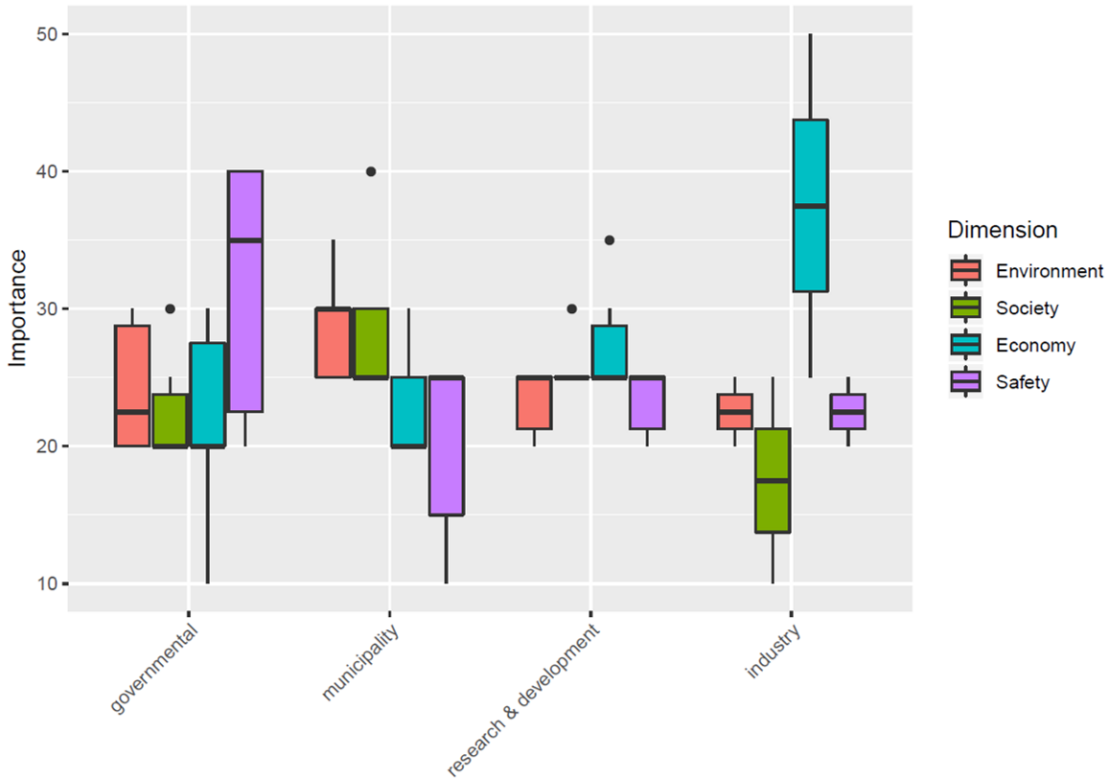


Figure 4.2 Indicated importance of goal dimensions, results for each organisation type. N=24.

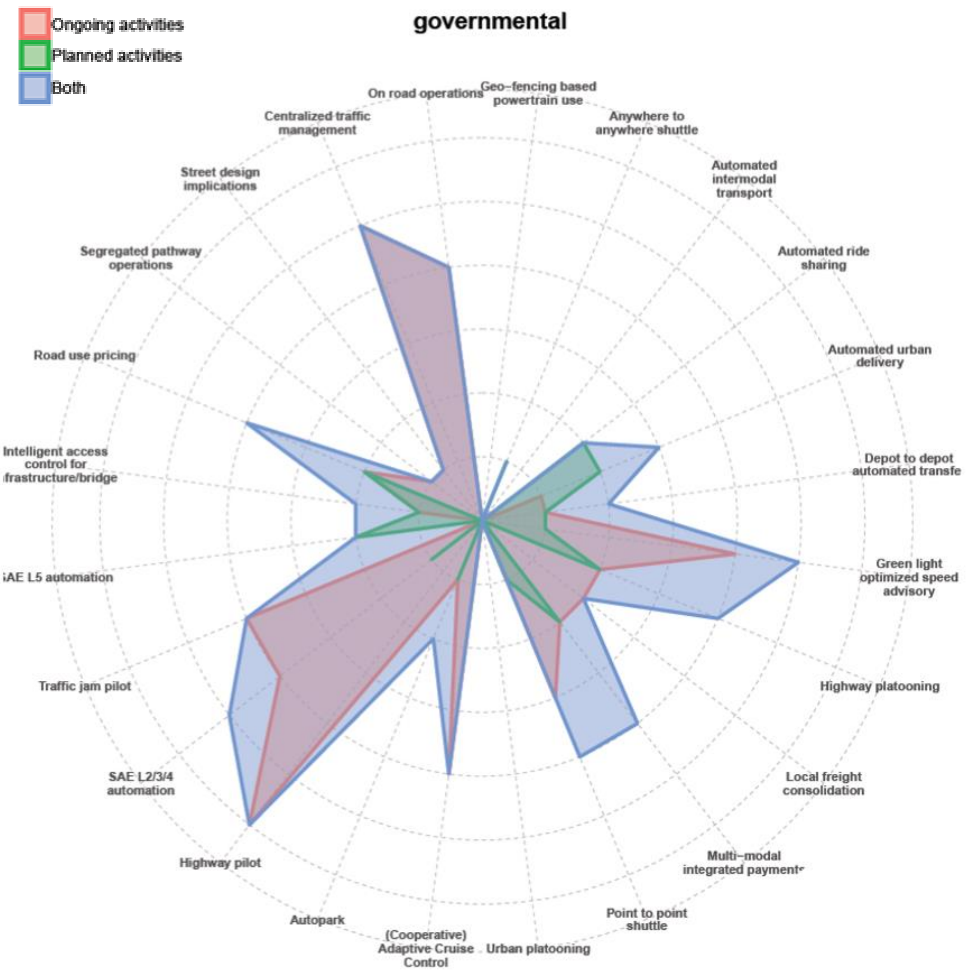


Figure 4.3 Ongoing and planned activities on the sub-use cases within governmental organisations. N=24.

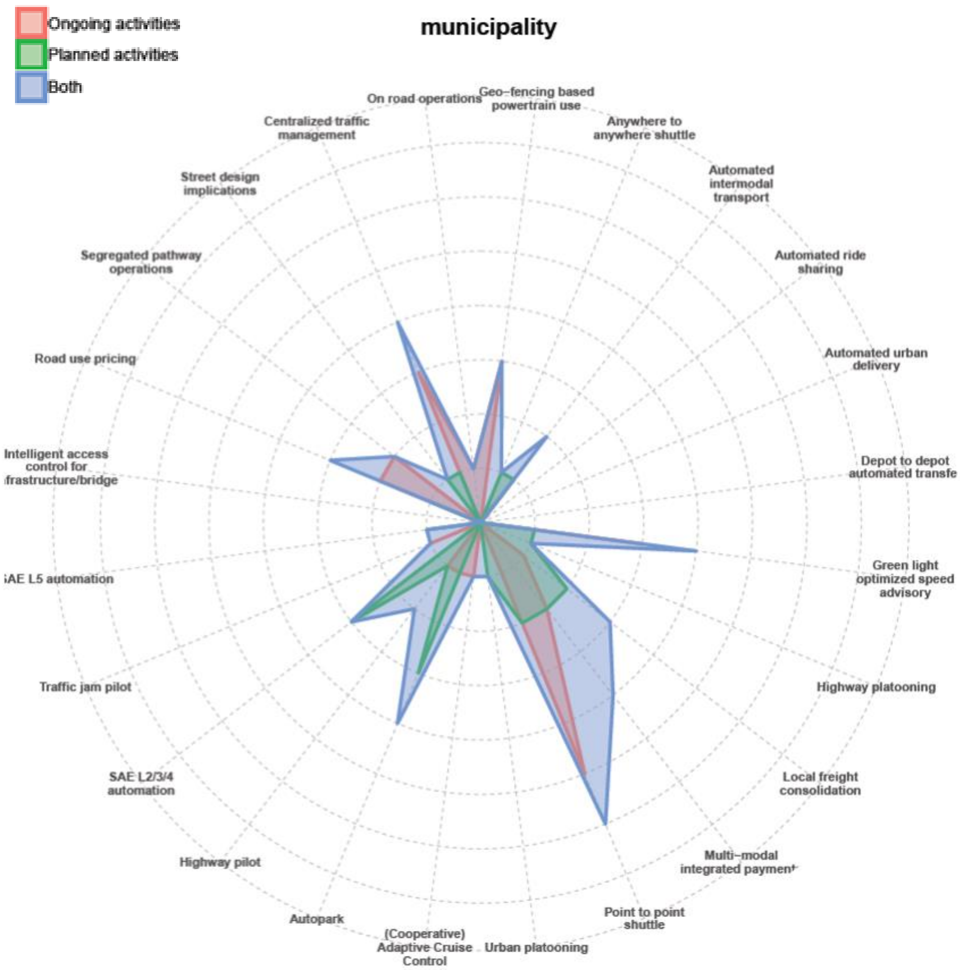


Figure 4.4 Ongoing and planned activities on the sub-use cases within municipalities. N=24.

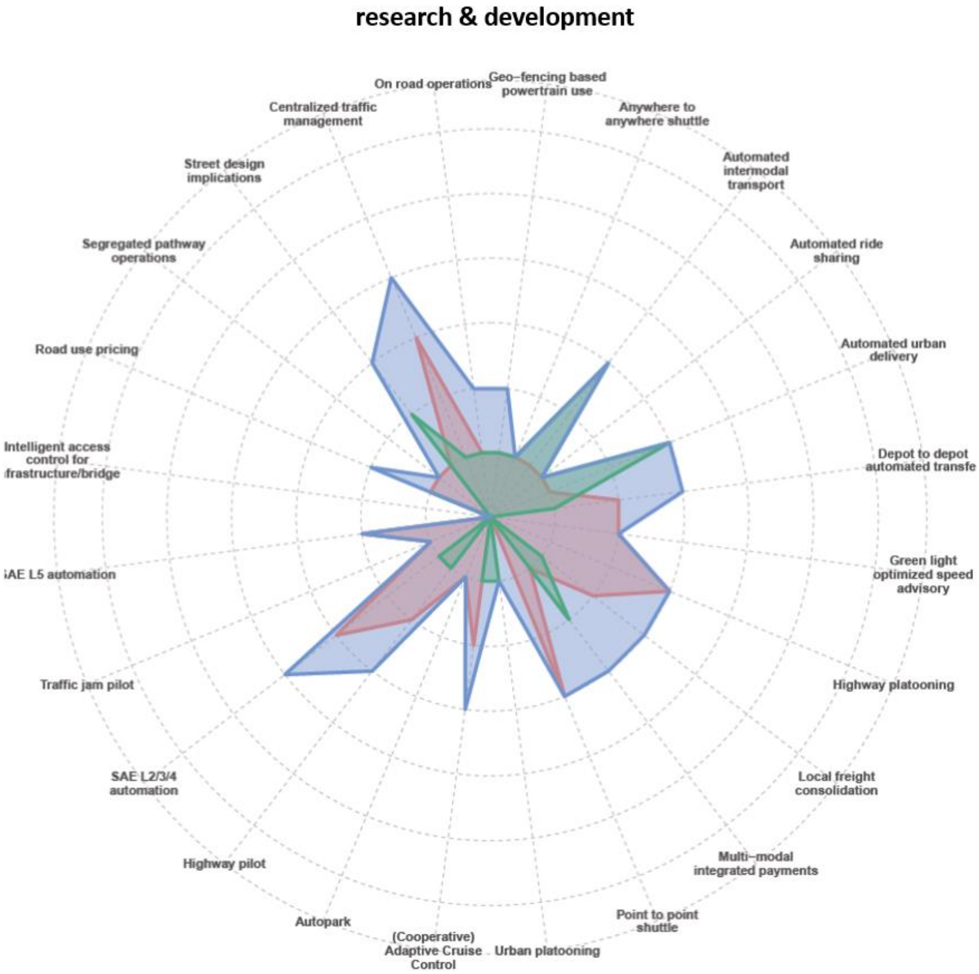


Figure 4.5 Ongoing and planned activities on the sub-use cases within research and developmental organisations. N=24.

4.2 Session 1 – Defining futures

This session was designed to gauge the stakeholders' view on how they plan for the future to meet their goals.

4.2.1 Future overview

Question

When you think of future cities, what positive outcomes do you think CATS will bring?

Response:

Response from participants is summarised in Figure 4.6. Comments are grouped into appropriate categories.

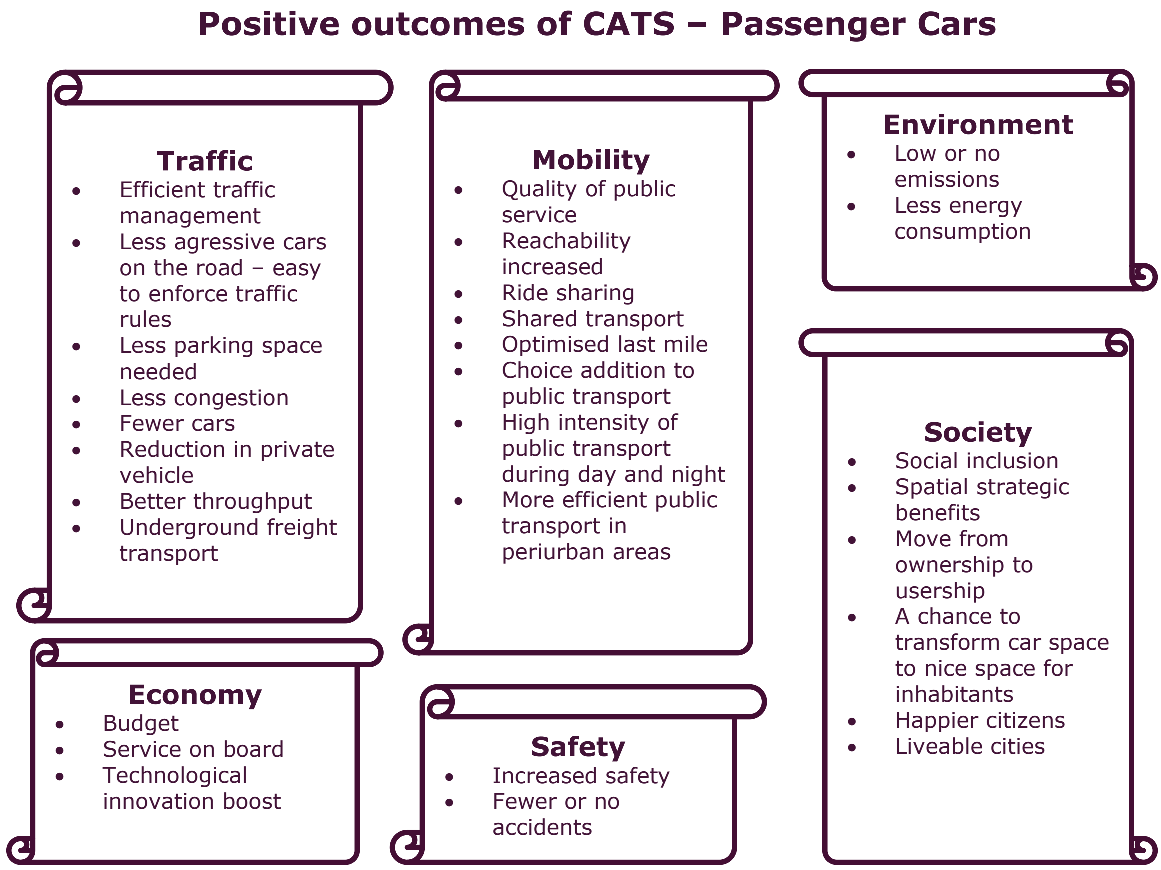


Figure 4.6 Summarised comments from the workshop participants on positive outcomes of CATS.

Question
When you think of future cities and CATS, what are the biggest challenges will need to be overcome to achieve the positive outcomes that you think of?
Response:
Response from participants is summarised in Figure 4.7. Comments are grouped into appropriate categories.

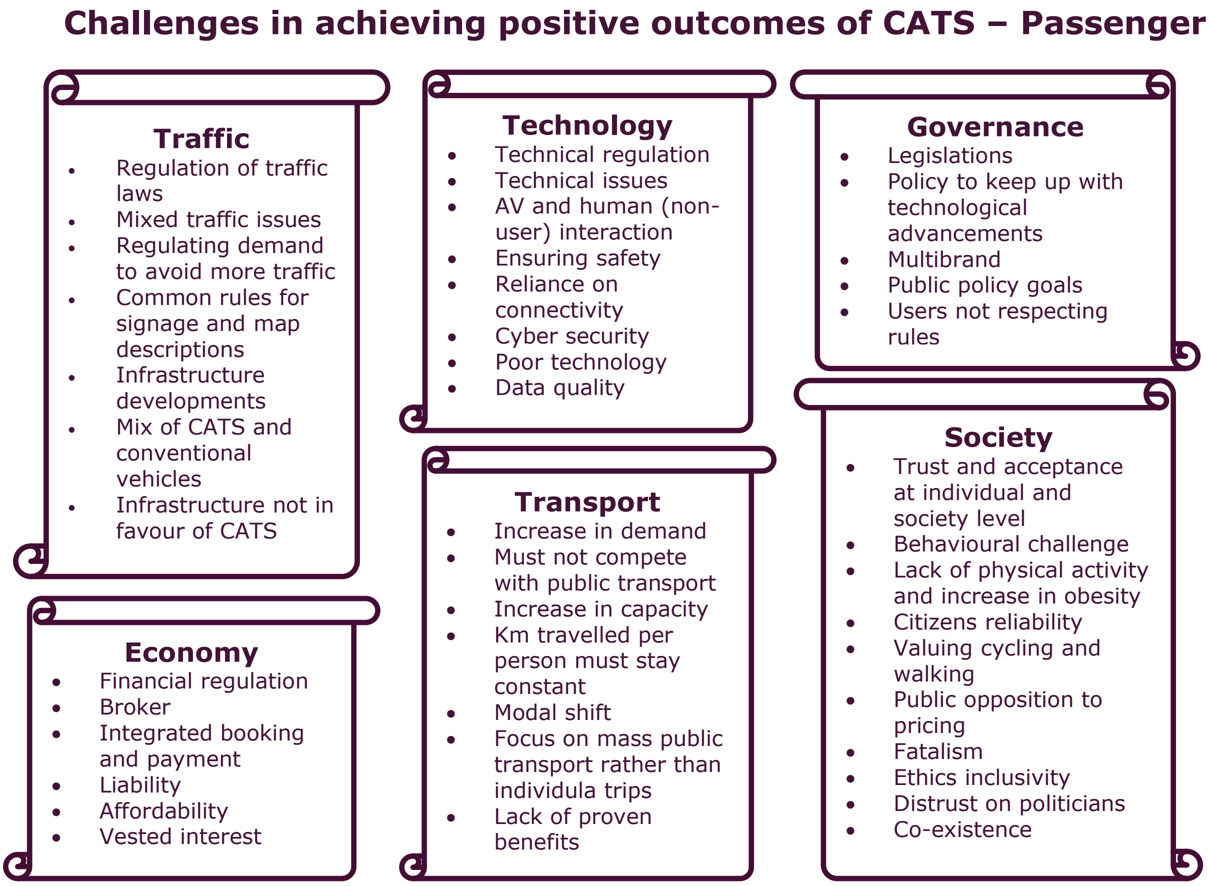


Figure 4.7 Summarised comments from the workshop participants on challenges to overcome to achieve positive outcomes of CATS.

It is clear that CATS are expected to bring benefits to the society, economy and environment through increase in safety and mobility and, optimised traffic. However, there are organisational and societal level challenges that need to be addressed. Not surprisingly, the technological and traffic management related issues are immediate but there is also rising need for governance. Financial regulation will need to be in place to avoid vested interests and have affordable transport for public. There are questions arising in terms of adoption of the technology, behavioural change and public health.

4.2.2 Current approaches to future planning

Set of questions:

- *Describe the current approach to plan for the future of urban transport/passenger car/freight (specific to table)?*
- *What are the main principles of the approach?*
- *How far in the future do you plan, is short, medium and long term defined?*
- *What features of a future do you expect to occur/take into account when planning? E.g. technologies (mobility as a service, vehicle platooning, V2X communications), infrastructure (parking space availability), change in driver behaviour (reduced vehicle use), change to economy, change in employment skills etc*

- *What are the biggest difficulties to planning (find the "pain points" the PST might help with?*

Responses:

Planning
Technology - Currently, they (responders in the workshop) look at application level (SAE levels of autonomy in driverless cars) vs. key technology enablers to plan for the future. For example, they look at car connectivity technology and their readiness levels. Also, will the communication between cars and pedestrians be effective? This is taken into account when they plan for the arrival of cars with various level of autonomy.

Adoption - People's behaviour is also an important consideration. When planning for a change in transport system, does the modal shift occur for example people who are using buses will now use bicycles? Or do new users (for example, Non-public transport user) come on board for an introduction of transport stream?

It is also necessary to integrate the new system with existing transportation system, to offer the choices of modes and associated arrival time.

It is also necessary to have enabling infrastructure to allow introduction of CATS. For example, you need traffic lights that are connected directly to the cars. Having a reactive approach to planning can unearth some benefits not previously thought of.

Cause and effect – In order to assess impacts of the technology, there was a strong preference to be able to run some experiments to assess cause and effect relationship before deciding on their implementation.

Planning is difficult when there is dependency on enablers who are not part of the same organisation. For example, in planning for CATS, infrastructure will need to plan their activities first and have investment plan for 25 years so that vehicle manufacturers and users can plan out their activities around that.

Timeline
In average, they have considered roughly 5 years per SAE level making it around year 2040 when highly automated cars will be available on the market. In addition, they also look at average life cycle of cars.

4.2.3 Expectations of the future

Set of questions:

Mind map voting and parameter notes

- *Place your dots on the features which you expect will have greatest importance for the short, medium and long term?*

Responses:
Several short-, medium- and long-term features were identified and rated. A mind map was generated during the workshop discussions and is provided in Figure 6.2 within Appendix. This mind map was generated with Passenger cars in the centre and general

theme that was emerging were placed around it. Table 4.1 shows the features from the mind map that were given ratings.

Table 4.1. Voting for parameters that were identified during the discussions of passenger cars in workshop. Number of occurrences of letters in the table shows number of votes. Parameters are shown in Bold whereas the elements that were considered within that are shown in Italics. N=16.

Parameters/Elements	Short-term (S)	Medium-term (M)	Long-term (L)
Policy	SS	M	
Acceptability	S	M	L
Young users see technology differently			L
Behaviour change	S	MM	L
Influence modal shift	S	MM	L
Traffic flow	S	MM	L
Avoid travelling of empty vehicles	S	M	L
Environmental pollution	S	M	L
Technology	SSS	M	L
Position accuracy	S		
Priority traffic lights (who for?)	S		
Cost			
Financial		M	
Promote innovation	S		
Infrastructure			
Ring roads and school environment are easier to map and automate		M	
Cost to park and use road	S		
System (transport)	S	M	L
Lack of evidence of future impact		M	
Run tests in real environments		M	L

It seems that the short-term expectations on *technology* and *policy* is most important according to the participants in the passenger cars theme. In terms of medium-term expectations, *behavioural change, influencing modal shift* and *traffic flow* were the most important features. In terms of long-term expectations, there was no clear importance of a particular feature but *acceptability (technology adoption), traffic flow, impacts on environment, system* and *testing in real environments* were considered to be more important than other features that were identified during the workshop (Figure 6.2).

4.3 Session 3 - Selecting interventions and activities

It should be noted that session 2 was not relevant for this work package and therefore, the results are not included here. They are included in deliverable 4.1.

4.3.1 Pre-workshop survey

Workshop participants were asked to fill in a survey before coming to the workshop. This survey included planned and ongoing activities around CATS within their organisations. Organisations were further categorised into governmental, municipality and research and development organisations. Specific results are presented in Figure 4.3, Figure 4.4 and Figure 4.5 in the appendix. However, according to their top priorities, it seems that some sub-use cases were common among them all, but some were only common across two types of organisations. These are listed in Figure 4.8 accordingly.

Additionally, sub-uses cases that were prioritised by **only** governmental organisations are,

- On road operations
- Traffic jam pilot

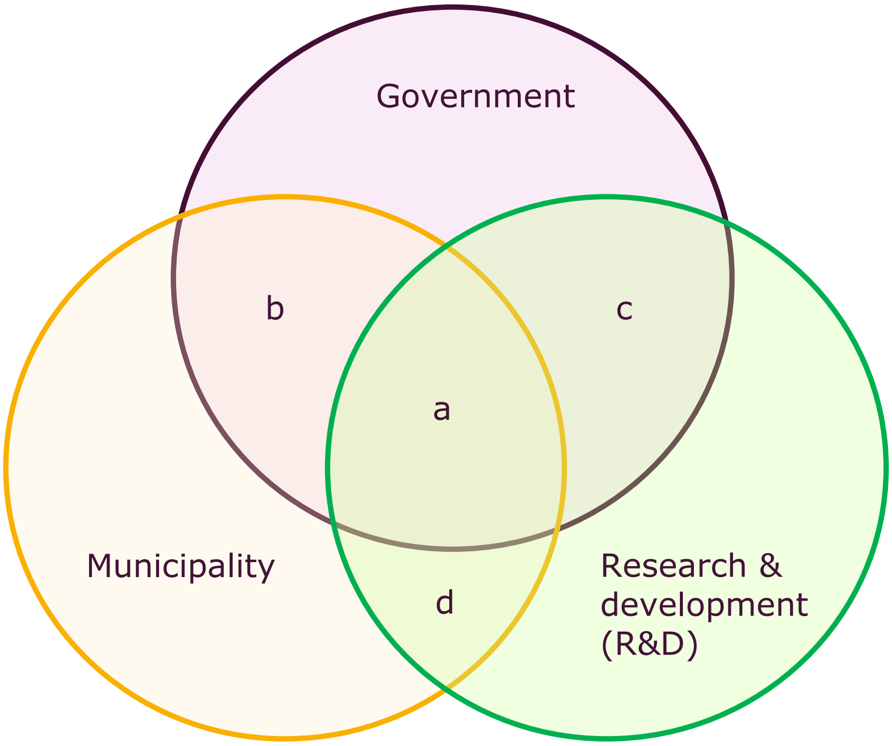
sub-uses cases that were prioritised by **only** municipality organisations are,

- Autopark
- Geo-fencing-based powertrain use

sub-uses cases that were prioritised by **only** research and development organisations are,

- Street design implications
- Depot to depot automated transfer
- Automated urban delivery
- Automated intermodal transport

It seems that most activities are related to passenger cars and public (urban) transport and all organisations are focused on those related sub-use cases. In contrast, only municipalities and some research and development organisations are focused on freight related sub-use cases.



(a) Common sub-use cases across all

1. Centralised traffic management
2. SAE L2/3/4 automation
3. Point-to-point shuttle
4. Multi-modal integrated payments

(b) Common sub-use cases between government and municipality (but not R&D)

1. Road use pricing
2. Green light optimised speed advisory

(c) Common sub-use cases between government and research & development organisations (but not municipality)

1. Highway pilot
2. Cooperative Adaptive Cruise Control (CACC)
3. Highway platooning

(d) Common sub-use cases between research & development organisations and municipality (but not government)

4. Local freight consolidation

Figure 4.8 Common priorities amongst government, municipalities and research and development organisations that were deduced from pre-workshop survey.

4.3.2 Prioritisation of interventions

During this session, a selection of sub-use cases was presented to participants in its prioritised form, shown below in Figure 4.9. The priorities were deduced from the pre-workshop survey as mentioned earlier with results presented in Figure 4.3, Figure 4.4 and Figure 4.5. Note that Figure 4.9 shows all sub-use cases not just for passenger cars.

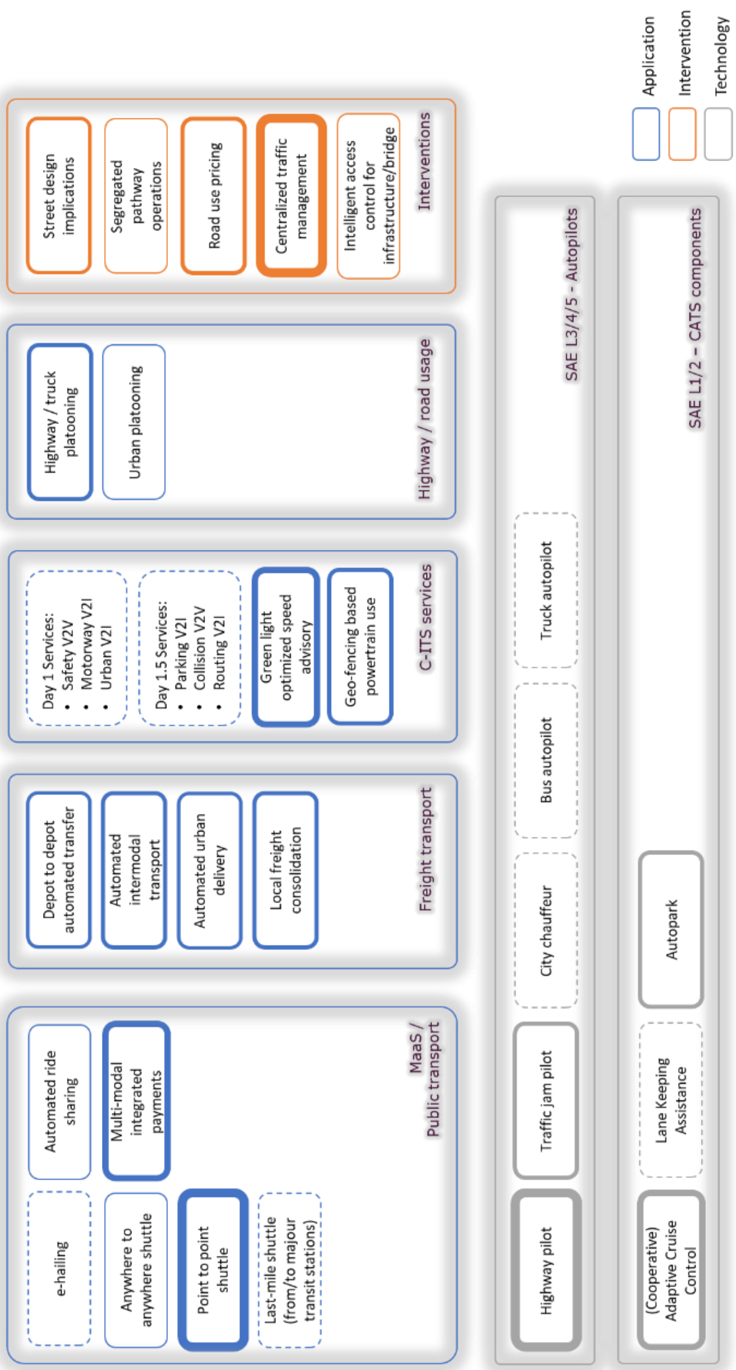


Figure 4.9 List of sub-use cases that were clustered together before workshop and prioritised based on pre-workshop survey. The thickness of boxes show priority, going from thickest with high priority to thinnest for low priority.

The workshop participants were then asked following questions.

Question:
Do you agree with this (presented) order of the sub-use cases?

Response:
14 participants (63.64%) out of 22 disagreed with the presented order of the sub-use cases.

Set of questions:
Which sub-use case you consider important but less feasible?
Brainstorming - how the sub-use cases that are not easily feasible can be realised?
Which of these sub-use cases are most appropriate for the short, medium and long term?

Response:
Autopark – the first challenge is to find a parking space. In the context of connected vehicles, a directed parking reservation system would be required that can direct the user for appropriate parking spot. The next step would be when vehicles are automated, the car can park itself, but it will potentially require less space considering that the doors will not need to be opened as the passengers would have left the vehicle at the entrance. So, the first challenge is to be able to find a parking space and reserve it. Automated car should be able to handle this. Without this system, autopark is essentially same as present situation where we might not have information beforehand where to park, causing unduly added delays in journey and causing congestion. Also, in the case of shared vehicles or level 4/5, the car could be waiting instead of parking in some situations. The important thing is not how the car actually gets to the waiting or the parking position, it is the enablers in terms of where do you find the parking spot? Where do you find the customer? Where are the most likely customers for the next trip, etc.?

In terms of parking, there were a variety of parking types that emerged from the discussions. These are listed below:

- Find and reserve parking space
- Direct to a parking space
- Auto valet – leave the car at appropriate place and the car can park itself somewhere, may it be outside or inside the city, nearest parking place, etc.
- Waiting time – shared ownership may not require parking and could provide transport services to other people whilst waiting.

Additionally, there was suggestion of a name change for Autopark. Autopark may refer to a technology where a car can park itself from a traffic lane to a parking space via parallel parking or an angle parking manoeuvre. According to the discussions, in this project, Autopark should be renamed to 'Valet parking' as this would refer to car driving itself to a parking place and park itself in an appropriate space.

Table 4.2. Identifying sub-use cases for short-, medium- and long-term futures. N=10.

Sub-use cases	Short-term (S)	Medium-term (M)	Long-term (L)
Anywhere to anywhere shuttle			L

Multi-modal integrated payments			L
Last-mile shuttle (from/to major transit stations)	S		
Green light optimised speed advisory	S		
Road use pricing	SS		
Centralised traffic management		M	L
Intelligent access control for infrastructure/bridge		M	
City chauffeur	S	M	L
Benefits to the society	S	M	L
Impact on other road users when using CATS	S	M	
Acceptability and technology adoption	S	M	L
Lowering demand – modal shift	SS	M	

4.3.3 Challenges

Set of questions:
Which are the most important (1-2) sub-use cases that must necessarily take place in the project and be part of the PST?
Given your experience what are the challenges that might be faced for the implementation of each one of these sub-use cases in the cities?
How each one of the top challenges can be tackled in your opinion?

Response:
Traffic management centre – there should be different guidance from traffic management centre on route options depending on whether the car is empty or occupied. For empty car, it may not be necessary to take a quickest route.

Travel planner – In the future, there may be travel planner system in-built into the car that can give you choice in multitude of parameters. For example, quickest route, shortest route, environmental-friendly route, routes avoiding urban areas, etc.

Urban platooning – they need to be connected to the traffic light system because the whole of the platoon will need to pass through the traffic light junction just like a tram in present days.

Within PST, it is suggested to have a basic building blocks, i.e. technologically linked use cases. So, for example, in order to implement urban platooning, traffic lights need to be adapted to allow it.

It was suggested that a PST should be able to inform the city to which degree a particular service is standardised. This is because a smaller city would not want to have a proprietary solution because of fear of being left out (i.e. stuck with that particular solution that may not be standardised across the region/nation).

Interaction between automated car and human road users – it is important that humans are able to understand intentions of automated car to be able to perform routine tasks of street crossing and walking, cycling, etc. This is because to be able to do any of these tasks we make judgement based on others' behaviour. So, it would be ideal for us to understand automated car's behaviour.

4.3.4 Interventions (sub-use cases) list completion

Set of questions:
Do you consider that the list of sub-use cases is complete?
What other sub-use cases would you add? State 1-2 and why they are important.

Response:
The list below is summarised from the discussions in this entire session.
Sub-use cases that were mentioned

- Cooperative adaptive cruise control for traffic jam pilot
- Street design – it is important consideration because the implications are that automated vehicles may not require wider streets/lanes as they have better control to keep between the lines. Streets could be redesigned to provide more space for pedestrians and cyclists.

Sub-use cases that were considered to be missing

- In-vehicle signage – provision of legal road signage inside the vehicle as it moves along the road.
- Parking – variety of parking that includes following
    - Find and reserve parking space
    - Direct to a parking space
    - Auto valet – leave the car at appropriate place and the car can park itself somewhere, may it be outside or inside the city, nearest parking place, etc.
    - Waiting time – shared ownership may not require parking and could provide transport services to other people whilst waiting.
- Travel planner – connected system that advises user on available route choices including suggestions for parking if necessary.

Considerations in PST:

- Acceptability measures/technology adoption – how can acceptance and adoption of automated cars be increased?
- Benefits to the society
- Impact of an individual using CATS on other road users and environment (at person level rather than system level)
- Multi-modal transport in 1 journey
- Emission reduction

- Interaction between CATS and pedestrians and cyclists.
- Standardised regulations
- Lowering demand to support modal shift.
- Technology linked use case

4.4 Key outcomes

The aim of workshop was to gauge stakeholders' view on defining the future of CATS and prioritising use cases of passenger cars which we call sub-use cases in this project. It appears that the stakeholders have huge expectations from CATS and they also recognise challenges to achieving those. When planning futures, they have considered roughly 5 years per level of automation (those defined by (SAE International, 2018)). In their opinion, technology readiness, appropriate policies and technology adoption were the most important things to consider in planning.

In terms of sub-use cases (also interventions), it was found that all organisations had some common sub-use cases that they have either planned activities or were ongoing. However, this list did not come across strongly during the discussions within the passenger cars group. It seems that the discussion was more focused around parking issues, navigation and street planning. It was also emphasised that analysis should be made human-centric rather than technology centred. Participants identified that some sub-use cases were missing in the list and therefore added those and that Autopark was too generic and distinction between different technologies within Autopark should be made.

5 Conclusions and future work

5.1 Conclusions

5.1.1 Defining the future of passenger cars

To progress in impact assessment, a future was needed to be defined and this was considered by examining literature on available market penetration forecasts along with technology roadmaps and, information gathering through a stakeholders' workshop. Even with some inconsistencies, a consensus was found. It must be emphasised that the technological roadmaps are generally focused on when a particular technology is likely to be available but not on its diffusion into the market, i.e. market penetration. Therefore, it was difficult to translate roadmaps into market penetration and so only those reports that provide market forecasts were considered.

Based on reviewed literature (Figure 3.2), it appears that there is consensus on market penetration of level 3-5 automated vehicles below 50% by 2030. Also, according to Litman (2016), it seems that the market penetration of level 4-5 automated vehicles may not be achieved close to 100% before 2050. However, market penetration of connected vehicles will be close to 100% within the next decade (2030) according to Frost and Sullivan (2019).

Literature on potential impacts of automation technologies within the passenger car domain was reviewed. Evidence from ADAS technologies was first analysed as they are considered to be Level 1 / 2 technologies. It appeared that the forecasts of ADAS penetration were overestimated, although ADAS systems with greater focus on driver comfort had higher penetration rates. Furthermore, initial screening of literature on CATS suggests that they have potential to increase the capacity of lanes and a reduction in congestion and fuel consumption. Also, it could increase travel demand due to changes in destination choices (for example, longer journeys), changes in transport mode (shift from public transport) and introduction of new users.

It was considered that for the purposes of this project, short-, medium- and long-term impacts would be those defined by deliverable 3.1 in this project (Elvik et al., 2019) as direct, systemic and wider impacts, respectively. They have collected all future impacts discussed from literature and collated them into direct, systemic and wider impacts appropriately. These impacts will be considered to be forecasted in task 6.2, 6.3 and 6.4 of work package 6 in this project.

According to the stakeholders, the short-term expectations/priorities were *technology readiness (of AVs and enabling technologies)* and implementation of appropriate *policies and regulations*. In terms of medium-term expectations, they considered *behavioural change* and *traffic flow* to be most important. There was no clear consensus on long-term expectations.

5.1.2 Passenger cars sub-use cases

In addition to the sub-use cases list for passenger cars that was collated, workshop participants suggested a few new use cases for passenger cars. Those include specific detailed parking related sub-use cases and in-vehicle signage. It was emphasised that in order to have a better future of AVs, parking issues would need to be solved.

Sub-use cases of the passenger car use case will be prioritised for their consideration in further investigation. When prioritising, factors such as widespread studies being followed on those sub-use cases and the feasibility of impact assessment will be considered. However, the following use cases of automated passenger cars seem to strongly emerge from initial impression from literature review, workshop and industry movements.

1. Automated parking and its variants.
2. Highway automation
3. Centralised traffic management
4. Cooperative Adaptive Cruise Control
5. Platooning

Furthermore, it is assumed that for the appropriate level of automation, there is adequate infrastructure in existence and appropriate policies are in place along with their regulation. Also, it is assumed that the technological obstacles are solved for the sub-use case in consideration.

5.2 Future work

Further work to be carried out in WP6 is as follows:

1. Prioritisation of sub-use cases
2. Literature review specific to sub-use cases and impacts
3. Analysing impacts using appropriate methodologies (from task 3.2)
4. Provide input to WP8.

Tasks 6.2, 6.3 and 6.4 will respectively assess short-, medium- and long-term impacts on society, economy, environment and safety. These impacts will be subjected to introduction of sub-use cases (including interventions) that have been identified in this deliverable. Introduction of sub-use cases would be considered case-by-case. For example, some sub-use cases can be introduced gradually such as SAE level 4 automation for passenger car by means of market penetration. Whereas, some intervention such as multi-modal integrated payments can be introduced almost instantly on a relative timescale (in decades).

Types of impacts that are presented in deliverable 3.1 of LEVITATE (Elvik et al., 2019) will be forecasted using appropriate assessment methods that are developed in task 3.2. For example, traffic micro-simulations can directly provide short-term impacts and therefore, they will be used to forecast short-term impacts to be able to develop relationships that can infer dose (in terms of introduction of sub-use case) and response (selected impact). They also provide further input to assess medium-term impact by processing those results appropriately to infer medium-term impacts. System level analysis (such as by tools within system dynamics) can provide measure of long-term impacts. These results relating to the relationships between sub-use cases, impacts and any intermediate parameters will be provided to WP8 to be incorporated in the PST so that impact assessment can be carried out.

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6 Appendix

6.1 Stakeholders' pre-workshop interview– Defining the future of passenger cars, urban and freight transport

Introduction

- Welcome, thank you for your time
- Aim of interview – Defining the short, medium & long term future of passenger cars, urban and freight transport
- Approx. 30min discussion
- All data protection rules are followed.

Part 1: First thoughts on future cities and CATS

- When you think of future cities and CATS, what do you think of?

Part 2: What is currently being done for future planning and is it working?

- *Please describe what is currently being done to plan for the future of CATS and what are the main principles?*
- *Consider any project or experience you have regarding CATS introduction, what were the challenges and obstacles you faced?*
- Which approach is working well, and which not? Why?

Part 3: specific future vision

- *What do you envisage the short, medium and long term future of passenger cars will look like?*
- *What do you envisage the short, medium and long term future of urban transport will look like?*

- *What do you envisage the short, medium and long term future of freight will look like?*

(Penetration, Vehicles, Infrastructure, People acceptability)

Mention as many features of this future as you can. Are there any obstacles mentioned previously (Q2) that are relevant?

Part 4: Sub-use cases

A list of proposed sub use cases can be mentioned from the interviewer.

- *Could you think of any other use cases that are missing and would be valuable?*
- *Could you select top use cases within each type (urban transport, passenger car, freight) that you would most like to be able to explore in the future PST?*
- *What problems and questions is each use case addressing?*
- *What are the expected results given your experience?*

Part 5: the PST

- *Considering the future you are trying to plan for, what are the features you would like to see in the PST?*
- *How useful would you find it?*

Closing

- Comments and questions
- Thank you

6.2 A copy of online pre-workshop survey questionnaire

Part 1

Thank you very much for participating in this survey, which will give us a first impression about expectations and activities in relation to Connected an Automated Vehicles in different cities in Europe. We will ask you about general development plans and different potential measures in your region. Please answer the questions to the best of your knowledge. The survey will take you about 10 minutes.

Part 2: Background

a. **Please provide some information about your background:**

a. Organisation: ☐ *Required*

b. Position: ☐ *Required*

c. Type of organisation: ☐ *Required*

- governmental
- municipality
- civil society
- organisation
- international
- association industry
- research &

d. Country: ☐ *Required*

e. Please indicate the city or region you will be referring to in your answers. ☐ *Required*

Part 3

2. **Please assess the importance of the following general goal dimensions in the strategic development of your region in relation to each other by allocating specific percentages to the four goals. Please make sure that the sum of the percentages for all the 4 goal dimensions is 100%.**

b. Environment

c. Society

d. Economy

e. Safety

Part 4: Indicators & Goals

3. Please indicate for the following selection of indicators for the development of a livable city are monitored (regularly measured) in your city and whether there are related specific goals (values) defined for the short (appr. 5-10 years), medium (appr. 15-20 years) or long term (appr. 25-30 years).

Indicators

Please don't select more than 4 answer(s) per row.

	Monitored	Short term goal defined	Mid term goal defined	Long term goal defined
Transport safety: Number of injured per million inhabitants	☐	☐	☐	☐
Transport safety: Number casualties per million inhabitants	☐	☐	☐	☐
Transport safety: other important indicators (please specify on next page)	☐	☐	☐	☐
Reachability: Average travel time per day	☐	☐	☐	☐

Reachability: Number of opportunities per 30 minutes per mode of transport	☐	☐	☐	☐
Reachability: other important indicators (please specify on next page)	☐	☐	☐	☐
Energy consumption per person in total	☐	☐	☐	☐
Energy consumption per person transport related	☐	☐	☐	☐
Energy consumption: other important indicators	☐	☐	☐	☐
Emissions: SO2	☐	☐	☐	☐
Emissions: PM2,5	☐	☐	☐	☐
Emissions: PM10	☐	☐	☐	☐
Emissions: NO2	☐	☐	☐	☐
Emissions: NO	☐	☐	☐	☐
Emissions: Nox	☐	☐	☐	☐
Emissions: CO	☐	☐	☐	☐
Emissions: O3	☐	☐	☐	☐
Emissions: other important indicators (please specify on next page)	☐	☐	☐	☐
Public space: Lane space per person (e.g. Vienna: multi- purpose area map)	☐	☐	☐	☐
Public space: Pedestrian/cycling space per person	☐	☐	☐	☐

Public space: urban atlas data (Eurostat)	☐	☐	☐	☐
Public space: other important indicators	☐	☐	☐	☐
Urban sprawl: Building volume per square kilometre in total	☐	☐	☐	☐
Urban sprawl: Building volume per square kilometre per built-up area	☐	☐	☐	☐
Urban sprawl: Population density (Eurostat)	☐	☐	☐	☐
Urban sprawl: other important indicators (please specify on next page)	☐	☐	☐	☐
Inclusion: Distance to nearest publicly accessible transport stop (including MaaS)	☐	☐	☐	☐
Inclusion: Affordability/discounts	☐	☐	☐	☐
Inclusion: Barrier free accessibility	☐	☐	☐	☐
Inclusion: Quality of access restrictions/scoring	☐	☐	☐	☐
Inclusion: other important indicators (please specify on next page)	☐	☐	☐	☐
Transport system satisfaction: Satisfaction with active transport infrastructure in neighbourhood (walking and/or cycling)	☐	☐	☐	☐

Transport system satisfaction: Satisfaction public transport in neighbourhood	☐	☐	☐	☐
Transport system satisfaction: other important indicators (please specify on next page)	☐	☐	☐	☐
Prosperity: Taxable income in relation to purchasing power	☐	☐	☐	☐
Prosperity: other important indicators (please specify on next page)	☐	☐	☐	☐

Part 5

4. Please list other important indicators related to the development of a livable city you are monitoring.

Part 6

5. Are there any other specific goals you have defined for a certain time period? Please specify.

Part 7: Strategies

6. Which of the following strategic measures are being taken in your country/by your organisation?

- [ ] National
- [ ] strategy Action
- [ ] Plan
- [ ] Pilot Testing
- [ ] Methodological
- [ ] standards Research
- [ ] Programme Legal

Part 8: Interventions and activities

7. In which of the following areas in relation to CATS have you started or are you planning to start activities?

Application: Geo-fencing based powertrain use

☐ More info

- Ongoing
- activities
- Planned
- activities No

Application: Anywhere to anywhere shuttle

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Automated intermodal transport

☐ More info

☐ Ongoing
☐ activities
☐ Planned

☐ Don't know

Application: Automated ride sharing

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Automated urban delivery

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Depot to depot automated transfer

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Green light optimized speed advisory

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Highway platooning

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Local freight consolidation

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Multi-modal integrated payments
☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Point to point shuttle

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Application: Urban platooning

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Technology: (Cooperative) Adaptive Cruise Control

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Technology: Autopark

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Technology: Highway pilot

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Technology: SAE L2/3/4 automation

☐ More info

☐ Ongoing activities

☐ Planned
☐ activities No
☐ activities Don't

Technology: Traffic jam pilot

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Technology: SAE L5 automation

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Intervention: Intelligent access control for infrastructure/bridge

☐ More info

☐ Ongoing
☐ activities
☐ Planned

☐ Don't know

Intervention: Road use pricing

☐ More info

☐ Ongoing ☐ activities ☐ Planned ☐ activities No

Intervention: Segregated pathway operations

☐ More info

☐ Ongoing ☐ activities ☐ Planned ☐ activities No

Intervention: Street design implications

☐ More info

☐ Ongoing ☐ activities ☐ Planned ☐ activities No

Intervention: Centralized traffic management

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Intervention: On road operations

☐ More info

☐ Ongoing
☐ activities
☐ Planned
☐ activities No

Other:

Part 9: Final Part

Thank you for taking the time to complete this survey!

*Here is a link to **Levitate** project:*

https://levitate-project.eu/about/

6.3 Agenda of the SRG workshop

LEVITATE 1st Stakeholder Workshop

28 May 2019, Gothenburg

Lindholmen Conference Centre, Lindholmspiren 5, 417 56 Gothenburg

Societal Level Impacts of Connected and Automated Vehicles	
08:30-09:00	*Registration & Coffee*
09:00-09:20	**Welcome & Introduction to the project** *Pete Thomas, Loughborough University*
09:20-09:30	**Presentation of pre-workshop survey results: Landscape of Goals and Plans** *Alexandra Millonig, AIT Austrian Institute of Technology*
09:30-10:30	**Discussion Round 1: Visions of CAT Futures** *Ashleigh Filtness, Loughborough University* Parallel Group Discussions: • Automated Urban Transport • Passenger Cars • Freight Transport & Logistics
10:30-10:50	*Refreshment Break*
10:50-11:00	**Introduction: Building Ideal Futures with Conflicting Goals** *Alexandra Millonig, AIT Austrian Institute of Technology*
11:00-12:00	**Discussion Round 2: Ideal Futures** *Alexandra Millonig, AIT Austrian Institute of Technology* Parallel Group Discussions: • Environment • Society • Economy • Safety
12:00-13:30	*Lunch Break (including demo visits and video interviews)*
13:30-13:50	**Plenary Discussion: Overlaps & Conflicts** *Alexandra Millonig, AIT Austrian Institute of Technology*
13:50-14:50	**Discussion Round 3: Selecting Interventions & Activities** *Julia Roussou, National Technical University of Athens* Parallel Group Discussions: • Automated Urban Transport • Passenger Cars • Freight Transport & Logistics
14:50-15:30	**Introduction to the Policy Support Tool (PST), followed by discussion on expectations and needs regarding the PST** *Julia Roussou, National Technical University of Athens*
15:30-16:00	**Closing & networking coffee, demo visits, video interviews**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824361.

Figure 6.1: Agenda of the SRG Workshop on 28 May 2019.

6.4 Results from the stakeholders engagement workshop

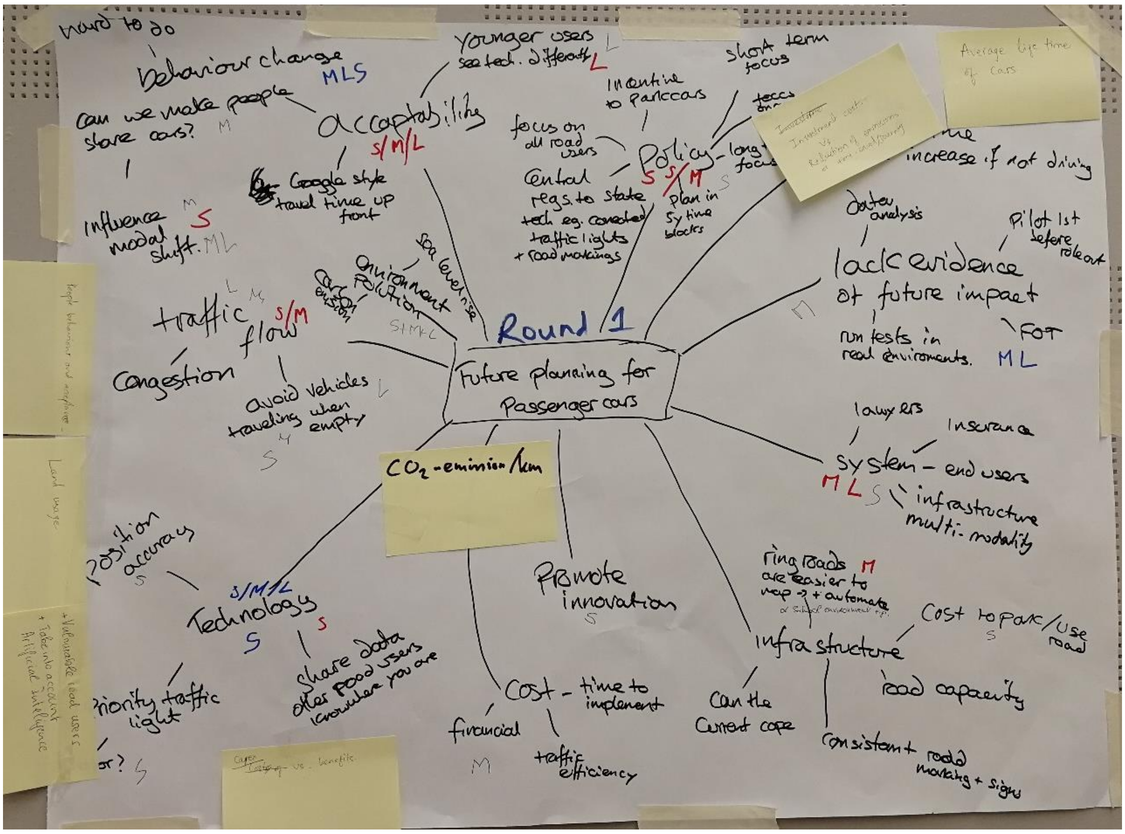
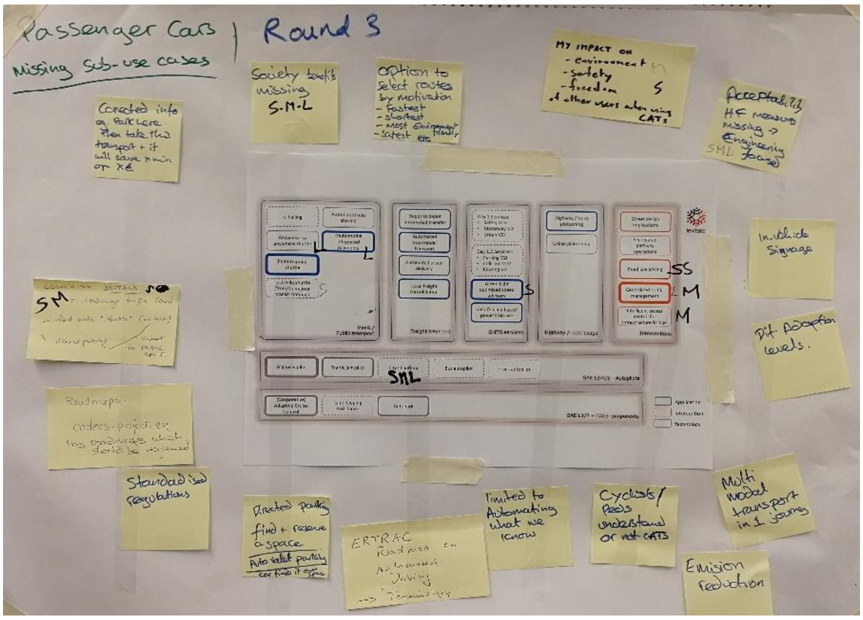


Figure 6.2 Mind map generated during workshop on passenger cars theme – Defining futures.

(a)



(b)

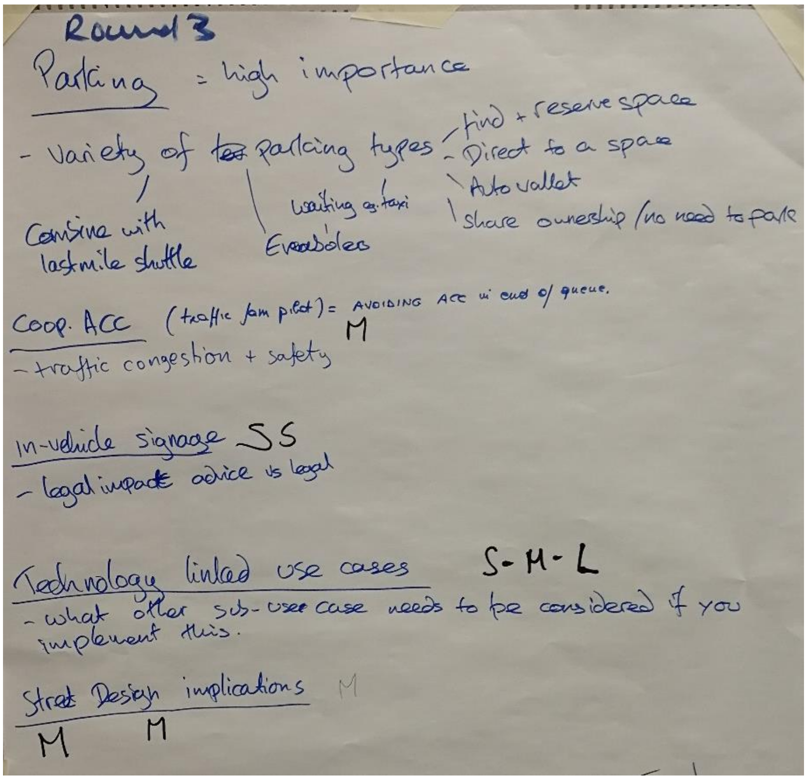


Figure 6.3 (a) Additional sub-use cases and comments that were added to the list of sub-use cases during session 3 of workshop. (b) Important use-cases that have emerged towards the end of session 3 in the workshop.

6.5 EU Projects on CATS

Table 6.1 Past and current EU Projects on CATS

EU Projects on CATS		
CoEXist 05/2017 – 04/2020	https://www.h2020-coexist.eu/	focusing on the technological development of microscopic and macroscopic transport modelling tools, CAV-simulators and CAV control logistics and aims to strengthen the capabilities of urban road authorities for the planning and integration of CATS on their networks
AUTOPILOT 01/2017-31/12/2019	http://autopilot-project.eu/	AUTOPILOT brings together relevant knowledge and technology from the automotive and the IoT (internet of Things) value chains in order to develop IoT-architectures and platforms which will bring automated driving towards a new dimension
Connected automated driving.eu (SCOUT, CARTRE) Both completed	https://connectedautomateddriving.eu/about-us/	two projects (SCOUT, CARTRE) that work together with a broad range of international stakeholders to ensure that these technologies are deployed in a coordinated and harmonised manner, which will accelerate the implementation of safe and connected automated driving in Europe.
SCOUT (H20202) 01/07/2016-2018	https://connectedautomateddriving.eu/about-us/scout/	aims to promote a common roadmap of the automotive and the telecommunication and digital sectors for the development and accelerated implementation of safe and connected and high-degree automated driving in Europe. It will support identification of deployment scenarios in LEVITATE.
CARTRE (H2020) 01/10/2016-2018	https://connectedautomateddriving.eu/about-us/cartre/	aims to establish a joint stakeholders forum in order to coordinate and harmonise automated road transport approaches at European (e.g. strategic alignment of national action plans for automated driving) and international level (in particular with the US and Japan).
ARCADE (will continue the work of CARTRE) 01/10/2018-2021	https://connectedautomateddriving.eu/arcade-project/	aims to coordinate consensus-building across stakeholders in order to enable smooth deployment of connected and automated driving (CAD) on European roads and beyond. EC, Member States and industry are committed to develop a common approach to development,

		testing, validation and deployment of connected and automated driving.
interACT 01/05/2017-30-04/2020	https://www.interact-roadautomation.eu/	Works towards cooperative interaction of automated vehicles with other road users in mixed traffic environments
L3Pilot 09/2017-2021	http://www.l3pilot.eu/home/	The overall objective of L3Pilot is to test the viability of automated driving as a safe and efficient means of transportation, exploring and promoting new service concepts to provide inclusive mobility (assessment of level 3 & 4 in-vehicle functions).
AdaptIVe Level1 -level 4 of automation 01/2014-06/2017	https://www.adaptive-ip.eu/	AdaptIVe develops various automated driving functions for daily traffic by dynamically adapting the level of automation to situation and driver status. Further, the project addresses legal issues that might impact successful market introduction.
iTETRIS 2008-2010?	http://www.ict-itetris.eu/simulator/	iTETRIS integrates wireless communications and road traffic simulation platforms in an environment that is easily tailored to specific situations allowing performance analysis of cooperative ITS at city level. The accuracy and scale of the simulations leveraged by iTETRIS will clearly reveal the impact of traffic engineering on city road traffic efficiency, operational strategy, and communications interoperability.
FUTURE-RADAR (H2020) *Jan 2017 – Dec 2020*	https://www.ertrac.org/index.php?page=future-radar POLIS is project partner	- support action for ERTRAC and EGVIA to create and implement the needed research and innovation strategies for a sustainable and competitive European road transport system. ERTRAC has a Working Group on road transport automation.
CIVITAS SATELLITE (H2020) *2002-2020*	https://civitas.eu/ POLIS is project partner	- CIVITAS can help to maximise the outreach of LEVITATE results. This includes, among others, making tools available in the online CIVITAS transport tools inventory.
Drive2theFuture (H2020) *2019-2022*	https://www.ait.ac.at/en/research-fields/integrated-	- The aim of the Drive2theFuture project is to prepare future "drivers" and travellers for

	mobility-systems/projects/drive2thefuture/	networked, cooperative and automated means of transport and to increase acceptance accordingly.
MAVEN (H2020) *2016-2019*	http://maven-its.eu/ POLIS is project partner	- aims to provide solutions for managing automated vehicles in an urban environment (with signalised intersections and mixed traffic). - It develops algorithms for organising the flow of infrastructure-assisted automated vehicles.
STAPLE (CEDR) 2018-2020	AIT is project partner http://www.stapleproject.eu/	- Identification of relevant connected and automated driving test sites in Europe and beyond and creation of an online catalogue to be used and further enhanced by the NRAs for further research beyond the project duration - Investigation of the relevance of test sites against the NRA core business taking into account the roles and responsibilities of different stakeholders and looking at the areas of road safety, traffic efficiency, customer service, maintenance and construction
CityMobil 05/2006 – 12/2011	http://www.citymobil-project.eu/	- Safety applications and technologies: safe speed and safe following, lateral support, intersection safety, active 3D sensor technology for pre-crash and blind spot surveillance.
PICAV 08/2009 – 09/2012	https://cordis.europa.eu/project/rcn/91186/factsheet/en	- Passenger transport, urban traffic, car sharing, networking, assisted driving, vulnerable road users.
CATS 01/2010 – 12/2014	https://cordis.europa.eu/project/rcn/93669/factsheet/en	- Robotic driverless electric vehicle, passenger transport, transport management, urban transport.
FURBOT 11/2011 – 02/2015	http://www.furbot.eu/	- Fully electrical vehicle for freight transport in urban areas, robotics.
V-Charge	http://www.v-charge.eu/	- Autonomous valet parking, EVs coordinated recharging, smart

06/2011 – 09/2015		car system, autonomous driving, multicamera system, multi-sensor systems.
Cargo-ANTs 09/2013 – 08/2016	https://ict.eu/case/eu-fp7-project-cargo-ants/	- Create smart Automated Guided Vehicles (AGVs) and Automated Trucks (ATs) that can co-operate in shared workspaces for efficient and safe freight transportation in main ports and freight terminals.
CityMobil2 09/2012 – 08/2016	http://www.citymobil2.eu/en/	- Automated road transport system, automated vehicle, driverless, urban transport, safety, infrastructure, legislation.
PReVENT 02/2004 – 03/2008	https://trimis.ec.europa.eu/project/preventive-and-active-safety-application	- Development and demonstration of preventive safety applications and technologies (advanced sensor, communication and positioning technologies). -
Have-it 02/2008 – 07/2011	https://cordis.europa.eu/project/rcn/85267/factsheet/en	- Automated assistance in congestion, temporary auto-pilot.
ASSESS 07/2009 – 12/2012	https://cordis.europa.eu/project/rcn/91187/factsheet/en	- To develop a relevant set of test and assessment methods applicable to a wide range of integrated vehicle safety systems, mainly AEB for car to car. Methods developed for driver behavioural aspects, pre-crash sensing performance and crash performance under conditions influenced by pre-crash driver and vehicle actions.
Digibus Austria (National Austrian Funding) *2018-2021*	https://www.digibus.at/en/ AIT is project partner	- pursues the goal to research and test methods, technologies and models for proofing a reliable and traffic-safe operation of automated shuttles on open roads in mixed traffic in a regional driving environment on automated driving level 3 ("Conditional Automation") and creating foundations for automation level 4

		- The results form the basis for an Austrian reference model for the real testing and operation of highly or fully automated vehicles in local public transport. -
DIGITrans (National Austrian Funding) *2018-2023*	https://www.testregion-digitrans.at/ AIT is project partner	- Exploration of needs and cases of application regarding heavy duty and special purpose vehicles - Use of automated vehicles in areas of logistics hubs, e.g., inland ports like Ennshafen, airport or company sites - Common use of infrastructure for test regions regarding automated driving -
auto.Bus - Seestadt (National Austrian Funding) *2017-2020*	https://www.ait.ac.at/en/research-fields/integrated-mobility-systems/projects/autobus-seestadt/	- The findings of the project will be: (a) robustness through the use and fusion of modern image processing technology, (b) trust and acceptance-building interactions with passengers and other road users as well as their impact, and (c) planning and design principles. - These findings form the central prerequisites to enable a successful use of autonomous buses for public transport covering tomorrow's mobility needs.

Further list of projects can be found in Annex of Automated Driving Roadmap document from ERTRAC available at: https://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf