Levitate Project

Societal Level Impacts of Connected and Automated Vehicles

Final Technical Report

PU

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

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Executive Summary

Summary

The Levitate project

- has a focus on cities and is helping administrations achieve policy goals against a background of increasing automation
- has analysed the impact of the introduction of CAVs onto EU roads
- has developed methods to forecast the impacts of CAV technologies and services
- has applied the methods to ‘hot topics’ proposed by the cities
- has developed a new policy support tool to provide policymakers with the best forecasts for their city
- has developed a toolbox of methods that can be used widely

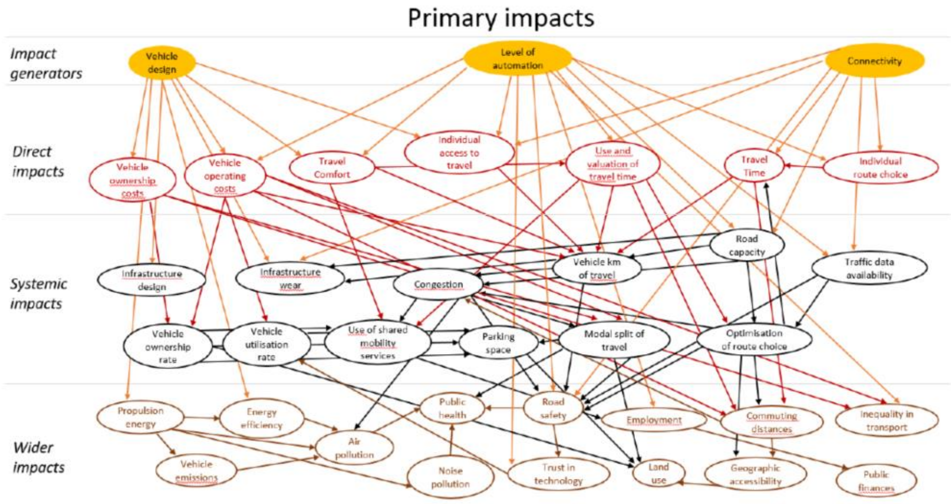
Background

Increasing deployment of connected mobility technologies and the prospect of highly automated vehicles in use has raised the public expectations of major benefits to society. Safety, mobility, transport efficiency and wider societal benefits are all expected once connected and automated vehicles (CAVs) become widespread. As well as benefits that derive directly from the deployment of these technologies there are also the benefits from services that are enabled by the availability of connectivity and automation.

There is already a considerable body of research that focuses on the safe operation of automated vehicles and the development of effective mobility services, however there is very little knowledge about the wider impacts on society and on cities in particular. The Levitate project has therefore been established to develop a new body of evidence to enable cities to identify opportunities where CAVs can support policy goals and also to identify potential negative impacts that cities may need to address through new interventions.

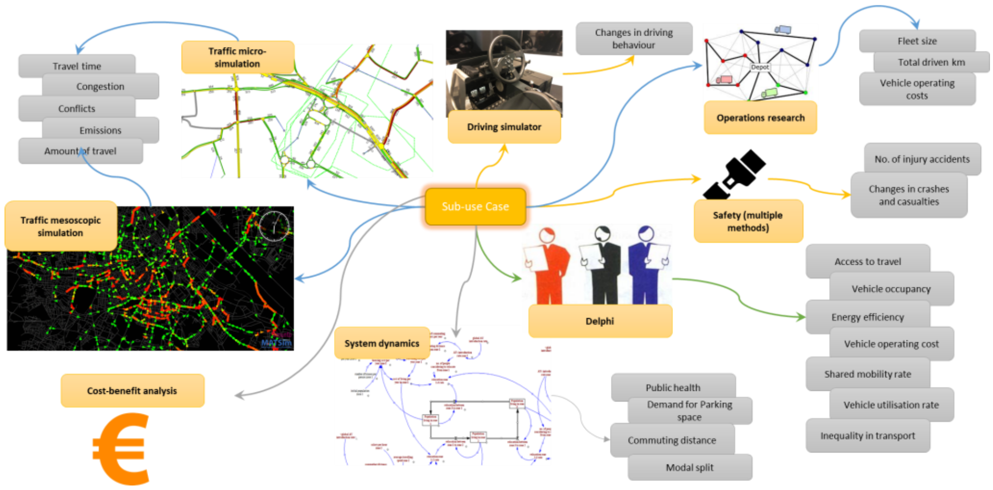
There is a wide range of impact dimensions that are a consequence of connected and automated mobility services and these may have considerable levels of interaction and inter-dependency as shown below. Within the Levitate project these are classified into three groups

- Direct impacts - noticed on each trip and corresponding to short-term impacts
- Systemic impacts – observed across the transport system and corresponding to medium term impacts
- Wider impacts – observed across wider society and corresponding to long-term impacts



23 primary impacts have been identified that may be used to measure these direct, systemic and wider impacts. Each can be defined quantitively and has a suitable analytic underpinning to enable forecasting.

No single method is available to enable all of these 23 impacts be forecast simultaneously so a toolbox of methods was deployed to enable specific CCAM technologies and services to be evaluated. The methods and impacts are illustrated below.



The analytic approach involved several challenges to be overcome in order to conduct impact forecasts. Most importantly, there are no automated vehicles driving in large fleets in general traffic, so no data is available to define the specific driving parameters to be used in the simulation procedures. The SAE levels of Driving Automation (SAE 2021) describe functional capabilities, not driving characteristics so are not helpful in this case. The characteristics of human drivers, which are well known, were therefore used as a benchmark to define two categories of CAV, first generation CAVs which are less capable than human drivers and second generation CAVs which are more capable. These were the basis of the simulation models.

Much of the previous research into the impacts of CAVs has focused on direct traffic indicators and has used small scale, artificial road networks which are suitable for comparisons of technologies but are not able to supply quantitative impact assessments that have real-world relevance. Therefore, the simulation approaches used in the project all utilized validated city networks including Vienna, Greater Manchester, Athens, and Santander.

The needs of the cities were at the heart of Levitate enabling the project team to identify the most important impact dimensions as well as the key CCAM technologies and services which were distributed across three Use Cases and 14 sub-use cases as shown in the table below. Each of these sub-use cases was evaluated against several possible deployment methods.

Use case	Sub-use cases				
Urban mobility	Single point to point shuttle	Point to point shuttle across wide area	On demand anywhere to anywhere shuttle	On demand last mile shuttle	On demand e-hailing service
Passenger cars	Dedicated lanes for CAVs	Road use pricing	Parking space regulations	Automated ride sharing	Green light optimal speed advisory
Freight and logistics	Automated urban delivery	Automated freight consolidation	Hub to hub automated transport	Platooning on urban bridges	

While the supporting cities in the project's Stakeholder Reference Group required forecasts of the CCAM impacts they also wished to understand better how to use the technologies to achieve their policy goals. A backcasting approach was therefore developed that would enable cities to identify the best combination of CCAM services and technologies that would maximise the key impact indicators relevant to their goals.

The impact forecasts for the 14 sub-use cases generated a large amount of data which is fully reported in the project deliverables. To facilitate access and to enable a level of customization a new Policy Support Tool (PST) has been developed that enables cities and other stakeholder groups to access the results in a meaningful way and to customize them to increase the relevance to the user's city. The PST brings together all of the project results in single web-based tool (ccam-impacts.eu) and incorporates the active estimator, backcasting and cost-benefit modules with a knowledge base and summaries of the tools deployed in the project.

Policy recommendations: The main conclusions and recommendations from the forecasts and analyses undertaken in the project are:

- Future CCAM services and technologies may have a mixture of positive and negative societal impacts. Policy measures should be based on a full impact assessment in order to identify improved opportunities to achieve city policy goals or set measures to mitigate negative impacts.

- In the early phases of CAV deployment with a mixed fleet of automated vehicles and vehicles with human drivers in the transport system can result in marginal decrease and in some cases increased conflicts and collisions.
- As advanced automated vehicles form the largest part of the vehicle fleet, it is anticipated that crash rates will reduce substantially below the current levels.
- Early generations of automated vehicles, which operate below the level of human driven vehicles with increased headways, highly cautious sensitivity to the detection of other road users– so increased stops - and therefore slower travel and increased delays, are expected to reduce the capacity of cities for traffic.
- Several policy measures that have been examined can bring positive environmental impacts; however, powertrain electrification has an overwhelmingly larger impact on emissions compared to the studied policy interventions
- Commonly any improvement in passenger car mobility through the increased automation will reduce the use of public transport and active travel.
- The Levitate project has shown the benefits of conducting detailed impact forecasts based on a broad spectrum of modelling methods. The methods can be applied to other CCAM interventions and can also be adapted to evaluate real-world trials of CCAM services and technologies.

1 Project objectives

Connected, cooperative, and automated mobility (CCAM) services and technologies are expected to be introduced in increasing numbers over the next decade. Automated vehicles have attracted the public imagination and there are high expectations in terms of safety, mobility, environmental benefits and economic growth. With such systems not yet in widespread use, there is a lack of data and knowledge about impacts.

Furthermore, the potentially disruptive nature of highly automated vehicles makes it very difficult to determine future impacts from historic patterns. Estimates of future impacts of automated and connected mobility systems may be based on forecasting approaches, yet there has been no agreement over the methodologies nor the baselines to be used. The need to measure the impact of existing systems as well as forecast the impact of future systems represents a major challenge.

Finally, the dimensions for assessment are themselves very diverse, including safety, mobility and environment but with many sub-divisions adding to the complexity of future impact forecasts.

The aim of the LEVITATE project, illustrated in Figure 1.1, 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.

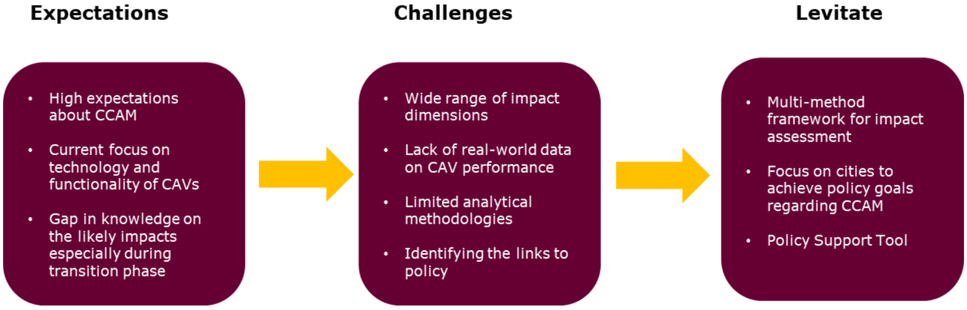


Figure 1.1: Motivation and scope of the LEVITATE project

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 had four key objectives:

1. To establish a multi-disciplinary methodology to assess the short, medium, and long-term impacts of CCAM on mobility, safety, environment, society, and other impact areas. Several quantitative indicators will be identified for each impact type
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 apply the methods and forecast the impact of CCAM 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.
4. To incorporate the established methods within a new web-based policy support tool to enable city and other authorities to forecast impacts of CCAM 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 CCAM measures that will result in their desired policy objectives.

2 Analytic framework development

2.1 Associated deliverables

Table 2.1: List of deliverables that contributed to section 2.1.

D3.1	A taxonomy of potential impacts of connected and automated vehicles at different levels of implementation	This deliverable presents a taxonomy of potential impacts of connected and automated transport systems (CATS) at different levels of implementation. The taxonomy is based on a systematic review of recent studies that have proposed taxonomies of impacts of CATS.	Identification and classification of impacts is necessary for developing methods for assessing and predicting the impacts of CCAM.

2.2 Background

Developing methods for assessing and predicting the impacts of CCAM involved the following main stages:

1. Identification and classification of the impacts of connected and automated driving
2. Description and measurement of the impacts of connected and automated driving
3. Development of methods of backcasting and forecasting of the impacts of connected and automated driving
4. Evaluation of comparability and amenability to monetary valuation of the impacts of connected and automated driving
5. Method for analysing the costs and benefits of connected and automated driving
6. Methods for generating options and scenarios for policy at the city level with respect to the introduction of connected and automated driving

It is envisaged that forecasting will concentrate on those impacts that are regarded as most important and relevant from the stakeholder perspective of policy makers.

With regard to identifying potential impacts of CCAM, a wide net was cast through the available knowledge in the literature and the causal pathways connecting these impacts to each other.

The overview of the project components and workflow is shown in Figure 2.1

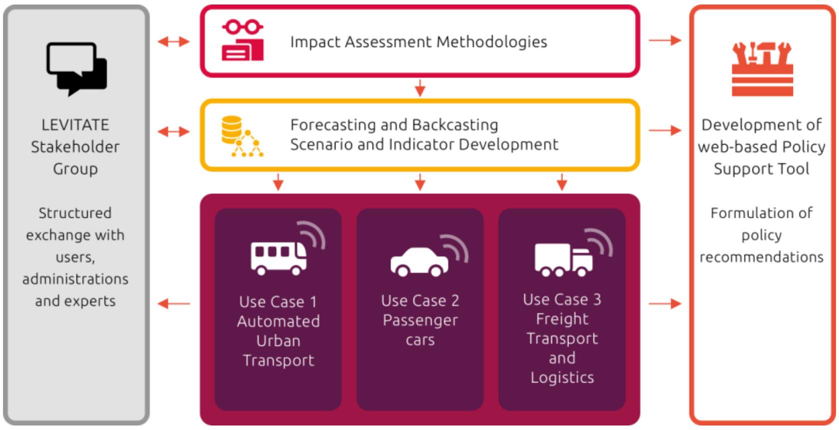


Figure 2.1: Overview of project components and workflow

2.3 Impact Dimensions

A taxonomy of potential impacts of CCAM, at different levels of implementation, was established in the project (Elvik et al., 2019) on the basis of a systematic review of recent studies that have proposed taxonomies of impacts of CCAM. It is illustrated in Figure 2.2 and there is considerable overlap among the lists of impacts presented by the studies, suggesting a high level of scientific consensus about the potential impacts of CCAM.

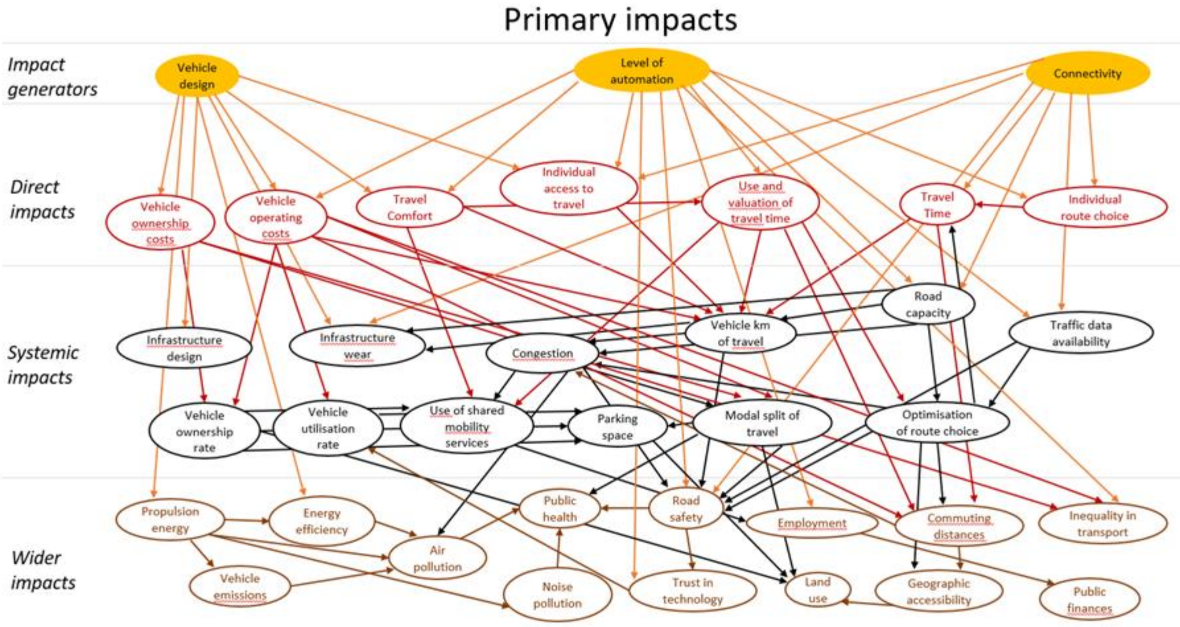


Figure 2.2: Taxonomy of impacts generated by transition to connected and automated vehicles (LEVITATE D3.1, Elvik et al., 2019)

A distinction is made between direct, systemic and wider impacts. Direct impacts are changes that are noticed by each road user on each trip. Systemic impacts are system-wide impacts within the transport system. Wider impacts are changes occurring outside the transport system, such as changes in land use and employment. Figure 2.3 below presents an overview of the list of impacts considered in the project.

Figure 2.3: Impacts dimensions of CCAM studied within LEVITATE
Direct (inner circle), systemic (middle circle), and wider (outer circle) impacts

Furthermore, a distinction is made between primary impacts and secondary impacts. A primary impact is an intended impact and goes in one direction only; it emanates from the automation technology and has a well-defined outcome. A secondary impact (rebound impact; behavioural adaptation) is generated by a primary impact and feeds back to the source of the primary impact. An example is that reduction of travel time as a result of less congestion tends to induce more traffic, which in turn increases congestion (although not necessarily back to the original level).

Some impacts are nested within each other. For example, lower operating costs, improved travel comfort and reduced travel time all contribute to reducing the generalised costs of travel. Table 2.2 further provides the description on each impact variable.

Table 2.2: Description of impact variables

Impact	Description
Travel time	Average duration of a 5Km trip inside the city centre
Vehicle operating cost	Direct outlays for operating a vehicle per kilometre of travel
Freight Transport Cost	Direct outlays for transporting a tonne of goods per kilometre of travel
Access to travel	The opportunity of taking a trip whenever and wherever wanted (10 points Likert scale)
Congestion	Average delays to traffic (seconds per vehicle-kilometre) as a result of high traffic volume
Amount of travel	Person kilometres of travel per year in an area
Modal split using public transport	% of trip distance made using public transportation
Modal split using active travel	% of trip distance made using active transportation (walking, cycling)
Shared mobility rate	% of trips made sharing a vehicle with others
Vehicle utilisation rate	% of time a vehicle is in motion (not parked)
Vehicle occupancy	average % of seats in use
Truck Platooning	Impacts of truck platooning on highway bridges
Road safety	Number of traffic conflicts per vehicle-kilometre driven (temp. until crash relation is defined).
Parking space	Required parking space in the city centre per person (m2/person)
Energy efficiency	Average rate (over the vehicle fleet) at which propulsion energy is converted to movement
NO_x due to vehicles	Concentration of NOx pollutants as grams per vehicle-kilometre (due to road transport only)
CO_2 due to vehicles	Concentration of CO2 pollutants as grams per vehicle-kilometre (due to road transport only)
PM10 due to vehicles	Concentration of PM10 pollutants as grams per vehicle-kilometre (due to road transport only)
Public health	Subjective rating of public health state, related to transport (10 points Likert scale)
Accessibility in transport	The degree to which transport services are used by socially disadvantaged and vulnerable groups including people with disabilities (10 points Likert scale)
Commuting distances	Average length of trips to and from work (added together)

2.4 Identified Policy Interventions and Analysis Scenarios

Several potential policy interventions (named as sub-use cases) to support or mitigate policy goals based on impacts of CCAM were identified through meetings with the stakeholders. In this regard, a stakeholder reference group (SRG) workshop, detailed in D 6.1 (Boghani et al., 2019) was conducted where consultation was obtained from the experts from city administrations and industry on the generation and prioritization of the sub-use cases. Within LEVITATE, this list has been prioritized and refined within subsequent tasks in the project to inform the interventions and scenarios related to passenger, urban, and freight transport. In turn, these policy interventions have been included in the LEVITATE Policy Support Tool (PST).
The prioritisation of the sub-use cases mainly took these three input directions into account:

- Scientific literature: Indicating the scientific knowledge and the available assessment methodologies for the sub-use cases. However, this might not be directly linked to their importance / relevance for practice.
- Roadmaps: Indicating the relevance of sub-use cases from the industrial/ political point of view, independent of available scientific methodologies.
- SRG Workshop: Containing first-hand feedback for the sub-use cases but might only reflect the opinions of organisations and people who participated.
- Results of the backcasting city dialogues conducted in LEVITATE WP4 for Vienna, Greater Manchester, and Amsterdam (Zach, Sawas, Boghani, & de Zwart, 2019; Papazikou et al., 2020a).

Considering the suggestions from SRG and existing knowledge through literature, the following sub-use cases have been defined within the project based on the transport mode.

Passenger Transport

- Road use pricing (RUP)
- Provision of dedicated lanes (DL) on urban highways
- Parking price polices
- Parking space regulations
- Automated ride sharing (ARS)
- Green light optimal speed advisory (GLOSA)

Urban Transport

- Point-to-Point Automated Urban Shuttle Service (AUSS)
- On-demand AUSS

Freight and Logistics

- Automated urban delivery
- Automated consolidation
- Hub-to-Hub automated transport
- Platooning on urban highway bridges

2.5 Methods within Levitate

It was envisaged that a broad range of methods must be used in order to adequately quantify as many of the potential impacts as possible. The types of impacts that are presented in LEVITATE Deliverable 3.1 (Elvik et al., 2019): A taxonomy of potential impacts of connected and automated vehicles at different levels of implementation (Elvik et al., 2019) have been estimated and forecast using appropriate assessment methods including;

- **Microscopic simulation**
- **Mesoscopic simulation**
- **Surrogate Safety Assessment Method**
- **System Dynamics**
- **Operations Research**
- **Delphi Panel Study**
- **Bridge Modelling**
- **Cost-Benefit Analysis**

Additionally, a **backcasting method** was also used to identify the potential policy measures that would lead to a desired future.

Traffic simulation can directly provide short-term impacts. Therefore, it (microscopic and mesoscopic simulation) was used to forecast short-term impacts regarding dose (in terms of introduction of sub-use case) and response (selected impact). Traffic simulation also provides further input to assess other types of impacts by processing those results appropriately to infer such impacts, such as safety impacts through identification of traffic conflicts which involves processing of vehicular trajectories through a surrogate safety assessment model.

System level analysis (such as by tools found within system dynamics) can be used to measure long-term impacts. For the sake of simplicity and applicability of assessment methods, it is assumed that for the appropriate level of automation, adequate infrastructure exists. It is also assumed that the pure technological obstacles for the sub-use cases in consideration are solved. All results relating to the relationships between sub-use cases, impacts and any intermediate parameters have been used for the development of the LEVITATE Policy Support Tool (PST). The results are integrated within the PST modules and functionalities so that impact assessment can be carried out by the user.

Figure 2.4 presents an overview of various methods used within the project to estimate the various impact indicators.

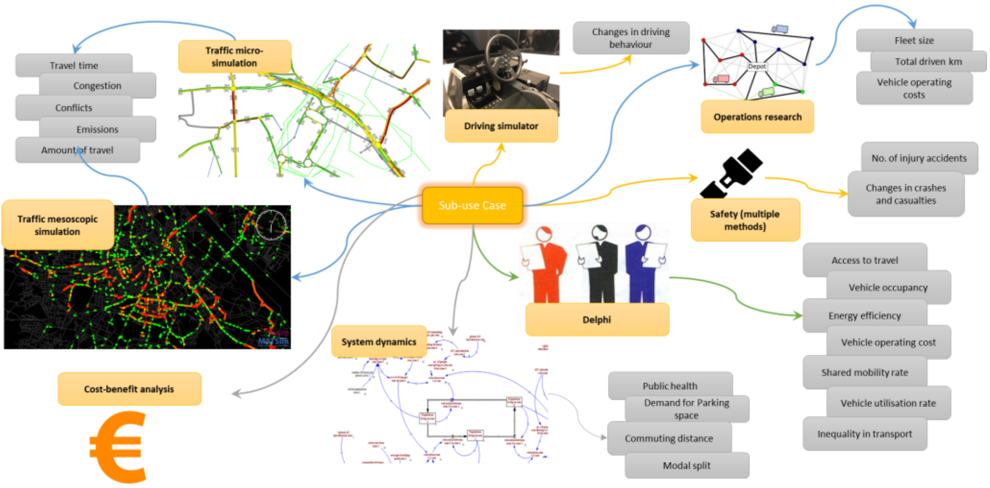


Figure 2.4: Multi-method framework within LEVITATE

2.4.1 CAV Parameters

With incremental development towards perfection in automation, the concept of first and second generation systems was introduced in traffic simulation modelling. Both types are assumed to be fully automated vehicles with level 5 automation. The main idea behind modelling these two types is based on the assumption that technology will advance with time. Therefore, 2nd Gen CAVs will have improved sensing and data handling capabilities, decision making, driver characteristics, and anticipation of incidents etc. In general, the main assumptions on CAVs characteristics are as follows:

- 1st Generation: Sensing and computational capability is limited. These vehicles are considered to be conservative in their driving characteristics whereby they leave larger gap, have higher anticipation of lane change and incidents etc. (relating to connectivity) than human driven vehicles and takes more time during give way situations.
- 2nd Generation: Sensing and computational capability is advanced, can use data fusion and is more confident in taking decisions. These vehicles are considered to appear more aggressive in their driving characteristics whereby they leave smaller (compared to human driven vehicles) headway to preceding vehicle, have higher anticipation of lane change or incidents etc. (relating to connectivity) than human driven vehicles and 1st Generation CAVs, and takes less time during give way situations.

It is considered that all AVs will be connected. Decision-making by using information received using connectivity in 1st generation would be limited so some behaviours will be limited due to this. 2nd generation vehicles are considered to be advanced in decision-making by using information using connectivity and so, this will be reflected in their driving behaviours. The CAV driving behaviours developed in the LEVITATE project are presented in detail in Chaudhry et al., 2022.

3 Main findings

3.1 Associated deliverables

Table 3.1: List of deliverables that contributed to Section 3..

D5.1	Defining the future of urban transport	Selection and definition of the most suitable and realistic sub-use cases to forecast the impacts of CCAM on urban transport, based on an extensive literature review and on the stakeholders workshop findings	The selection and definition of the sub-use cases defines the scope of the research that is carried out in the whole WP.
D5.2	Short-term impacts of CCAM on urban transport	Analysis and assessment for the short-term impacts of the different urban transport sub-use cases. The studied impacts are travel time, vehicle operating cost and access to travel, and the assessment methods used are the mesoscopic simulation and the delphi.	The results of the short-term impacts are used for the development of the PST estimator module and for the policy recommendations in D5.5.
D5.3	Medium-term impacts of CCAM on urban transport	Analysis and assessment for the medium-term impacts of the different urban transport sub-use cases. The studied impacts are amount of travel, congestion, modal split, shared mobility rate, vehicle utilisation rate and vehicle occupancy. The impact assessment methods used are mesoscopic simulation, microscopic simulation and delphi.	The results of the medium-term impacts are used for the development of the PST estimator module and for the policy recommendations in D5.5.
D5.4	Long-term impacts of CCAM on urban transport	Analysis and assessment for the long-term impacts of the different urban transport sub-use cases. The studied impacts are road safety, parking space, energy efficiency, emissions, public health, accessibility of transport and commuting distance. The impact assessment methods used are microscopic simulation, road safety method, delphi and system dynamics.	The results of the long-term impacts are used for the development of the PST estimator module and for the policy recommendations in D5.5.
D5.5	Guidelines and recommendations for future policy of automated urban transport	Synthesized results from D5.2, D5.3 and D5.4, augmented with outcomes from WP3 and WP4.	The synthesis of results is used for the policy recommendations in D8.4 and the Levitate Policy Recommendations Brochure.
D7.1	Defining the future of freight transport	Selection and definition of the considered sub-use cases in freight transport based on literature review, roadmap and stakeholder engagement.	The selection of the sub-use cases defines the scope of the research that is carried out in the whole WP.
D7.2	Short term impacts of CCAM on freight transport	Assessment of short-term impacts of CCAM which are fleet	The results on the short-term impacts are used for

		size, driven km, vehicle operating cost, freight transport costs, and travel time.	the PST estimator in WP8 and the the policy recommendations in D7.5
D7.3	Medium term impacts of CCAM on freight transport	Assessment of medium-term impacts of CCAM which are congestion and the impacts of platooning on urban highway bridges.	The results on the medium-term impacts are used for the PST estimator in WP8 and the the policy recommendations in D7.5
D7.4	Long term impacts of CCAM on freight transport	Assessment of long-term impacts of CCAM which are were road safety, emissions, parking space, energy efficiency, and public health.	The results on the long-term impacts are used for the PST estimator in WP8 and the the policy recommendations in D7.5
D7.5	Guidelines and recommendations for future policy of cooperative and automated freight transport	Synthesized results from D7.2, D7.3, and D7.4, augmented with outcomes from WP3 and WP4.	Synthesis of results are used for the policy recommendations in D8.4 and the Levitate Policy Recommendations Brochure.

3.2 Findings on Urban mobility NTUA

In order to assess the introduction of CCAM in the urban transport, three sub-use cases have been studied. The point-to-point automated urban shuttle service (AUSS) connecting two modes of transport, the point-to-point AUSS in a large scale network and the AUSS on-demand, which includes the anywhere-to-anywhere, the last-mile and the e-hailing services. The results of the automated urban transport impact assessment are presented in in detail in deliverables 5.2 (Roussou et al., 2021a), 5.3 (Roussou et al., 2021b) and 5.4 (Roussou et al., 2021c). A synthesis of these results is presented in deliverable D5.5 (Goldenbeld et al., 2021).

Regarding the impacts on the environment, within LEVITATE, four indicators were used to measure these impacts: carbon dioxide (CO_2) emissions, nitrous oxide (NO_x) emissions, particulate matter (PM_{10}) emissions, and energy efficiency. The results are shown in Table 3.2 Based on the Delphi expert consultation the expected impacts of the "point-to-point" and "on-demand" AUSS on energy efficiency are positive. According to the experts consisting the Delphi panel, both forms of AUSS are expected to have an additional benefit for energy efficiency compared to increasing automation alone (Baseline) and the point-to-point AUSS is expected to have a larger impact than the on-demand AUSS. Of the scenarios of on-demand AUSS considered in the Delphi study: Anywhere-to-anywhere shuttles are expected to offer the largest improvement to energy efficiency at a level similar to point-to-point shuttles (22% increase at 0-0-100), Last-mile shuttles are expected to have the least positive effect on energy efficiency, slightly lower than the Baseline (12% increase at 0-0-100). Therefore, experts expect the environmental impact of an automated urban shuttle service to depend largely on its form of implementation and the types of trips the shuttles replace. The microsimulation results on emissions, have shown that the Baseline scenario will lead to large reductions in CO_2 emissions (-40%) when the share of first generation automated vehicles is at 40% and larger reductions (of-64% to 97%) when the share of second generation vehicles is above 20%. The expected improvement in lowering CO_2 emissions due to introduction of connect and automated vehicles is expected to be large due to the assumption that automated vehicles will also be electric vehicles. However, neither point-to-point nor on-demand shuttle services are predicted to have a large added benefit in terms of lowering CO_2

emissions when compared to the autonomous introduction of connected and automated vehicles (Baseline).

Table 3.2: Estimated impacts of automated urban shuttle services (AUSS) on CO2 emissions and energy efficiency: Delphi and microsimulation results.

Measured in terms of percentage change with respect to the Baseline 100-0-0 scenario

		Deployment scenarios: Market penetration rate of CAVs in entire vehicle fleet (Human-driven vehicle - 1st Generation CAV - 2nd Generation CAV)								
		100-0-0	**80-20-0**	**60-40-0**	**40-40-20**	**20-40-40**	**0-40-60**	**0-20-80**	**0-0-100**	
Impact	**Sub-use Case**	%	%	%	%	%	%	%	%	**Method**
Energy efficiency	Baseline (no AUSS)	0,0	3,0	7,1	8,4	15,7	14,1	14,1	14,1	Delphi (expert survey)
	Point-to-point AUSS	0,0	4,2	8,4	15,6	20,8	21,1	21,1	21,1	
	On-demand AUSS	0,0	4,0	5,9	9,5	13,8	16,7	16,7	16,7	
CO2 emissions	Baseline (no AUSS)	0,0	-16,7	-40,2	-64,3	-81,2	-97,2	-95,5	-95,3	Micro-simulation (Athens)
	Point-to-point AUSS	-0,1	-16,8	-40,3	-64,3	-81,2	-97,2	-95,5	-95,3	
	On-demand AUSS	0,8	-17,1	-40,6	-64,5	-81,2	-97,2	-95,4	-95,3	

Regarding the impacts on mobility, in Levitate, the mobility impacts (indicators) examined are: travel time, access to travel, amount of travel, congestion, modal split using active travel, modal split using public transport, vehicle utilization rate, vehicle occupancy, shared mobility rate. Based on the Delphi panel feedback, in the baseline situation, access to travel improves by 19% once second-generation automated vehicles comprise 20% of the vehicle fleet. This increases to 31-34% when the share of second-generation vehicles increases to more than 40% of the fleet. Compared to the baseline, both point-to-point and on-demand AUSSs will further improve access to travel across all CCAM penetration levels. At lower penetration levels, the estimated effect is similar for both AUSS cases but, at the highest three penetration levels, the point-to-point AUSS shows larger estimates of improvement in access to travel. In all cases, AUSS improves access to travel when compared to the baseline scenario. The experts indicate that AUSSs will improve access to travel between 1% and 15% depending on the level of first- and second-generation CCAM penetration rates. Of the on-demand scenarios considered the largest increase in access to travel was expected for anywhere-to-anywhere shuttles and the least for last-mile shuttles.

The impacts on total kilometres travelled and congestion levels were estimated using AIMSUN microsimulation software. The impacts on total kilometres travelled show a complex pattern: according to the baseline development, the total kilometres travelled in the simulated network will increase, although it briefly decreases when second-generation CAVs are first introduced. Once the second-generation CAVs reach penetration levels of 80% to 100%, the total kilometres covered in the network again increase. This development is related to the microsimulation outcomes which suggest that mixed traffic—including human-driven, first- and second-generation CAVS—leads to increased delays due to a less efficient traffic flow. Therefore, during any given simulation period, fewer trips (and fewer network kilometres) can be completed when compared to other mixes where traffic is more homogeneous. The sub-use cases have little additional impact on the development of total kilometres travelled in the network compared to the Baseline, due to the fact that travel demand remains constant across sub-use cases. The exception is with the introduction of on-demand AUSS in a situation of 100% human driven vehicles. Because the automated on-demand shuttles are modelled to cover 5-10% of the total travel demand, depending on the scenario, their introduction into the network has a similar effect to the Baseline 80-20-0 scenario in which 20% of the vehicle fleet becomes automated. Due to a more efficient traffic flow compared to the Baseline 100-0-0 scenario, more trips are able to be completed in one simulation period. As automation of private vehicles increases in the on-demand scenario, however, the difference between on-demand AUSS and the Baseline or point-to-point SUC become minimal.

The microsimulation results for the impacts on congestion show that congestion will be reduced (9-12% reduction) in the Baseline scenario when 1st generation CAVs take up between 20-40% of the vehicle fleet, and may be further reduced (42-45%) when 2nd generation CAVs become dominant. The point to point AUSS has little additional effect on congestion levels, but the on-demand AUSS shows a further reduction in congestion levels compared to Baseline at low penetration rates. This echoes the results of total kilometres travelled, which suggest that implementation of the on-demand AUSS results in a more efficient traffic flow compared to a largely human-driven Baseline most likely due to two factors: a shift in trips from mostly human-driven vehicles to automated shuttles, as well as the shift from private vehicles to a form of shared transport. Regarding the point-to-point SUC scenarios, the presence of a dedicated shuttle lane had negligible impacts on both the total kilometres travelled and congestion. Only the off-peak hour simulations showed lower levels, due to the reduced amount of traffic on the network. The on-demand SUC scenarios also showed little variation across the different shuttle capacities (8 vs. 15) and shares of demand (5% vs. 10%), with slightly larger effects observed for the 10% demand served scenarios.

Mesosimulation was used to estimate impacts of two types of on-demand AUSS on average travel time, amount of travel, modal split and vehicle utilization and occupancy rates. The average travel time for all vehicles in the network appears not to change much for the Baseline development and the last-mile sub-use case. Compared to the Baseline scenario, the introduction of anywhere-to-anywhere AUSS is associated with a substantial reduction in average travel time (6-9%). This reduction increases as the proportion of human-driven vehicles decreases and first and second generation automated vehicles increases. The effects of anywhere-to-anywhere shuttles on average travel time also changed in scale depending on fleet size, with a slightly larger effect observed in the larger fleet size scenario compared to the smaller fleet size scenario. The results concerning the modal split impacts (active modes, public transport, automated urban shuttle service AUSS) indicate that the estimated baseline development is a gradual modest reduction in public transport use (from 52% to 49%) and a more or less stable use of active modes of travel (8.1% - 8.3%). The last-mile and anywhere-to-anywhere urban shuttle services can each take up a share of about 2%-3% of trips travelled in the inner city. The last-mile shuttle service is associated with shares of active travel that are about two percentage points higher than under baseline conditions; the anywhere-to-anywhere shuttle service corresponds with shares of active travel that are about 1.5 percentage point higher compared with baseline. For both last-mile and anywhere-to-anywhere, their modal share is expected to be slightly higher for the larger fleet size scenarios.

For the vehicle utilisation and occupancy rate impacts of automated urban shuttles, a meaningful baseline is not applicable since these rates only apply to the shuttle vehicles themselves. The last-mile shuttle service is expected to remain relatively constant across different penetration rates of automated vehicles in the city's vehicle fleet; anywhere-to-anywhere shuttles are expected to decrease slightly as vehicle automation rates increase. Both vehicle utilization rate and occupancy rate are expected to be slightly lower in the scenarios implementing larger shuttle fleets.

Estimates of the impacts on society and economy (namely vehicle operating cost, parking space, public health and equal accessibility of public transport) were derived from the Delphi consultation results and are shown in Table 3.3. For the Baseline condition, experts indicated that an increasing penetration of connected and automated vehicles would lead to:

- A reduction of in vehicle operating costs (8-10% less) and required parking space (18-21% less), especially at or above a market penetration rate of 80% automated vehicles (from 20-40-40).
- An improvement in public health (2%-4%) when the share of automated vehicles is 60% or larger (from 40-40-20).
- The expected improvement in equal accessibility to transport in the baseline condition becomes more substantial (19-23% increase) as penetration rates of automated vehicle exceed 80% (from 20-40-40).

Compared to the Baseline development, the introduction of a point-to-point shuttle service is expected to deliver the following:

- Additional vehicle operating cost savings of between 8-12% compared to the Baseline
- Negligible difference in parking space requirements when compared to the Baseline
- Further improvement to public health by an additional 8% compared to the Baseline
- A slightly (albeit barely noticeable) negative impact on the equal accessibility of transport

Compared to the Baseline development, the on-demand AUSS is not expected to generate additional positive outcomes in terms of lowering vehicle operating costs, reducing required parking space or improving equal access to transport, but it is expected to lead to modestly better public health outcomes. Of the on-demand scenarios considered in the Delphi study, the following differences are notable:

- Vehicle operating cost: larger reduction expected for anywhere-to-anywhere shuttles than for last-mile or e-hailing
- Public health: slightly larger improvement expected for e-hailing
- Equal accessibility of transport: anywhere-to-anywhere expected to perform best for accessibility (9% improvement) while last-mile and e-hailing not expected to improve accessibility (-1% change)

In summary, the Delphi consultation process reveals that the automated point-to-point shuttle service is expected to deliver extra (benefits above the baseline development) social and economic benefits for the city in terms of additional lower vehicle operating costs, less parking space and better public health. The on-demand shuttle service is not believed to generate extra benefits apart from a slightly improved public health, and for an anywhere-to-anywhere service, slight improvements to accessibility and vehicle operating costs.

Table 3.3: Estimated impacts of automated urban shuttle services (AUSS) on society and economy, measured in terms of percentage change with respect to the Baseline 100-0-0 scenario and percentage of travel demand

		Deployment scenarios: Market penetration rate **of CAVs** in **entire** vehicle fleet (Human-driven vehicle - 1st Generation CAV - 2nd Generation CAV)								
		100-0-0	**80-20-0**	**60-40-0**	**40-40-20**	**20-40-40**	**0-40-60**	**0-20-80**	**0-0-100**	
Impact	**Sub-use Case**	%	%	%	%	%	%	%	%	**Method**
Vehicle operating cost	Baseline (no AUSS)	0,0	-2,7	1,1	-1,8	-8,3	-10,3	-10,3	-10,3	Delphi (expert survey)
	Point-to-point AUSS	0,0	-4,5	-6,2	-11,8	-15,7	-21,6	-21,6	-21,6	
	On-demand AUSS	0,0	0,4	-0,9	-2,8	-4,9	-7,6	-7,6	-7,6	
Parking space required	Baseline (no AUSS)	0,0	-2,5	-5,5	-14,2	-17,7	-21,1	-21,1	-21,1	Delphi (expert survey)
	Point-to-point AUSS	0,0	0,2	-5,2	-12,3	-17,8	-22,2	-22,2	-22,2	
	On-demand AUSS	0,0	-1,3	-4,0	-9,9	-13,9	-16,4	-16,4	-16,4	
Public health	Baseline (no AUSS)	0,0	1,0	1,0	3,6	2,2	4,1	4,1	4,1	Delphi (expert survey)
	Point-to-point AUSS	0,0	-0,2	3,7	5,0	8,0	11,9	11,9	11,9	
	On-demand AUSS	0,0	1,9	4,5	4,8	4,4	5,9	5,9	5,9	
Equal accessibility of transport	Baseline (no AUSS)	0,0	4,4	9,7	13,9	19,2	22,5	22,5	22,5	Delphi (expert survey)
	Point-to-point AUSS	0,0	0,3	-3,8	2,0	-3,0	-4,4	-4,4	-4,4	
	On-demand AUSS	0,0	-0,2	-0,2	-2,0	-0,9	2,1	2,1	2,1	

Naturally, the present impact assessment approach adopted within LEVITATE has some limitations. First of all, a certain degree of uncertainty is underlying in every method, while this quantity is inherently different for each method. Additionally, each quantitative method has different parameters and is applied in a different city model, for example the mesoscopic simulation is using the MATSim model for Vienna and the microscopic simulation considers the AIMSUN model for Athens, partly due to the resources in which the LEVITATE partners had access to. Regarding the Delphi method, limitations are posed by the number of experts, and the accuracy of their estimations. Thus, the Delphi results will be used to fill in the PST when no other method can provide outputs. Approaches such as Delphi can be updated when the CCAM reach increased maturity and revisited for future efforts either in projects such as LEVITATE or in broader research. Furthermore, all methods are bound to specific MPR scenarios, with the aim to create a functional PST, and thus the results lack degrees of freedom they might otherwise have. Finally, another limitation of the LEVITATE project is that there was enough capacity to examine only two CAV profiles, even though it is probable that much more granular CAV profiles will function in the future network. Ultimately, the PST user will be informed regarding transferability of results and will be able to receive an educated estimate of how to use these results for CCAM-related predictions or design.

3.3 Findings on Passenger Cars LOUGH

From the stakeholder reference group (SRG) workshop, detailed in D6.1(Boghani, 2019), consultation was obtained from the experts from city administrations and industry on the generation and prioritization of the sub-use cases. Within LEVITATE, this list was prioritized and refined within subsequent tasks in the project to inform the interventions and scenarios related to passenger transport. In turn, these SUCs were included in the LEVITATE Policy Support Tool (PST).

Considering the suggestions from Stakeholder Reference Group (SRG) and existing knowledge through literature, six key sub-use cases were defined within passenger transport use case, which are as follows:

1. Road use pricing (RUP):
2. Provision of dedicated lanes for AVs on urban highways
3. Parking price policies
4. Parking space regulation
5. Automated ride sharing, and
6. Green Light Optimal Speed Advisory (GLOSA)

The following sub-sections present key findings on various societal impacts, while the detailed analyses and discussions can be found in LEVITATE deliverables D6.2, 6.3, 6.4, and 6.5 (Haouari et al., 2021; Sha et al., 2021; Chaudhry et al., 2021; Gebhard et al., 2022).

2.2.1 Road Use Pricing

Road use pricing is expected to lead to a number of additional benefits over the baseline impacts: better energy efficiency (dynamic toll more than static toll or empty km pricing), less reduction in the use of active modes and public transport, higher vehicle occupancy rate, and lower parking space demand. On the negative side, road use pricing is expected to lead to increase in vehicle operating costs, and less equal accessibility of transport. The scenario "empty km pricing" is expected to contribute more positively towards keeping vehicle operating costs within bounds compared to the "static toll" and "dynamic toll" scenarios. The "static toll" scenario is expected to result in the highest shares in active transport modes and public transport. The "dynamic toll" scenario is expected to lead to the highest vehicle occupancy rates.

Environment

The Delphi results indicate that under the road use pricing, the "dynamic toll" scenario is estimated to further improve energy efficiency the most at all penetration levels. Introducing a dynamic toll in situations where 20-100% of the vehicles are electric CAVs is expected to further improve energy efficiency by 3-17% more than baseline values. Both the static and dynamic tolls are expected to have the most added benefit when human-driven vehicles still make up around half of the vehicle fleet, while empty kilometre pricing is expected to become more beneficial at higher CAV penetration levels.

Travel time

The results indicate that average travel time is higher throughout all penetration levels when a "dynamic toll: €1,4/km" is implemented, and slightly higher when a "static toll: 10 euros" is implemented compared to the baseline. In the baseline scenario, average travel time decreases slightly (up to 0,5%) as CAV penetration rates increase. This is due to travellers choosing to switch from private vehicle transport (which may be the fastest) to another toll-free mode, such as public transport, which may have a slightly longer travel time. The dynamic toll appears to have a stronger effect on this shift than the static toll.

Amount of travel

The amount of travel, defined as the average distance travelled by a person on a weekday, shows a slight decrease in the baseline and "static toll: 10 euros" scenarios as CAV penetration rates increase, while the "dynamic toll: €1,4/km" indicates a small increase in the amount of travel (0,1 and 0,2 %). Neither road use pricing nor the development of CAVs appear to have a large impact on the average distance a person travels on a weekday. Because travel activity patterns (e.g. home – work – home) remain constant, a slight increase due to a modal shift similar to the increase in travel times might be expected; however, it appears that actual distances travelled do not increase with a mode shift as much as travel time does.

Modal Split

Regarding the mode share of public transport, road use pricing is expected to increase public transport use compared to the baseline at every penetration rate of CAVs. While the baseline shows a 17% reduction at full CAV penetration, implementing road use pricing results in only a 2% reduction (and an initial increase of 19% before CAVs)

The introduction of road use pricing to an extent mitigates the negative impact of CAV penetration and seems to stimulate people to walk and cycle. At 0% CAV penetration, the mode shares of active modes after introducing RUP is 13% higher than in the baseline, meaning that initially it increases active mode share when compared to the baseline. As CAV penetration rates increase, the modal share of active modes decreases by only 19%, keeping the share of active mode higher than in the baseline (56% reduction).

Access to travel, shared mobility, vehicle utilisation and occupancy

Road use pricing policies (empty km pricing, static toll, dynamic toll) is also predicted to negatively impact access to travel as compared to the baseline condition. RUP is also indicated by the experts to reduce vehicle utilisation rate than under baseline condition while vehicle occupancy is expected to increase as indicated by the Delphi panel study.

Public Health

Regarding the city toll scenarios, the Delphi results on all tolling scenarios showed some oscillations depending on AVs market penetration rates. However, public health was indicated to improve with the implementation of road use pricing with respect to the baseline scenario (potentially due to increase in active travel) and will also improve in the long term for 100% AVs market penetration rate, which can also be explained by their impact on energy efficiency and emissions.

Accessibility in transport

When compared to the baseline, road use pricing is estimated to negatively impact equal accessibility, especially for a dynamically controlled toll.

Demand for Parking

The system dynamics results on road use pricing implementation showed significant reduction in the demand for parking space significantly, very similar to the parking price policies.

Commuting Distances

The system dynamics model results showed larger commuting distances with the implementation of road use pricing. Even if this might seem surprising, it can be explained in the model due to the fact that also inner-city residents would be subject to road use pricing and might therefore decide to relocate to outer zones (which might not happen in reality if they are exempted). While road use pricing would not help to reduce the commuting distances, it would likely support a switch to other (non-car) modes as shown in D6.3 (Sha et al., 2021).

Vehicle Operating Cost

Regarding road use pricing measures, experts estimate that both static and dynamic toll road use pricing will increase vehicle operating costs over the baseline estimates. Empty kilometre pricing will initially reduce VOC over the baseline but as penetration rates increase the intervention will negate some of the benefits caused by CAV introduction (the reductions are less than in the baseline).

2.2.2 Provision of Dedicated Lanes for CAVs on Urban Highways

Compared to the baseline, dedicated lanes for CAVs do not make a clear difference for emissions, travel time, kilometres travelled, and road safety. On the positive side, dedicated lanes are expected to lead to better access to travel when lanes are "dynamic," slightly reduced congestion in mixed human-driven/CAV traffic, a higher vehicle utilisation rate, higher vehicle occupancy rate, and lower vehicle operating costs. The "dynamic" lanes scenario performs better than the "fixed" lane scenarios in terms of improvements on energy efficiency, access to travel, vehicle occupancy rate, vehicle operating costs, and in terms of a lesser decrease of the active mode share.

Environment

The microsimulation based results on dedicated lanes for CAVs shows that a dedicated CAV-lane does not have much additional benefit in terms of reduced CO_2 emissions when compared to the baseline. As with the baseline, the environmental impacts of increased CAV penetration rate are positive. These results support previous findings in the literature as well in Levitate deliverable 6.4 (Chaudhry et al, 2021).

From Delphi results for dedicated lanes for CAVs, although initially a higher improvement in energy efficiency is observed with the ”dynamic dedicated lane”, at penetration rates higher than 60%, the “fixed dedicate lane” has a slightly higher positive impact on energy efficiency.

Travel time

Introducing dedicated lanes for CAVs is predicted to have a marginal positive effect on travel times (less increase) when compared to the baseline at some low penetration levels of 1st generation CAV (60-40-0 and 20-40-40). When roughly equal numbers of CAVs and non-CAVs use the network, travel times may, however, increase compared to the baseline. In the stages of penetration where both CAVs and non-CAVs share the road, the baseline scenario shows an increase in travel time (up to 7%). The dedicated lane for CAVs seems to reduce these congesting effects of interactions between 1st generation CAVs and human driven vehicles particularly when there is a large share of both vehicle types in the network (60% human-driven vehicles, 40% 1st generation CAV).

Amount of travel

Looking at the dedicated lanes for CAVs SUC, implementing a “fixed dedicated lane” shows a similar trend to the baseline which varies between a slight decrease and a slight increase in kilometres travelled. The last three penetration rates cannot be compared because no values were calculated for the “fixed dedicated lane” as there is 100% CAV penetration and therefore all lanes are only used by CAVs.

Congestion

The results from the dedicated lanes for CAVs sub-use case show a general decrease in congestion as CAV penetration rates increase in the baseline scenario, and mixed results with the inclusion of a “fixed dedicated lane.” The inclusion of the dedicated CAV lane leads to a small reduction in congestion compared to its baseline values for two out the four penetration rates for which a dedicated CAV lane was considered; for the other two penetration rates, slightly more congestion was found. Therefore, no clear effect is predicted for dedicated CAV lanes on congestion.

Modal Split

Under baseline scenario, modal split of public transport is predicted to be negatively impacted with increasing fleet penetration of CAVs. Provision of dedicated lanes is not expected to cause any significant change in public transport modal split as compared to the baseline scenario.

Prediction on any changes on modal split due to AV dedicated lanes was assessed through the Delphi study findings where majority of experts indicated that under AV dedicated lanes, active travel would not decrease as much as under the baseline scenario with increasing automation. However, disagreements were also reported by some experts in the Delphi study.

Access to travel, shared mobility, vehicle utilisation and vehicle occupancy:

For dedicated CAV lanes, results differ per scenario. A "fixed" dedicated CAV lane is expected to result in a similar or slightly reduced access to travel compared to the baseline, while a "dynamic" dedicated CAV lane is predicted to improve access to travel compared to the baseline. Dedicated lanes scenarios are expected to increase vehicle utilisation rates and vehicle occupancy as compared to baseline scenario.

Road Safety

Dedicated lanes are expected to increase the number of crashes per km travelled compared to the baseline scenario (no dedicated lane) at low and high MPR levels. This can be explained by high traffic volumes in respectively lanes for non-automated vehicles and lanes for automated vehicles. When the vehicle fleets are more equally split, a small benefit can be seen of dedicated lanes when implemented on A-level roads.

Public Health

Regarding impact of the AV dedicated lane scenarios on public health, all prediction curves presented some oscillations depending on AVs market penetration rates. In the long term for 100% AVs market penetration rate, all scenarios will improve public health, which is also explained by their impact on energy efficiency according to experts.

Accessibility in transport

Regarding the AV dedicated lane scenarios, the results present some fluctuations depending on AVs market penetration rates. The scenario of AV dedicated lane on the outermost motorway lane will negatively affect accessibility in transport reaching a maximum reduction of almost 10% for 80% AVs market penetration rate. It was estimated that under the schemes of dynamically controlled AV dedicated lane, and the AV dedicated lane on the outermost motorway lane and A-road, the accessibility to transport will generally improve by almost 6% and 10% respectively, at 60% AVs market penetration rate. In the second round, majority of the experts moderately agreed with these results.

Demand for Parking

The general experts' opinion was that the introduction of AVs in the urban environment will negatively (-28,1%) affect parking space required. The introduction of AV dedicated lane on the outermost motorway lane and the introduction of a dynamically controlled motorway lane will not significantly affect parking space.

Vehicle operating cost

According to experts, the baseline scenario (no intervention) will increase (11,7%) vehicle operating cost in the short term when AVs market penetration rates are lower, but with the increase of AVs MPR, this augmentation of vehicle operating cost will be reduced. The introduction of AV dedicated lanes also presents a reduction of vehicle operating cost for AV market penetration rates up to 100%. More precisely, dynamically controlled AV dedicated lane will have the biggest impact on vehicle operating cost, leading to a decrease of -18,5%. AV dedicated lane on the outermost motorway lane will reduce by -14% the studied impact. AV dedicated lane on the innermost motorway lane and AV dedicated lane on the outermost motorway lane and

A-road will similarly affect vehicle operating cost leading in the long term to a reduction of 10%.

2.2.3 Parking price policies

Parking price regulation does not seem to make a noticeable difference on CO_2 emissions or shared mobility rate. On the positive side, parking price regulation is expected to compensate some of the negative impacts of CAVs on the mode share of public transport and active modes, resulting in more walking, cycling and public transport use than in the baseline development. However, in both cases these interventions cannot overcompensate for the negative impact that CAVs are expected to cause to the modal share of public transport and active modes. Less private vehicle use than in the baseline also results in a reduced demand for parking space, according to the system dynamics model. The alternative parking behaviours resulting from parking price regulation are predicted to have some potentially negative (or less positive) effects compared to the baseline development on energy efficiency, travel time and congestion, and road safety. However, these negative effects predicted by microsimulation and Delphi do not take into account the effects on modal split predicted by system dynamics which may counteract these effects to a certain degree if private vehicle transport is reduced. Reduced benefits are also predicted for access to travel, equal accessibility of transport, vehicle utilisation rate, and vehicle operating costs, due to the increased costs of parking in central locations.

<u>Environment</u>

The second sub-use case, parking price regulation, shows a similar trend in CO2 emissions for the baseline and the scenario "adjusted parking behaviour." Because only CAVs adopt the adjusted parking behaviour, behaviour of the CO2-emitting human-driven vehicles remains largely unchanged. Both scenarios show an over 98% reduction in emissions.

For the parking price regulation scenarios, it is interesting that the baseline scenario has a much higher positive impact (31%) compared to the "adjusted parking behaviour" scenario (10%) where automated vehicles would largely avoid parking in city centres and instead drive around empty or leave the centre to park. Especially the "drive around" scenario (see Appendix D) is predicted to have a negative effect on energy efficiency.

<u>Travel Time</u>

For parking price regulation, the implementation of an "adjusted parking behaviour" increases travel time by up to 26% (compared to 17% in the baseline, an effective further increase in travel time of 9% as a result of the pricing policy adopted). In this scenario, the majority of CAVs which would otherwise park at the destination instead choose one of the following options due to higher parking prices at the destination: return to origin (22%), drive outside centre to park (45%), or drive around until the passenger is ready to be collected (20%). While increases are also seen in the baseline for the Santander network, these increases are mostly less than when parking price regulation is implemented especially once human-driven vehicles make up 20% or less of the vehicle fleet. At high CAV penetrations, more of the vehicle fleet exhibits the adjusted parking behaviour, therefore causing more congestion and increases in travel time due to the larger number of empty kilometres driven.

Amount of Travel

The parking price regulation scenario "adjusted parking behaviour", shows a large reduction in the total kilometres travelled (ranging from 30% to 42%) across different penetration rates. As mentioned, a decrease in kilometres travelled is seen as a negative impact since it is largely caused by congestion in the network and therefore suggests a decline in accessibility and mobility. In the baseline, there is also a decrease in kilometres travelled except for the last penetration level (0-0-100), where there is a 7% increase in kilometres travelled. At all penetration rates, the shift from parking in the city centre of Santander (baseline) to driving around or parking elsewhere (adjusted parking behaviour) appears to increase the total amount of congestion in such a way that less kilometres can be travelled during a simulation period.

Congestion

The parking price regulation SUC shows that congestion levels in the baseline scenario increase markedly in the penetration rates with mixed human-driven and CAV traffic. Only once the penetration levels of 2nd generation CAVs reach 80% do congestion levels decrease by between 1 and 3% in the baseline. The "adjusted parking behaviour" scenario shows some lower congestion levels than the baseline when 40% or more of the vehicle fleet is still human-driven; however, as penetration levels of CAVs increase, the scenario with adjusted parking behaviour shows higher levels of congestion than the baseline. As discussed for travel time, in the adjusted parking behaviour scenario, the majority of CAVs which would normally park at the destination now travel to somewhere else to park or drive around while waiting. These alternatives are therefore predicted to cause some additional traffic congestion compared to the baseline where vehicles park at their destination.

Modal Split

Parking price regulation with balanced parking behaviours can also potentially prevent reduction in active travel. At 0%CAV penetration, introducing parking price with balanced parking behaviours is predicted to increase active travel by 19% as compared to baseline. With increasing CAV penetration, the share of active travel can likely decrease; however, it will still remain more than baseline (at full penetration 31% reduction as compared to 56% reduction in baseline).

Access to travel, shared mobility rate, vehicle utilisation and vehicle occupancy:

Adjusted parking behaviour under parking price regulations are expected to mitigate most of the benefits predicted in the baseline estimations, resulting in less improvement in access to travel when the policy is implemented in an increasingly automated transport system. Vehicle utilisation is predicted to decrease while vehicle occupancy is expected to increase with the implementation of parking price policy (adjusted parking behaviours).

Road Safety

The sub-use case focusing on parking price and parking behaviour shows that crash rates might increase at lower MPRs, with 20-40% of the vehicle fleet being automated. This is primarily due to interactions between human-driven vehicles and automated vehicles, which are expected to have different driving styles and capabilities. This increased risk due to mixed traffic is particularly visible in the "drive-around" scenario, where the automated vehicles cause additional congestion on the road—and therefore, additional opportunities for conflicts.

Public Health

A significant decline in public health was foreseen by majority of the experts under 'drive around' scenario due to parking price, reaching up to 25% in long term which can be explained by its impact on energy efficiency. Whereas 'park inside' and 'park outside' scenarios were predicted by most of the experts to improve public health in long-term reaching up to 9%. 'Return to origin' scenario was indicated to have no effect on public health.

Accessibility in transport

Under parking price policies, experts predicted improvement in accessibility in transport under 'return to origin' parking scenario. However, in all other scenarios a negative impact of parking price policies was observed. The worst impact was foreseen in 'drive around' scenario, with a decrease of around 10%.

Demand for Parking

Under parking pricing, policies causing balanced parking behaviours were analysed as it was found to be most suitable strategy through microsimulation analysis presented in D 6.2. As expected, this policy intervention is estimated to significantly reduce demand for parking as compared to the baseline with the relative demand for parking space staying constantly slightly above 20% with increasing MPR. Majority of experts' opinion in this regard also suggested that the CAVs parking behaviour would reduce the requirement of parking spaces. CAVs parking inside the city centre would decrease the parking demand up to 40%. The requirement of parking spaces for CAVs returning to origin, driving around and parking outside scenarios will be reduced by 19.7%, 36.2% and 12.2% respectively for 100% AVs market penetration rate.

Vehicle operating cost

Regarding parking price policies, the Delphi results indicated that the pricing policy requiring CAVs to park outside the city centre will have positive impact on vehicle operating cost. Policies that encourage CAVs to park inside the city centre, return to origin to park, and drive around until pick-up will increase vehicle operating cost by almost 16%, 23%, and 21%, respectively at full MPR. In the 2nd round results, 50% of experts estimated that parking inside city centre will not affect vehicle operating costs while parking outside will increase at an average of +10% to +20%.

2.2.4 Parking space regulations

The interventions aimed at replacing on-street parking show similar results to the baseline (no added effect) in terms of CO_2 emissions. Positive effects on mobility in terms of reduced travel time and congestion are predicted due to the reduction in parking manoeuvres. For many of the impacts, the effect of replacing on-street parking was dependent on the scenario: removing half of spaces, replacing with driving lanes, replacing with pick-up/drop-off spaces for shared CAVs, or replacing with public space or cycling lanes. Replacing with "public space" was found to be particularly beneficial for energy efficiency, shared mobility rate, modal splits of active and public transport, vehicle occupancy rate, vehicle operating cost, road safety, and public health, but negative in terms of access to travel. Meanwhile, replacing on-street parking with "driving lanes" is expected to improve access to travel and use of active modes (to a lesser degree than public space), but reduce the mode share of public transport and negatively impact public health and parking space demand. The scenario "pick-up/drop-off" generally performs worse than the other scenarios in terms of energy efficiency, travel time, kilometres travelled, congestion, shares of active transport modes and public transport, shared mobility rate, and road safety. On the positive side, the "pick-up/drop-off" scenario is expected to result in better results for access to travel and equal accessibility of transport than the other scenarios in the replacing on-street parking SUC.

Environment

The sub-use case dealing with replacing on-street parking shows a decrease in CO2 emissions with the implementation of all SUC scenarios (removing half on-street parking spaces, replacing with driving lanes, replacing with pick-up/drop-off points, replacing with public spaces, and replacing with cycling lanes). Comparing the parking removal scenarios with the baseline, it is clear that once the levels of human-driven vehicles drop to 20% and below, the removal of parking spaces shows no added benefit in terms of CO2 emissions. However, at lower CAV penetration rates, the removal of on-street parking leads to a larger reduction in emissions than the baseline scenario. This is likely related to the reduction in traffic congestion in the network resulting from the removal of on-street parking spaces. For the two SUC scenarios in which on-street parking spaces are still partially used (removing half of the on-street parking spaces and replacing with pick-up/drop-off points), the difference from baseline is correspondingly lower.

Experts in the Delphi survey estimate that Replacing on-street parking with "space for public use" will have a similar or slightly higher positive impact on energy efficiency compared to the baseline. However, experts predict that replacing on-street parking with a "driving lane" or "pick-up/drop-off" spaces for shared vehicles will have a negative impact on energy efficiency.

Travel Time

In general, replacing on-street parking with any of the scenarios (removing half on-street parking spaces, replacing with driving lanes, replacing with pick-up/drop-off points, replacing with public spaces, and replacing with cycling lanes), improves travel time. In the microsimulation, parking manoeuvres are a source of congestion which can increase travel times; therefore, the scenarios where on-street parking is completely removed (replaced with driving lanes, public space, or cycling lanes) have the largest effects on travel time. The scenario that improves travel time the most is "replacing on-street parking with driving lanes" which is expected since it provides more capacity. The baseline scenario also improves travel time but much less than the sub-use case scenarios.

Amount of Travel

For the replacing on-street parking sub-use case, different results are observed per scenario. For the baseline scenario there is a mostly negative development in total kilometres travelled. Out of the five scenarios in this sub-use case, two of the scenarios, "removing half on-street parking spaces", and "replacing with pick-up/drop-off points" also show a general negative impact on kilometres travelled. The other three scenarios, "replacing with driving lanes", "replacing with public spaces", and "replacing with cycling lanes" show an increase in total kilometres travelled of around 12%. In these three scenarios, on-street parking is completely removed, which when present can be a source of a congestion (leading to fewer kilometres travelled in a simulation period).

Congestion

Replacing on-street parking shows a promising impact on congestion. The implementation of each of the five SUC scenarios results in a decrease in congestion of between 20% and 54%, all substantially more than estimated for just the baseline. High congestion reduction levels can even be seen at low CAV penetration rates in three scenarios where on-street parking is completely removed: "replacing with driving lanes", "replacing with public spaces", and "replacing with cycling lanes". As discussed earlier, in the microsimulation, parking manoeuvres are a source of congestion. Therefore, removing these manoeuvres completely results in a larger reduction in congestion. The other two scenarios remove only some of the parking manoeuvres and therefore have a smaller, yet still sizeable, effect.

Modal Split

With parking space regulations, the SD model results indicated a slight increase in active travel due to replacing on-street parking with driving lanes. Removing half of on-street parking spaces shows a mixed effect on active mode use: initially, there is an increase in active modes compared to the baseline when CAV penetration is still less than 20% of the vehicle fleet. However, as CAV penetration increases, the benefits of removing half of on-street parking spaces diminish and the SUC results in a similar decrease to the baseline results. Replacing on-street parking is also predicted to negatively impact use of public transport, especially in the "replace with driving lanes" scenario which more than doubles the reduction in public transport use compared to CAVs alone. This is likely due to increased road capacity and large reductions in congestion, making private vehicle use a more attractive option and therefore attracting a share of public transport users.

Access to travel, shared mobility, vehicle utilisation and vehicle occupancy:

Replacing on-street parking with "driving lanes" or to a lesser degree "pickup/drop-off" spaces is expected to improve access to travel, while replacing the parking with "space for public use" is expected to reduce access to travel more than in the baseline. The experts' prediction on vehicle utilisation rate due to replacing on-street parking scenarios showed some variation; however, reduction is indicated at higher MPR of CAVs as compared to the baseline case.

The effect of replacing on-street parking depends on the facility replacing parking spaces: "space for public use" and "pick-up/drop-off" spaces are expected to be beneficial for vehicle occupancy rates, while converting parking to "driving lanes" results in a similar decrease in occupancy to the baseline results.

Road Safety

According to the results of the microsimulation, removing or replacing on street parking by other facilities does not seem to have an additional impact on the crash rate of car-car crashes compared to the baseline scenario in which parking spaces are not removed. The replacement of on-street parking with cycling lanes or public space can be expected to have an impact on VRU accident numbers. The replacement of pick-up and drop-off points could affect pedestrian safety, via unexpected interactions between pedestrians and cyclists or cars.

Public Health

Regarding parking space regulations, as expected, the Delphi results indicated that replacing on-street parking space with public spaces will improve public health the most. On the other hand, replacing on-street parking space with driving lanes will deteriorate public health.

Accessibility in transport

Experts indicated that replacing on-street parking space with driving lanes or with pick-up/drop-off spaces will both positively affect accessibility in transport. Replacing on-street parking space with public spaces will reduce accessibility in transport.

Demand for Parking

Implementation of parking space regulations involving 50% on-street parking removal would likely have negative impact on automobile travel and lower the demand for parking as compared to the baseline condition. On the other hand, the policy intervention of conversion to driving lanes would likely lead to an increased travel demand (as compared to 50% parking space removal) due to encouraging additional vehicles on road. In comparison with baseline, the increase in parking demand will potentially occur with increased automation (at least 50% or above). General experts' opinion in this regard indicated that the introduction of parking regulations will progressively reduce parking spaces required.

Vehicle operating cost

The impact of parking space regulation may differ based on the introduced policy measure. The responses from experts in the 1st round indicated that replacing on-street parking spaces with driving lanes and pick-up/drop-off spaces will increase vehicle operating costs by almost 14% and 11% respectively at full MPR.

2.2.5 Automated ride sharing

Automated ride sharing does not make a noticeable difference for CO2 emissions or parking space demand. Compared to the baseline, extra benefits are expected in terms of energy efficiency, access to travel, public transport use, shared mobility rate (at lower CAV penetrations), vehicle occupancy rate, and vehicle operating costs. Compared to the baseline, it has a negative impact on congestion (due to empty vehicle kilometres needed to reposition vehicles), travel time, use of active modes, and vehicle utilisation rate. The impact on road safety is mixed: at low CAV penetrations, automated ride sharing improves safety by serving a share of otherwise human-driven trips. However, as all trips become automated the added benefit reduces and the extra congestion caused by ride sharing rather serves to slightly increase crash rates compared to the baseline at high penetration rates. Furthermore, the impacts of automated ride sharing depend on what share of the users are willing to share trips with other users. When willingness to share is low (20% scenario), fewer positive results are predicted for mobility and road safety due to the larger number of trips and vehicles needed to serve the demand (travel time and congestion increase; kilometres travelled and road safety decrease).

Environment

The automated ride sharing (ARS) SUC is expected to be beneficial for CO2 emissions if drivers of non-CAV/non-electric vehicles participate in ARS, mainly due to trip sharing reducing the total vehicle kilometres travelled. Since CAV vehicles are assumed to be electric and therefore have limited/no impact on emissions, ARS were predicted to have little or no added impact at high CAV penetration rates. Therefore, the results show a similar trend in CO2 emissions throughout all scenarios (baseline, 20% of demand & 20% willing to share, and 20% of demand & 100% willing to share). Of all the estimated ARS scenarios (see Appendix D.1), most scenarios showed a slightly reduced environmental benefit at lower CAV penetration rates compared to the baseline. This includes the scenario of serving 20% of demand with 100% willingness to share. The exception to this finding is the 20% of demand & 20% willingness to share scenario, which increases congestion due to the high number of ARS vehicles travelling in the network. This congestion serves to reduce the number of human-driven vehicle kilometres within a simulation run and therefore the predicted CO2 emissions. This finding is therefore more related to specific characteristics of the microsimulation method and does not necessarily represent an improvement in environmental performance. In general, the network effect of 20% of all private vehicle trips switching to ARS on overall emissions is negligible in the modelled scenarios.

The estimates for the Automated ride sharing sub-use case also indicate a higher positive impact on energy efficiency compared to their baseline cases. especially at higher CAV penetration rates.

Travel Time

Automated ride sharing is not predicted to improve travel times compared to the baseline scenario. This can largely be explained by the increase in empty kilometres driven with implementation of an automated ride sharing system, as the automated ride sharing vehicles circulate in the network to pick up the next passenger. Even when willingness to share is high, not every trip will be suitable for sharing as the choice to share cannot cause large delays to the other passenger(s). The additional empty kilometres therefore have the potential to overcompensate for benefits due to trip sharing, especially when willingness to share is low, and can cause increased congestion and travel times. In addition, travel times may increase slightly during shared trips due to picking up and/or dropping off additional passengers. The baseline scenario has a small improvement in travel time, but the sub-use case scenarios mostly increase travel time. For higher CAV penetration rates the “20% willing to share” has a higher travel time impact (between 13% and 14%) compared to the “100% willing to share” scenario which has a slight improvement (1,5%) in travel time at the 0-0-100 penetration rate. This suggests that the willingness of users of automated ride sharing to share trips with other travellers can have an important effect on the traffic situation by reducing the number of automated taxi vehicles and trips present in the network.

Amount of Travel

In general, automated ride sharing is expected to lead to an increase in vehicle kilometres, due to the empty repositioning of vehicles to pick up passengers potentially being larger than the reductions due to the trips which can actually be shared. In the microsimulation results, scenarios with higher willingness to share (see Appendix D for all scenarios) show this expected increase in kilometres travelled compared to the baseline results. In the "100% willing to share" scenario, automated ride sharing is predicted to increase total kilometres travelled by 4% at full penetration compared to a decrease of - 8% in the baseline. When willingness to share is lower, however, significantly increased delays due to congestion in the network reduce the number of trips and vehicle kilometres which can be completed within a simulation period. This leads, somewhat counterintuitively, to a decrease in kilometres travelled in the "20% willing to share" scenario. The results suggests that trips with a higher willingness to share are expected to improve traffic flow.

Congestion

As discussed for travel time and total kilometres travelled, automated ride sharing is expected to cause some increased congestion, especially when the willingness to share trips are low. This increased congestion is largely related to the additional empty vehicle kilometres necessary to pick up their next passenger. While trip sharing can reduce some of the un-occupied kilometres, not all trips will be suitable for combining and not all passengers are expected to be interested in sharing their trips. This results in an overall increase in congestion in the "20% willing to share" scenario of up to 18%. This while in the baseline scenario, increasing CAV penetration is predicted to reduce congestion by up to 11%. When all ride sharing users (20% of the total travel demand) are willing to share their trips with other ride sharing users within the allowable detour time (5-10 minutes), congestion results much closer to the baseline reduction are reached: the "100% willing to share" scenario shows a decrease in congestion of -2% to -9% once 2nd generation CAVs make up 80% or more of the vehicle fleet, only slightly higher than for the baseline (-10% to -11%).

Modal Split

Regarding the mode share of public transport, automated ride sharing is expected to increase public transport use compared to the baseline at every penetration rate of CAVs. While the baseline shows a 17% reduction at full CAV penetration, while automated ride sharing results in a 3% final reduction (and a 15% increase before CAVs). The increased modal share in public transport with the automated ride sharing service is due to the fact that this new mode is included as part of public transport.

Lastly, automated ride sharing is predicted to reduce the use of active modes of travel compared to the baseline at all penetrations of CAVs. In an entirely human-driven context, walking and cycling accounts for a 9% reduction in share of travelled kilometres compared to the baseline (a decrease from 16% to 14,5% in absolute mode share).

Access to travel, shared mobility rate, vehicle utilisation and vehicle occupancy

Lastly, automated ride sharing is predicted to improve access to travel substantially, with experts predicting a 41% increase with automated ride sharing compared to a 26% increase in the baseline when all vehicles are CAVs.

Vehicle occupancy is expected to increase with automated ride sharing. Vehicle utilisation is predicted to increase a little at low MPR but would reduce with increasing MPR of CAVs, as compared to the baseline condition.

Road Safety

Automated ride sharing is expected to slightly increase crash rates of car-car crashes compared to the baseline scenario, although the differences are small and appear to show some random variation. Neither the percentage of demand served nor the willingness of passengers to share trips show a clear relationship with the crash rate.

Public Health

Automated ride sharing services are expected to improve public health by almost 12% at full fleet penetration of AVs. This can be expected with increasing willingness to share the ride, leading to reduction in number of personal vehicles on road, which in turn will decrease emissions. It is important to note that such services could negatively impact active travel, as indicated by the SD results in D 6.3 (Sha et al., 2021).

Accessibility in transport

In this regard, the experts' opinion on automated ride sharing services was that it will improve the equality in access to transport almost from 10 to 22%.

Demand for Parking

Majority of the experts predicted reduction in parking demand with inclusion of services like automated ridesharing, almost by 25% as found through the Delphi study. However, system dynamics modelling results indicated almost no change in parking demand as compared to the baseline, considering 20% share of total demand and 100% willingness to share. Intuitively, more demand served by SAVs would reduce the number of personal vehicles cars on the road. However, due to pick-ups, drop-offs, and waiting for passengers, the requirement for parking spaces may not significantly reduce.

Vehicle operating cost

In general, experts' opinion indicated that the introduction of an automated ridesharing service will reduce vehicle operating cost up to 21% at full MPR.

2.2.6 Green Light Optimal Speed Advisory (GLOSA)

The GLOSA sub-use case is associated with no noticeable additional impacts on CO_2 emissions or kilometres travelled. Compared to the baseline it shows positive impacts on travel time, congestion, public transport use, road safety, and vehicle operating costs. A negative (or less positive) impact compared to the baseline is predicted for access to travel, active mode share, shared mobility rate, vehicle utilisation rate, public health, and equal accessibility of transport.

Environment

Like in the previous sub-use cases, the GLOSA scenarios have a similar trend in reducing and eventually eliminating road related CO2 emissions. However, when compared to the baseline, GLOSA as simulated here, has no real added benefits in terms of reducing emissions. Because GLOSA was implemented on a small scale (3 intersections) in the simulation, the effect on traffic in the overall network is not large enough to be seen back in a change in CO2 emissions compared to the baseline electrification trend.

The estimates for the GLOSA sub-use case also indicate a higher positive impact on energy efficiency compared to their baseline cases. Especially at higher CAV penetration rates, the introduction of these SUCs is expected to have an additional positive impact.

Travel Time

The last sub-use case applied to travel time is GLOSA. For the baseline, travel time increases as CAV penetration rate increases. However, implementing the "GLOSA on three intersections" initially reduces travel time, and only increases travel time at a penetration rate of 0-20-80 (2%), but not as high as the baseline scenario (4%). It must be mentioned that GLOSA affects only 3 intersections in the network and therefore the overall network effects are small.

Total km travelled

The last sub-use case for which the impact on total kilometres travelled was estimated is GLOSA. For this SUC it is predicted that in both the baseline and "GLOSA on three intersections", the total kilometres travelled slightly decreased (up to less than 2%) and the difference between baseline and GLOSA is marginal. Implementation of GLOSA is therefore predicted to have little additional effect on kilometres travelled.

Congestion

The last sub-use case used to evaluate the impact on congestion using microsimulation is GLOSA. Both the baseline and "GLOSA on three intersections" decrease congestion, while the "GLOSA on three intersections" scenario has a slightly higher impact on reducing congestion: an almost 7% reduction, compared to the 2% in the baseline at 0-0-100 penetration rate. GLOSA is therefore expected to have a positive effect on congestion.

Access to travel, shared mobility rate, vehicle utilisation rate and vehicle occupancy

Under GLOSA, the experts in the Delphi study predicted less improvement in access to travel when this is implemented in an increasingly automated transport system.

The results of Delphi study indicate towards a reduction in vehicle utilisation rate with GLOSA system implementation as compared to baseline scenario.

Lastly, GLOSA is expected to have a slightly negative effect on occupancy rates, resulting in less of an increase than in the baseline trend.

Road Safety

The surrogate safety assessment of GLOSA system showed improvement in safety (lower crash rate) with the GLOSA implementation at multiple intersections in the test network, particularly at low CAV MPR scenarios, as compared to baseline scenario (without GLOSA) and single intersection implementation.

Public Health

Regarding the impacts of GLOSA system, overall, majority of the experts indicated no effect at all on public health.

Accessibility in transport

Due to implementation of GLOSA system, some experts indicated a general increase in accessibility while half of the participants in the second round showed disagreement and indicated no effect at all due to GLOSA application.

Vehicle operating cost

The Delphi results indicated that GLOSA system will not have a significant impact on vehicle operating cost. Experts in the first round predicted a slight decrease of 3,5% at low MPR and an increase of 3.8% at full MPR, while 2nd round results suggest that GLOSA will not at all affect the vehicle operating cost.

3.4 Findings on Freight AIT

The focus of this use case was to assess the impacts of CCAM on the freight transport system, and to study the conceptual changes enabled by the automated vans and trucks. In particular we considered the following sub-use cases: (i) Automated urban delivery, (ii) Automated freight consolidation, (iii) Hub-to-hub automated transport, and (iv) the impact of platooning on bridges.

3.4.1 Automated urban delivery

This sub-use case compares the performance of parcel delivery in urban areas via manual delivery personnel and (semi-)automated concepts. Studies show that using smaller, electrified vehicles and robots addresses several acute problems: emissions, navigation in confined inner-city areas and the limitation of working time for manual parcel delivery (Jennings et al., 2019, Figliozzi et al., 2020). Based on the current manual delivery process, the envisioned automation technologies and concepts that will emerge in the next decades, we considered these delivery scenarios:

- **Manual delivery** (status quo) is used as a base scenario for comparison.
- **Semi-automated delivery** assumes that the delivery process is not fully automated yet. While the delivery van is automated, personnel are still undertaking the delivery task. However, since they do not need to switch between delivery and driving tasks, time can be saved during each stop.
- **Automated delivery** is where so-called robo-vans and small autonomous delivery robots replace all service personnel and operate beyond the road (to the off-loading areas using pavement, pedestrian area, etc.). The automated

van functions as a mobile hub where they perform short delivery trips to end-customers, i.e., a hub-and-spoke setup with moving hubs. This human-less delivery process can be carried out during off-peak hours when road traffic volumes are lower and be extended to evening or night-time delivery. For this concept, we assume that the parcel capacity of the van will be significantly reduced. The main reason is that it has to carry the delivery robots and the necessary equipment to load them.

- **Automated night delivery** is the same as above, but deliveries are limited to night time delivery only. Since the delivery time is restricted to night time only, this scenario will increase in the fleet size since the same volume of deliveries will have to be made in significantly less time compared to the previous scenario.

The primary impacts for freight delivery are freight mileage, freight transport cost, fleet operating cost and freight emissions, where we use operations research methods to forecast them. For the sake of simplicity and applicability of assessment methods, it is assumed that for the appropriate level of automation, adequate infrastructure exists (e.g., for receiving parcels at night). It is also assumed that the pure technological obstacles for the sub-use cases in consideration are solvable and do not hamper operations. They mainly consist of optimisation algorithms for route-planning, also commonly known as the vehicle routing problem (VRP), where the goal is to calculate the optimal route or set of routes at the lowest possible cost (and often also the shortest possible time) from a given depot to a number of customers (Toth and Vigo, 2014). Compared to private passenger transport, freight transport is less time-critical and plannable on an operational basis, which makes operations research a viable approach for the automated delivery and automated consolidation SUCs. Vienna is taken as the basis for analysing these two SUCs due to the availability of high-quality data. The results are shown together with automated freight consolidation in Table 3.3 in the next section.

3.4.2 Automated freight consolidation

The automated consolidation sub use case is a continuation of automated urban delivery. In this setting, the parcel delivery companies will consolidate their parcels at city-hubs instead of operating independently and delivering parcels straight to their final recipients. Ideally, the city-hubs and the last-mile delivery operate on a white-label basis, i.e., the delivery vehicles are not bound to a specific delivery company but operate the service for all companies. This removes a lot of redundancy in the delivery system nowadays. In addition, since these city-hubs are closer to the city centre than the original distribution centres, final delivery routes in a consolidated scenario are significantly shorter. This has a positive impact on the traffic and the environment (Allen et al. 2012, Quak et al. 2016). While the scientific works are more focused on finding the optimal locations for the hubs (Charisis et al. 2020), it is more of a political and urban planning problem in the real world.

We compare the following delivery scenarios:

- **Manual delivery** refers to the same scenario in the previous SUC
- **Automated delivery** refers to the automated delivery scenario in the previous SUC

- **Manual delivery with bundling at city-hubs** uses bundled parcel delivery via city-hubs, but both the servicing of city-hubs and the delivery to end-customers are done manually.
- **Automated delivery with bundling at city-hubs** is the final scenario that combines the automated delivery via robo-vans and the city-hubs for bundling.

In all automated scenarios, we assume that the delivery is done during day and night, whereas the transport from distribution centres to city-hubs is done during the night via automated trucks. Solutions or prototypes for automatic loading and unloading already exist for packages and pallets (Cramer et al. 2020).

Table 3.4 compares all delivery variants with respect to their fleet composition and driven km per day. The columns show the number of delivery trips, fleet size, average number of stops (parking operations) per trip, average trip length and mileage of all delivery trips. This is followed by the mileage of the consolidation trips by trucks (i.e., trips for delivering to parcels to the city-hubs), and finally the total mileage of all vehicles. Results are shown in Figure 3.1.

Table 3.4: Results for automated delivery and automated consolidation

	Delivery via van / robo-van			Consolidation trips by trucks	Total driven km
	#trips	Fleet size	Driven km	Driven km	
No consolidation					
Manual delivery	1,799	1,799	80,389 km	-	80,389 km
Semi-automated delivery	1,440	1,440	70,805 km	-	70,805 km
Automated delivery	2,692	898	10,6177 km	-	106,177 km
Automated night delivery	2,692	1,795	10,6177 km	-	106,177 km
Consolidated delivery					
Manual delivery with city-hubs	1,806	1,806	24,675 km	10,445 km	35,120 km
Automated delivery with city-hubs	2,716	906	32,347 km	10,445 km	42,792 km

We see that on the one hand, the mileage is significantly shortened by the consolidated delivery via the centrally located city-hubs, and on the other hand, mileage increases due to the lower capacities of the robo-vans for automated delivery. However, with automated delivery using smaller vehicles more delivery shifts (three as opposed to 2 in the day and 2 as opposed to 1 at night) can be introduced requiring fewer vehicles in the fleet at any given time. We also note that the mileage driven for the for the automated delivery scenario is the highest.

Next, we estimated the annual fleet cost (Million EUR), vehicle operating costs (EUR/km) and freight transport cost (EUR / tonne-km). For the freight transport cost, we assume an average parcel weight of 1.37kg per parcel (Wirtschaftskammer Wien, 2020). Table 3.5 and Figure 3.2 show the results obtained for Vienna based on the current volume of packages delivered.

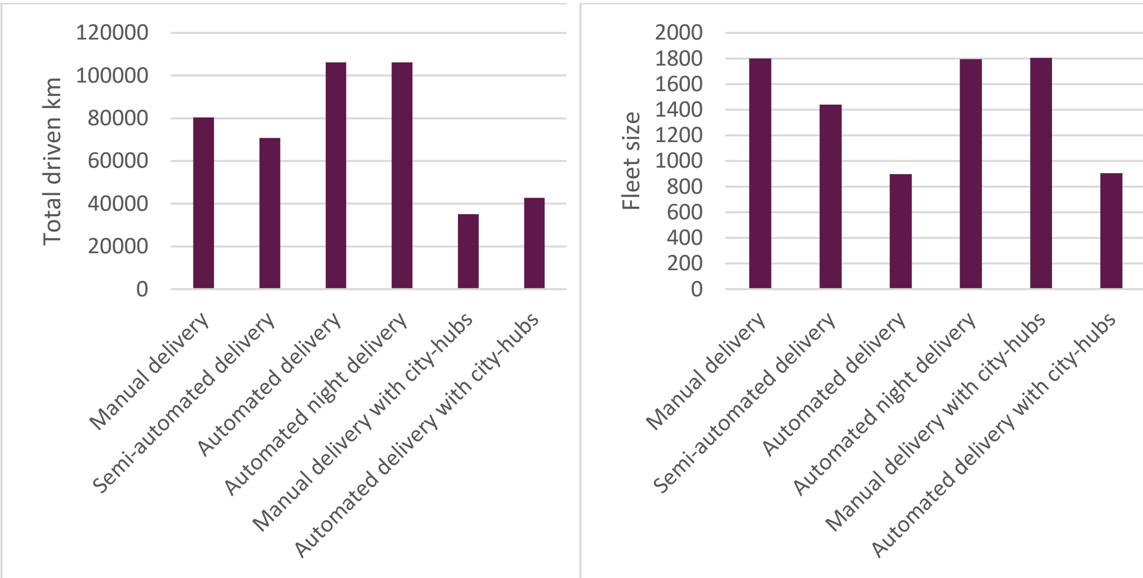


Figure 3.1: Fleet size (left) and total driven km (right)

Table 3.5: Vehicle operating cost and freight transport cost given 5 freight CAV implementation scenarios.

	Fleet size	Driven km	Annual fleet cost (Million EUR)	Vehicle operating cost (EUR / km)	Freight transport cost (EUR / tonne-km)
Manual delivery	1,799	80,389 km	96.2	3.9	18.8
Semi-automated delivery	1,440	70,805 km	79.9	3.6	14.8
Automated delivery	898	106,177 km	30.5	0.9	6.8
Automated night delivery	1,795	106,177 km	61.0	1.9	13.5

Manual delivery with city-hubs	1,806	24,675 km	96.6	12.6	61.5
Automated delivery with city-hubs	906	32,347 km	30.8	3.1	22.4

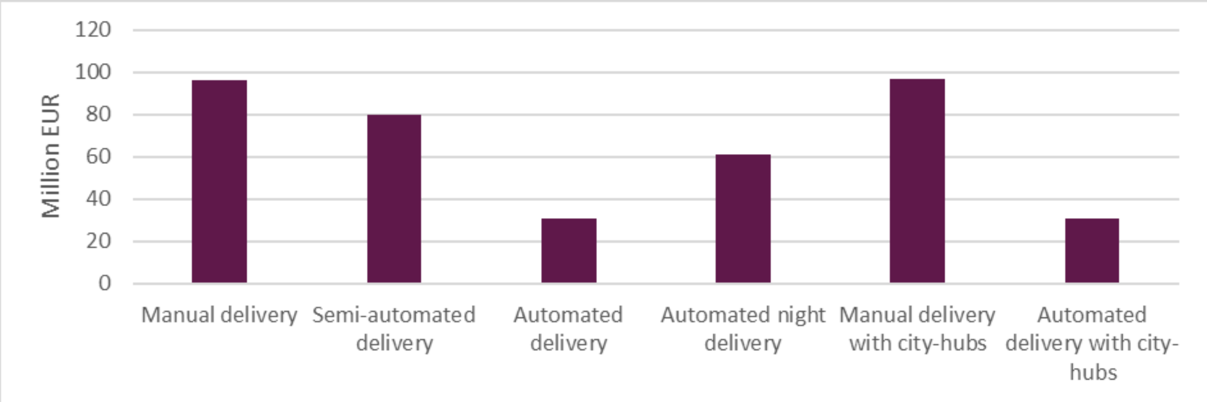


Figure 3.2: Annual fleet cost (Million EUR)

We conclude that the current delivery system has a high redundancy since multiple delivery companies operate in the same area, thus one delivery address is often approached multiple times by different delivery companies. Therefore, consolidation through city-hubs is in the spotlight, especially white-label concepts where the infrastructure is shared among different logistics provider companies in order to reduce redundancy (Schodl et al., 2020). While the mileage will decrease significantly, the implementation is very challenging: Beside the expensive upkeep for the city-hubs, the overhead in the freight operation and the additional personnel requirement is significant when the delivery system is operated manually. Without automation, adding the additional consolidation step means that freight has to be transported to the city-hubs and then processed, before the actual delivery can begin. This alone causes a delay of several hours in the delivery process (which very critical for the Business to Business or B2B sector) and we must ask how the labour situation will change as a result of such a consolidated process. Extending the working times of current delivery personnel, particularly drivers, will be legally challenging whereas additional personnel means additional costs. Automated logistics solves this problem completely since servicing the city-hubs can be automated and shifted to the night, when all incoming parcels arrived. This can be seen as the critical enabler for freight consolidation.

3.4.3 Hub-to-hub automated transport

For the hub-to-hub automated transport SUC, we looked into a small area in the south of Vienna, which fulfils realistic conditions for the implementation of an automated transfer hub:

- Synergy: It is within an industrial area with a large number of logistic facilities, which provides the demand for the transfer hub.
- Accessibility: The location of the transfer hub is next to the highway ramp, which is essential for the operation of AV trucks at level 4 automation.

- Land acquisition: The considered area is unused and large enough, which facilitates the implementation at lower costs.

The study area (city of Vienna), as shown in Figure 3.3, has been modelled into a simple model in AIMSUN (Figure 3.4). The traffic light circuits are modelled according to the real-world situation. The traffic volume is based on traffic counting on the highway, which reveals the daily inbound, outbound and thru traffic. To break down the traffic volume on an hourly basis, we take the time-dependent traffic volume for Vienna (Statistik Austria, 2020), as shown in Figure 3.5. We are aware that for an industry-heavy area the traffic distribution might be slightly different, but not essentially. In addition, especially the peak hours on the highway are accurate.

For the scenario where we assume that the automated transfer hub is implemented, we take the truck component of the overall traffic and modify the behaviour as follows.

- During the day (6am – 7pm), a proportion of trucks entering the highway via ramp are redirected towards the hub and return to their origin.
- During the night (7pm – 6am), the number of automated trucks entering the highway corresponds to the amount of redirected trucks during the day.
- The inbound traffic is changed analogously, i.e., during the night, automated trucks arrive at the hub and during the day, the freight is picked up by the manual trucks.
- The proportion of redirected trucks correspond to the freight AV penetration rate.

Figure 3.3: Area in the southern of Vienna where we assumed the location of the transfer hub

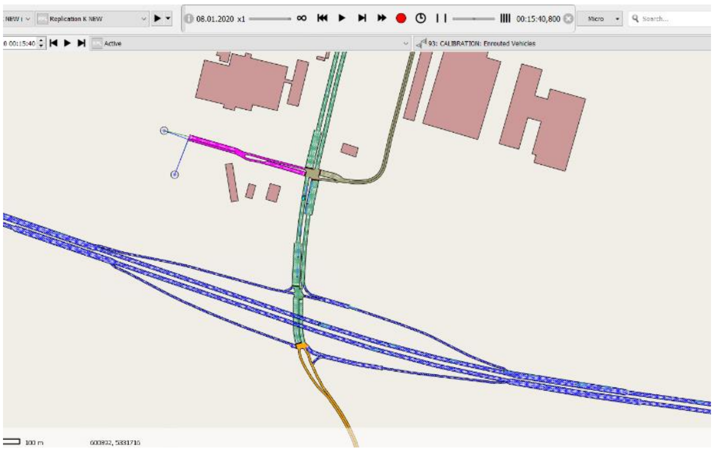


Figure 3.4: Modelled area for the transfer hub in AIMSUN

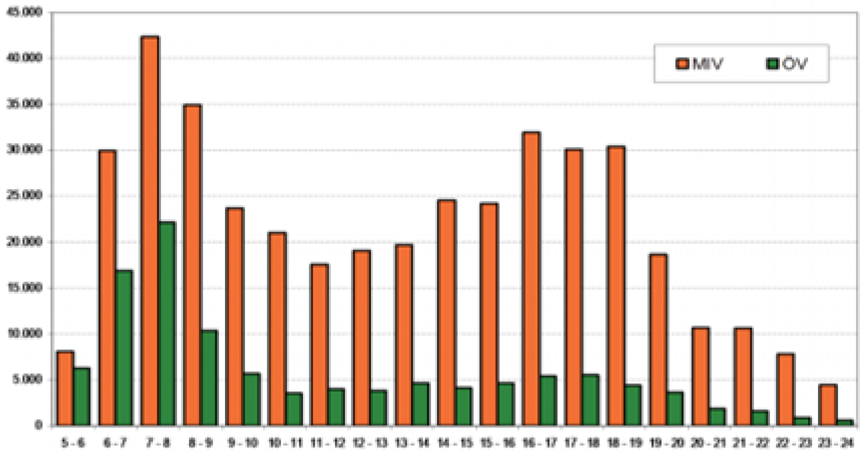


Figure 3.5: Time-dependent traffic volume in Vienna.
No data are available from 0:00-5:00 because of the minimal traffic volume on the road. In the simulation this was set to half of the amount of 23:00-24:00

Compared to the automated delivery and automated consolidation SUCs, the simulated area for the hub-to-hub SUC only considers a small area around the transfer hub. The results are therefore very local and shown in Table 3.6 and Figure 3.6. The focus was on the congestion, measured in delay (s/km), which could be reduced due to the transfer hub. Although the reduction is not very high when the transfer hub is used, it is visible, especially during the transition phase between scenario A (no AVs) and scenario H (full transition to 2nd generation AVs).

Table 3.6: Delay (s/km) for the background traffic with and without transfer hub

Simulation scenario	A	B	C	D	E	F	G	H
	(100,0,0)	(80,20,0)	(60,40,0)	(40,40,20)	(20,40,40)	(0,40,60)	(0,20,80)	(0,0,100)
No transfer hub	9,7	8,8	8,6	8,0	7,8	7,5	7,4	7,3
With transfer hub	9,7	8,6	8,0	7,6	7,4	7,3	7,3	7,1

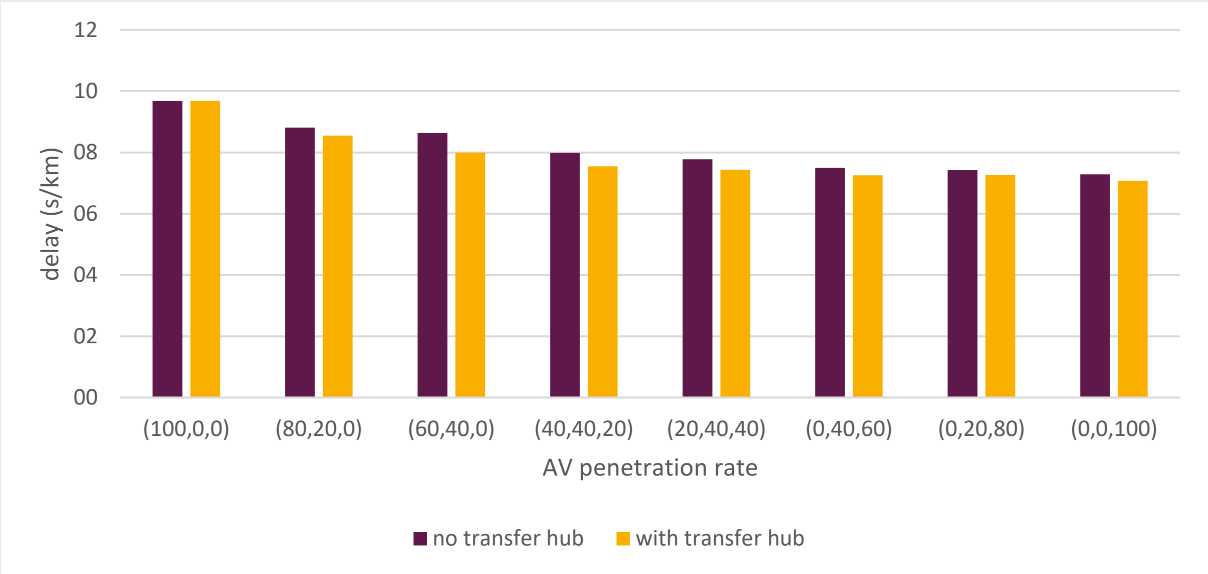


Figure 3.6: Delay (s/km) for the background traffic with and without transfer hub

3.4.4 Platooning on bridges

This SUC analyses the potential effects of truck platooning on urban highway bridges. The existing bridge stock was designed to carry traffic loads based on traffic composition at the time of creating the bridge-building codes. Truck platooning represents a change in the traffic composition, which has potential impacts on the bridge capacity to carry these new loads (Sayed et al. 2020). Following effects were identified as relevant and are analysed in this sub-use case:

- **Static traffic load effects**: the reduced vehicle distances in a platoon cause an increase of traffic load per road meter in the most used lane. Therefore, a potential increase of maximum traffic loads during bridge's lifetime can be expected.
- **Dynamic amplification**: the dynamic interaction between the vehicles, road surface and the bridge leads to an increase of the traffic loading. The repetitive composition of trucks in a platoon can potentially increase the values of dynamic amplification, if the interaction with bridge resonance properties turns out to be unfavourable.
- **Braking forces**: the total braking force of all vehicles on the bridge must be transferred from the bridge to the subgrade. Bridge bearings and/or piers assume this function. Trucks in a platoon are expected to brake in a coordinated way, which potentially increases the total braking force in comparison to flow of independent vehicles.

3.5 Findings on safety

The safety impacts of CCAM related developments have been analysed quite extensively within Levitate. First of all, road safety impacts of increasing penetration levels of CAVs were identified and quantified. The results of this activity are discussed in more detail in Weijermars et al (2021) and will be summarized in this section. Second, additional road safety impacts of the various SUCs that are included in Levitate were identified and quantified. These results are included in Deliverables 5.4, 6.4 and 7.4 (Roussou et al., 2021; Chaudhry et al., 2021; Hu et al., 2021) and summarized in Sections 3.1, 3.2 and 3.3 of this report. Finally, a driving simulator study was carried out to investigate the effects of the increasing penetration rate of automated vehicles on the driving behaviour of the other car drivers. The results of this study are discussed in more detail in De Zwart et al (2022) and summarized in this section.

3.5.1 Road safety impacts of increasing penetration levels of CAVs

Connected and Automated vehicles (CAVs) affect road safety directly (primary impacts) and indirectly (secondary impacts). The different ways in which road safety are affected are identified, elaborating on the general impact diagram that was constructed in Deliverable 3.1 (Elvik et al., 2019) by means of a literature review and consultation of experts within LEVITATE. The identified impacts were also discussed with experts outside LEVITATE in a Webinar.

The impacts were quantified as far as possible by means of a combination of different methods. Impacts on crash rates of crashes between motorized vehicles were estimated using the AIMSUN NEXT microsimulation model. Impacts on crash rates of crashes with vulnerable road users were estimated by means of combining accident data with assumptions concerning crashes that can be prevented with the introduction of CAVs. The impacts on crash rates were subsequently combined with estimated impacts on distance travelled by travel mode to estimate the expected change in the number of crashes.

3.5.1.1 Ways in which road safety is impacted by CAVs

Four types of impacts on road safety were identified on the basis of Deliverable 3.1, the literature review and expert consultation. These impacts are discussed below.

Improved driving behaviour

The essence of (C)AVs is that the driving task is transferred from the human driver to the vehicle itself. CAVs, when performing to specification, are expected to drive safer than human drivers. First of all, CAVs do not get tired or distracted and are (assumed to be) programmed to obey all traffic rules and regulations. Moreover, automated vehicles are expected to have lower reaction times and less variability in driving behaviour, especially if they are connected and thus able to communicate with each other.

New risks

Although CAVs are expected to drive safer than human drivers (when performing to specification), CAVs cannot be expected to 100% safe and may also introduce new risks. First of all, system failures may occur due to broken detectors or software malfunctioning. Moreover, CAVs might have difficulties with detecting or recognising other road users, obstacles, traffic signs or road markings, especially in case of poor visibility or inclement weather. Given the complexity of the road traffic environment, new or unexpected situations, will occur and human drivers are probably better equipped to deal with those situations. Another new risk is the risk of hacking or cyber-attacks. Due to the inherent vulnerabilities in CAVs it will be difficult to prevent all cyber-attacks. Finally, during the transition from human driven vehicles to fully automated vehicles, variability in driving behaviour will probably be large, resulting in an increased risk of crashes between CAVs and human driven vehicles.

Transition of control
Transition of control concerns the switch from fully automated driving to manual driving while in traffic. From the literature review (Weijermars et al., 2021) it can be concluded that take over requests lead to increased reaction times, reduced time-headways and an increase in collisions. Other potential risks related to transition of control include mode confusion, the uncertainty of human drivers of the current capabilities of the vehicle and the possibility to circumvent systems designed to check if the driver is engaged such as hands-on-wheel detection.

Indirect impacts
Next to the direct (or primary) impacts on road safety, CAVs also affect road safety indirectly, via impacts that in their turn have an effect on road safety. These indirect effects are:

- Road safety impacts caused by other road users adapting their driving or crossing behaviour due to automated vehicles
- Road safety impacts caused by an increase in distance travelled by (automated) cars, for example caused by CAVs driving around empty
- Road safety impacts resulting from a modal shift
- Road safety impacts resulting from changes in route choice
- Road safety impacts resulting from infrastructural changes like better road markings or removal of parking spaces.

3.5.1.2 Quantification of impacts

Not all impacts that are discussed in the previous section could be quantified within LEVITATE. It was not possible to make a reliable estimation for potential new risks and risks related to transition of control were not taken into account as the pragmatic choice has been made to focus on level 5 automated vehicles. Moreover, not all indirect impacts are taken into account in the quantification.

Improved driving behaviour as well as indirect road safety impacts resulting from a modal shift are quantified within LEVITATE. These impacts are quantified by applying a combination of methods. A major part is played by the microsimulation environment AIMSUN NEXT. One important limitation of the microsimulations done in Levitate is that vulnerable road users are not included in the applied microsimulation model. As CAVs are expected to affect crashes between cars as well as vulnerable road users, it was decided to estimate the latter based on crash statistics. The microsimulation and the crash statistics based approach result in expected changes in crash rates. These expected changes in crash rates are combined with expected changes in distances travelled by travel mode to estimate the expected change in the number of crashes.

Microsimulation
AIMSUN NEXT was used within LEVITATE to estimate impacts of CCAM developments on traffic and was also used to estimate the impacts of reduced reaction times and driver variability on road safety. The Surrogate Safety Assessment Model (SSAM) was used to analyse road safety impacts. SSAM performs statistical analysis on vehicle trajectory data and provides information about the expected number and severity of conflicts, i.e. instances where the so-called Time To Collision (TTC) is lower than a threshold value. As CAVs are expected to have a lower reaction time than human driven vehicles, the threshold value for TTC are set lower for CAVs than for human driven vehicles. On the basis of literature, the TTC thresholds were set to 1.5s for human-driven vehicle, 1.0s for 1st generation AVs and 0.5s for 2nd generation AVs. The estimated numbers of conflicts were converted into estimated numbers of crashes, based on an approach developed by Tarko (2018a,b).

Impacts on crashes between motorised vehicles were estimated for increasing penetration rates of 1st and 2nd generation CAVs (baseline scenario) and for all the SUCs defined in Levitate. This section only discusses the baseline results. Similar to the other impacts, impacts were estimated for increasing penetration levels of 1st and 2nd generation CAVs. Moreover, impacts are estimated for three calibrated and validated networks: Manchester (UK), Leicester (UK), and Athens (GR).
Figure 3.7 shows the estimated changes in crash rates for these three networks. It should be noted that goods vehicles and conflicts with TTC ≤ 0.1 sec could not be adequately modelled and are thus removed from the analysis. For more information see Weijermars et al (2021).

Figure 3.7 shows that crash rates (number of crashes per simulated km travelled) decrease with increasing penetration levels of CAVs. At 100% penetration of 2nd generation CAVs, crash rates are estimated to decrease by 87% in the Manchester network, 92% in Leicester, and 68% in the Athens network.

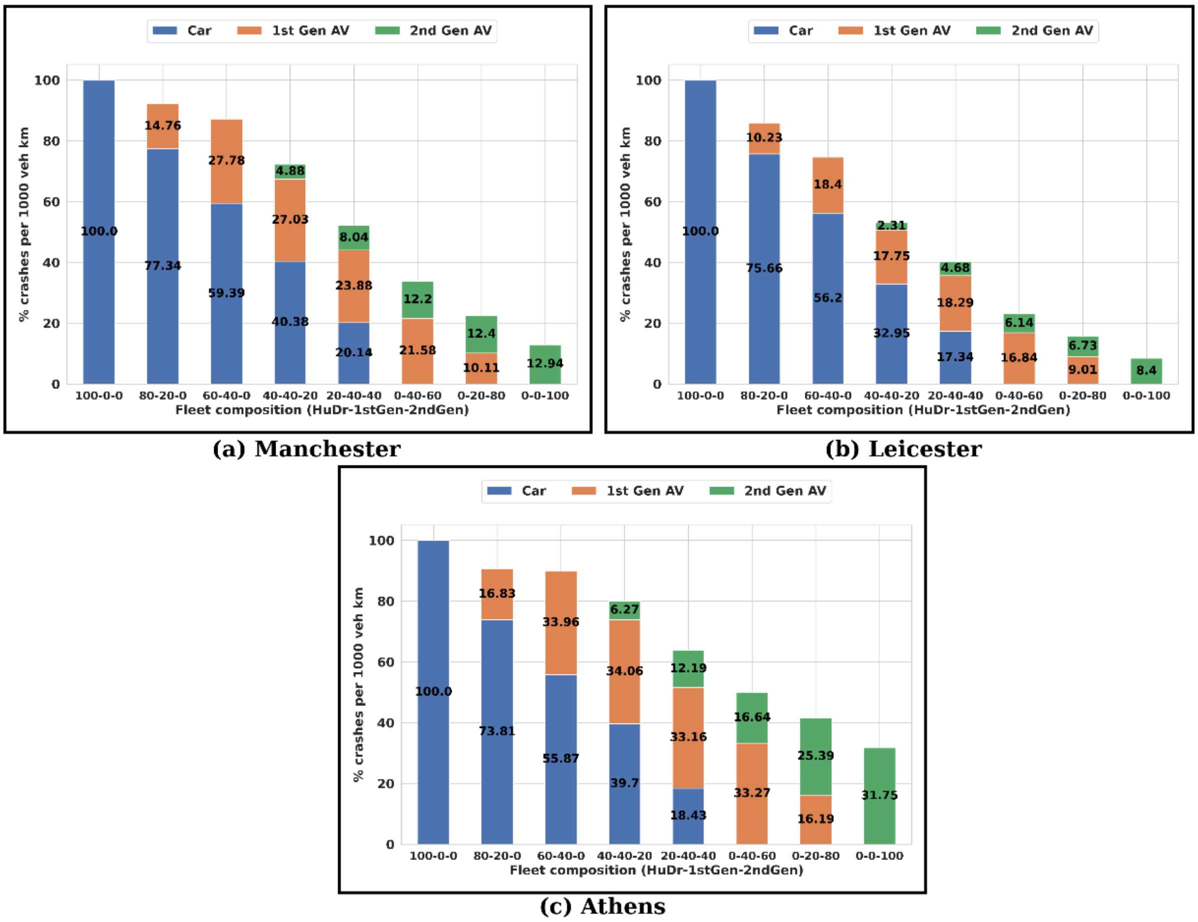


Figure 3.7 Percentage change in crashes per 1000 veh-km travelled with vehicle type based on varying MPR
(a) Manchester, (b) Leicester, (c) Athens

Vulnerable road users

One important limitation of the microsimulations done in Levitate is that vulnerable road users were not included in the applied microsimulation model. As CAVs are expected to also affect crashes between cars and vulnerable road users, it was decided to estimate the impact on these crashes by using crash statistics and the following assumptions:

- All crashes caused by human driven vehicles can be prevented by CAVs
- All remaining crashes (i.e. those caused by non-motorised traffic) are less severe when CAVs are involved – due to lower collision speeds resulting from lower reaction times

The share of crashes for which the pedestrian or cyclist is registered to be 'at fault' differs between cities and countries. On the basis of the available data we assumed for our estimate that 30% of all crashes are caused by VRUs. Moreover, it was also assumed that vehicles travel at an average speed of 40 km/h. The additional impact of lower collision speed is estimated by applying the power model proposed by Cameron and Elvik (2010).

Table 3.7 shows the expected proportion of crashes remaining for different penetration levels of 1st and 2nd generation CAVs. When applying the discussed assumptions. it is expected that 91% of the fatal crashes between VRUs and cars can be prevented at 100% penetration level of 2nd generation CAVs.

Table 3.7: The proportion of crashes remaining for different penetration levels of 1st and 2nd generation CAVs

Baseline Step	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Human	100%	80%	60%	40%	20%	0%	0%	0%
1st Gen AV	0%	20%	40%	40%	40%	40%	20%	0%
2nd Gen AV	0%	0%	0%	20%	40%	60%	80%	100%
Proportion crashes remaining	1.0	0.84	0.67	0.49	0.3	0.12	0.1	0.09

Indirect impacts and overall impacts

Impacts of increasing penetration levels and SUCs on distance travelled and on modal split were also estimated within LEVITATE by using system dynamics, meso-simulation and the Delphi method. These results were combined with the estimated changes in crash rates to estimate the final impacts on the number of crashes.

Because the expected changes in distance travelled by mode was only available for the Athens network (for the baseline scenario), the overall road safety impact for the baseline scenario is only estimated for Athens. The results are shown in Figure 3.8

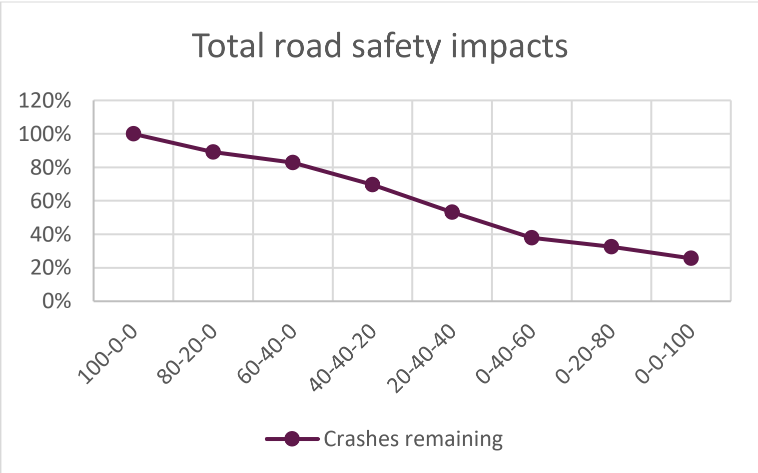


Figure 3.8: Total impact on road safety

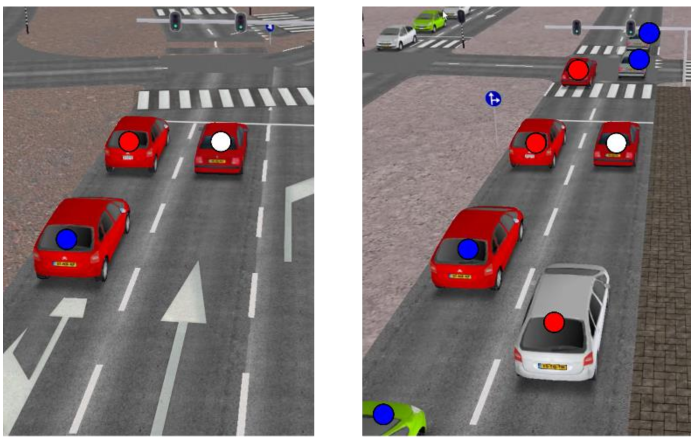
3.5.2 Driving simulator study: changes in driving behaviour human drivers

As mentioned in previous sections, CAVs are expected to behave differently than human drivers. More specifically, CAVs are expected to adopt smaller time-headways, have smaller reaction times, stricter speed control and less speed and lateral variations for compared to human drivers. These aspects of automated vehicles could be imitated by human drivers, influencing their driving behaviour. In order to investigate the effects of the increasing penetration rate of automated vehicles on the driving behaviour of the other road users and potential needed adjustments to driver behaviour models used in microsimulations a driving simulator study was set up. Originally, the idea was to link the driving simulator to the AIMSUN microsimulation mode to ensure the exact same behaviour of vehicles in the driving simulator as in the microsimulations. Unfortunately, this approach turned out not to be feasible within the available time. Moreover, as the simulator study had to be extended due to COVID restrictions, it was not possible to include the results of the simulator study in the microsimulations that were carried out in Levitate.

Study set-up
The performed study uses a within subjects design with the three conditions (0%, 50%, and 100% AVs) presented in a random order. A total of 32 participants were recruited online and participants were accepted into the study if they had a driving license for at least 5 years at time of recruitment and had no prior history of simulation or car sickness. Despite the check for known history of simulator sickness a total of 15 participants were unable to finish the full study due to feelings of sickness.

A fixed base driving simulator was used for data collection. In order to ensure that the driving behaviour of the other traffic in the driving simulator matches the modelled behaviour of AVs and human drivers in the AIMSUN NEXT microsimulation model, a series of adjustments was made to the existing driver behavioural models of the driving simulator.

All participants drive three times the same route, exposing them to three different conditions (0%, 50% 100% AVs in a random order). During each drive, two predetermined traffic events (see Figure 3.9) of interest occurred. In the first event, the participant was stopped at a traffic light with 2 vehicles in the lane next to the participant. The second event consisted of a straight section of road where the participant was surrounded by other traffic at cruising speed. These events were selected because they put the participant next to other traffic but still allow free choice of speed.



a b

Figure 3.9: Events encountered during the test trial in the 50 percent condition (standstill event on the left (a), cruising event on the right (b)). White dot: simulator car, red dot: simulated human vehicle and blue dot: AV. Colours of the vehicles were randomized during the test trials

Results
For each participant, the driving behaviour was compared between the three different drives. Analysis focussed on several dependent variables that relate to reaction times, lateral and longitudinal control and control of the vehicle.

For the standstill event at the traffic light, several significant effects were found. Participants showed lower reaction times to green light and a shorter time until maximum acceleration when the vehicles in the neighbouring lane consisted of AVs. So, the behaviour of the participants changes to more closely resemble the behaviour of the AVs.

For the cruising condition, participants adopted significantly smaller time-headways and lead distance when surrounding traffic consisted of more AVs. Moreover, the speed difference with the vehicle in front was significantly smaller in the conditions with higher penetration rates of AVs. Mean speed increased as the percentage of AVs increased with participants driving on average below the speed limit during all conditions. Speed deviations showed significant reduction when comparing the 0% condition with the 100% condition.

3.6 Findings on case studies

The aim of Case Studies (CS) was to address specialized topics in the WPs 5,6,7 that are beyond the scope of the SUCs. SUCs are considered from a more general perspective in order to showcase the methodologies developed in LEVITATE. Since the SUC results are used for the PST estimator, they are subject to a standardized output for the different impacts dimensions so that they are incorporated into the dynamic PST estimator tool. For these reasons, the scope of the SUCs is limited.

For the CS we lifted these limitations to address scenarios and settings that are too specific for SUCs, or we considered impacts that are not part of the PST estimator. For these reasons, we performed a total of six CS, two for each of use case. All CS are described in detail in the corresponding documents of the PST knowledge module and in the deliverable D8.3 (Hu et al. 2022).

- **Urban transport** (WP5):
    - Last mile shuttles (Vienna)
    - Automated ride sharing (Leicester)
- **Passenger cars** (WP6):
    - Road use pricing (Vienna)
    - GLOSA – Green light optimal speed advisory (Leicester)
- **Freight transport** (WP7):
    - Automated delivery and automated consolidation (Vienna and Manchester)
    - Platooning on urban highway bridges (Vienna)

3.6.1 Last mile automated shuttle service

The last mile automated shuttle service is implemented as a demand responsive transport (DRT) in a way that the operational areas of the shuttles are reduced to smaller zones in the periphery of the city. In each zone, there is a good train and/or metro station that provides a frequent connection to the city centre. The shuttle service is not allowed to travel to other zones to avoid trips across the city. The desired effect of this restriction is that the shuttle service is mainly used in combination with public transport, although use for monomodal trips within the zones is not prohibited.

The introduction of a shuttle service is a typical "pull" measure as it increases the attractiveness of public transport without reducing the attractiveness of owning a car. The introduction of last-mile shuttles is likely to require financial support from the public sector, as no private operator will voluntarily restrict its business to the generally less lucrative urban periphery. The mesoscopic simulation integrates the simulation of rebound effects, such as induced transport demand due to better traffic flow. However, other effects, such as pursuing activities in other locations or moving to other places, are not considered in the simulation.

Figure 3.10 shows for the district Simmering in Vienna the modal shift when the DRT as last mile automated shuttle service is implemented. The main mode of most of the trips remain the same. Beside car (AV2) and public transport, the shift from walking and bicycling trips is significant, since many trips within the district are replaced by DRT. When DRT is considered as part of the public transportation, this segment will increase substantially compared to the baseline.

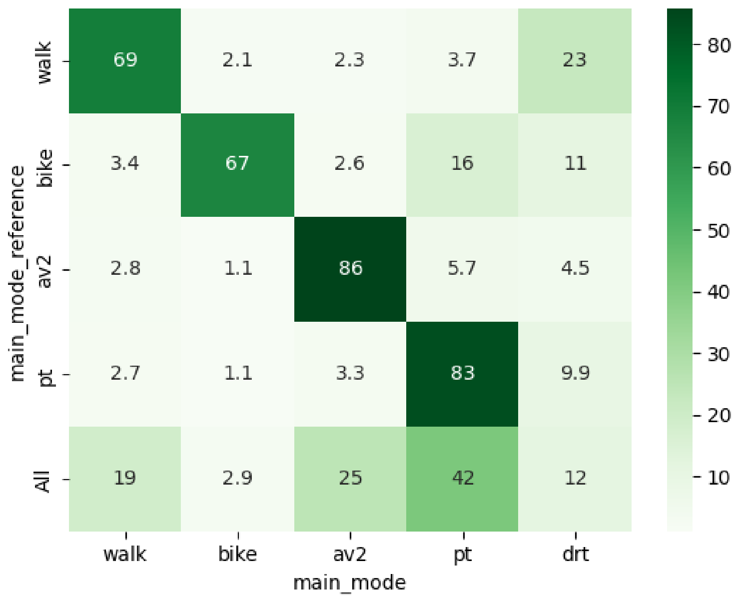


Figure 3.10: Modal shift for last mile automated shuttle service implemented in Simmering.

The scale is in percentage of trips in relation to the reference mode (indicated in the row)

3.6.2 Automated ride sharing

Automated ridesharing (ARS) service is a significant intervention due to the importance of potential impacts that could result from combining automation and on-demand shared mobility services. Impacts on vehicle ownership, congestion, land use, modal shift and emissions may be of particular interest to various stakeholders, such as transport planners, service operators, and cities, to assess the societal effects and evaluate the costs in relation to benefits. For this case study, an automated ride-sharing service that provides door-to-door service was considered.

The ARS is evaluated using microsimulation modelling based on the city centre network of Leicester and Manchester. The impact of this service was analysed under short term deployment scenarios where AVs are integrated into a ride-sharing service and share the road with conventional vehicles, i.e., analysing the current situation with ARS.

The impacts of both scenarios are analysed under different levels of demand that the ARS could serve and compared with the current situation (baseline scenario) through both networks. The passenger preference to use the service for individual or shared rides (i.e., willingness to share (WTS)) was also considered in the implementation of this SUC. The impact of the proposed service was studied under different combinations of demand rates that will be served by ARS and different levels of passenger WTS in order to identify the effect of these factors on mobility, safety, and the environment.

A critical component is the fleet size to serve the mobility demand. Table 3.8 shows the results for the Manchester and Leicester network for the different passenger WTS. The results indicate that the fleet size required to replace conventional personal vehicle trips gradually decreases as more passengers are willing to share their rides. Regarding SAV driven kilometres, the results show that a higher WTS reduced the total and empty travelled distance covered by the SAV fleet in both networks. The results also revealed that with a higher WTS, the empty driven kilometres will be gradually decreased.

Table 3.8: Optimisation results for Manchester and Leicester network

Network	No of trips	Willingness to share	Optimal SAV Fleet size	SAV Replacement Rate *	SAV Total Driven km	Empty driven km
Manchester	1134	0%	682	1,66	5,924.95	2,998.50
		50%	570	1,9	5344,72	2435,30
		100%	435	2,6	4420,16	1554,17
Leicester	937	0%	730	1,28	3792,63	2084,05
		50%	663	1,41	3574,37	1880,42
		100%	547	1,71	3167,84	1529,42
(*) Number of personal vehicles replaced by one shared AV (SAV)						

3.6.3 Road use pricing

Road-use pricing (RUP) refers to charges for the use of infrastructure, including distance and time-based fees, road tolls and various charges with the scope to discourage the access or long-stay of vehicles within an area. The different scenarios are based on

1) varied tolling charges,
2) dynamic or static tolling,
3) specific adaptions to the pricing levels based on

a) residential status of car owners in the tolling area and
b) the classification of roads as side-roads.

For each of these scenarios, the deployment of two driving profiles for automated vehicles (i.e., first and second-generation AVs, with the former being more conservative while the latter are expected to be more aggressive) is tested for four different vehicle fleet compositions to represent the expected increasing prevalence of automated passenger cars along the timeline. Introduction of road-use pricing for passenger cars is a "push" measure as it decreases the attractiveness of using a car within the area of the tolling zone and its surroundings.

The results show that the zonal RUP measure extends its intended effects similarly into the environment of the tolling zone. These effects of a shift from passenger car use towards more sustainable modes of transport is slightly less strong for connected automated vehicles than for conventional cars. Exempting the residents of the tolling zone from toll payment leads to considerable rebounds, however, the optimal degree of such an exemption is a matter of more detailed traffic supply and demand considerations, as well as social equity. Road-class based tolling to discourage traffic in side-roads (e.g., residential areas) leads to significant amplification of key policy impacts even at moderate pricing levels and provides a finely tuneable tool for policy measure implementation. Table 3.9 and Figure 3.11 shows an example where the baseline scenario is compared to a realistic application for tolling. A significant part of car users is shifted towards public transport.

Table 3.9: Comparison of baseline scenario and a realistic application for tolling.

Scenario	Toll type	Toll level	Resident toll level	Toll side roads
Baseline	None	0 €	--	--
Tolling	Dynamic	10 €	0 %	200 %

Figure 3.11: Mode shift comparison of baseline and tolling scenario

3.6.4 GLOSA – Green light optimal speed advisory

GLOSA is one emerging vehicle to infrastructure application that optimises traffic flow on signalised road networks reducing simultaneously emissions. It is a significant technology-based intervention due to the important potentially positive environmental and mobility impacts. Smoother traffic flows, less congestion and reduced emissions constitute a promising basis for the various stakeholders, transport planners and cities, to be interested in assessing the societal effects and evaluate the costs in relation to benefits. To assess the performance of GLOSA system, the Aimsun Next microsimulation of a road stretch from Leicester city (UK) was used. Three fixed-time signalised intersections were chosen in the network with an intermediate distance of at least 300m.

The results show that the traffic performance indicators do not show any improvement with the implementation of GLOSA algorithm in low traffic conditions. The reaction time, GLOSA penetration rate, and other variables of the GLOSA algorithm become ineffective with low traffic conditions, which worsens some of the KPIs, for instance, emissions. The improvement of GLOSA can be observed in high traffic conditions. This is shown in Figure 3.12 as an example for traffic flow. It can be observed that the impact of GLOSA is negligible when the traffic volume is low. This is because at low traffic volume, vehicles can move at free flow speed and their behaviour are similar. Figure 3.13 shows the results for delays with different combinations of response delays and GLOSA MPRs. It can be seen that delays are lower when the response delay was 0s at higher GLOSA MPRs.

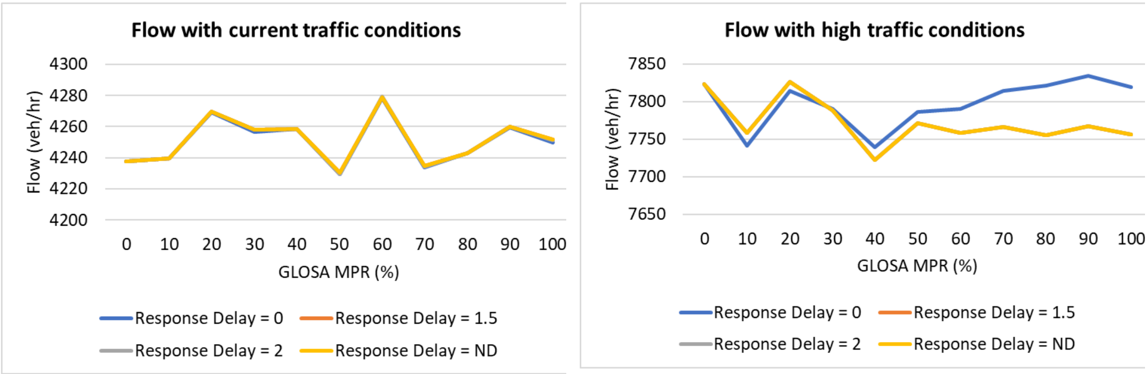


Figure 3.12 Traffic flow with current and high traffic flow

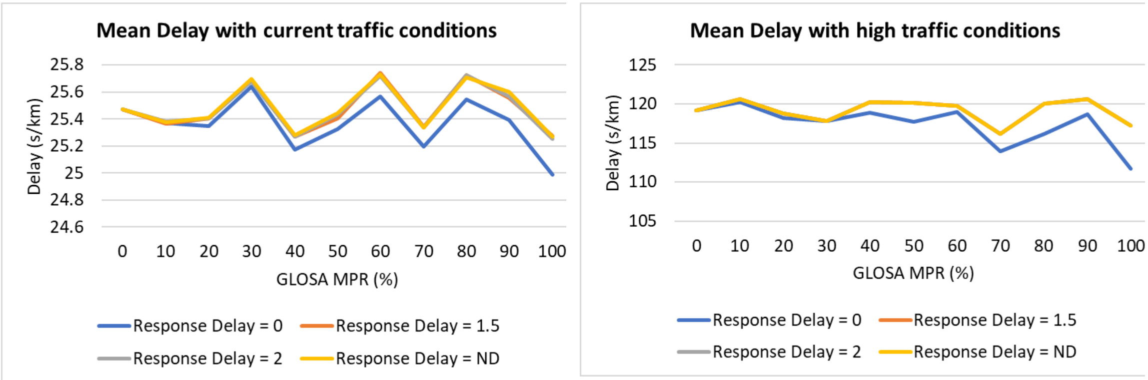


Figure 3.13 Delays with current and high traffic flow

3.6.5 Automated delivery and automated consolidation

Automated logistics will bring disruptive changes to the parcel delivery industry. The direct effect is that human labour will be replaced by automation, both for the driving task and the task of parcel handover. This could be achieved by the so-called 'robo-van' concept where an automated van functions as a mobile hub and small autonomous delivery robots perform short delivery trips to end-customers. On one hand, this system can utilise the off-peak hours and night for delivery where the road network is less crowded, despite increasing the total mileage of the delivery trips when compared to the current manual delivery system. The main reason is the assumption that the vehicle capacity will decrease due to the delivery robots and additional equipment. On the other hand, consolidation through city-hubs will reduce redundancy and therefore the freight mileage. Automated logistics will be a big support for the implementation of such systems since servicing the city-hubs can be automated and shifted to the night as well, which is not possible for conventional manual delivery systems nowadays.

Figure 3.14 shows for all delivery variants the total driven km per day. We see that on the one hand, the mileage is significantly shortened by the consolidated delivery via the centrally located city-hubs, and on the other hand, mileage increases due to the lower capacities of the robo-vans for automated delivery. Figure 3.15 shows a breakdown of freight mileage for different time periods of the day. While automated delivery generates more mileage, it is distributed over the full day, and even the rush hours 6am – 9am and 3pm – 6pm can be entirely avoided. The consolidation tours to service the city-hubs via trucks are done at 6am for the manual scenario and between 0am and 6am in the automated scenario.

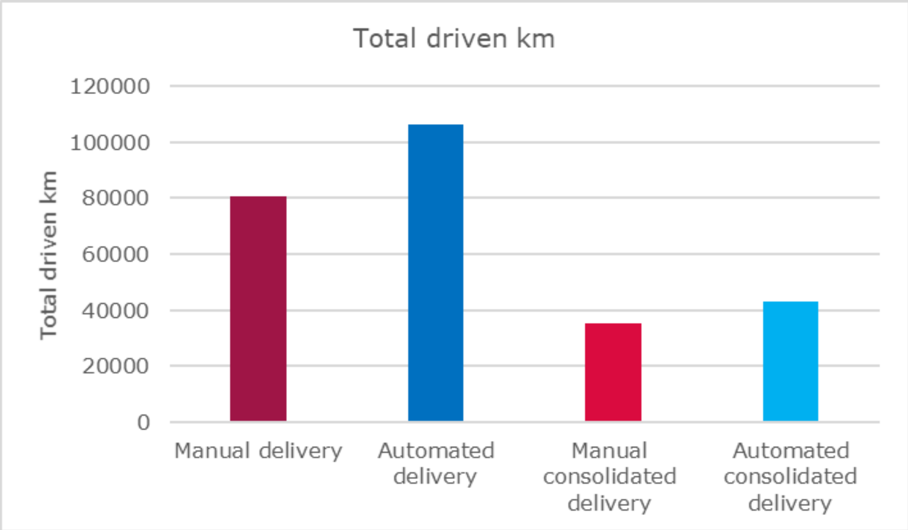


Figure 3.14: Mileage results for automated delivery and automated consolidation in Vienna

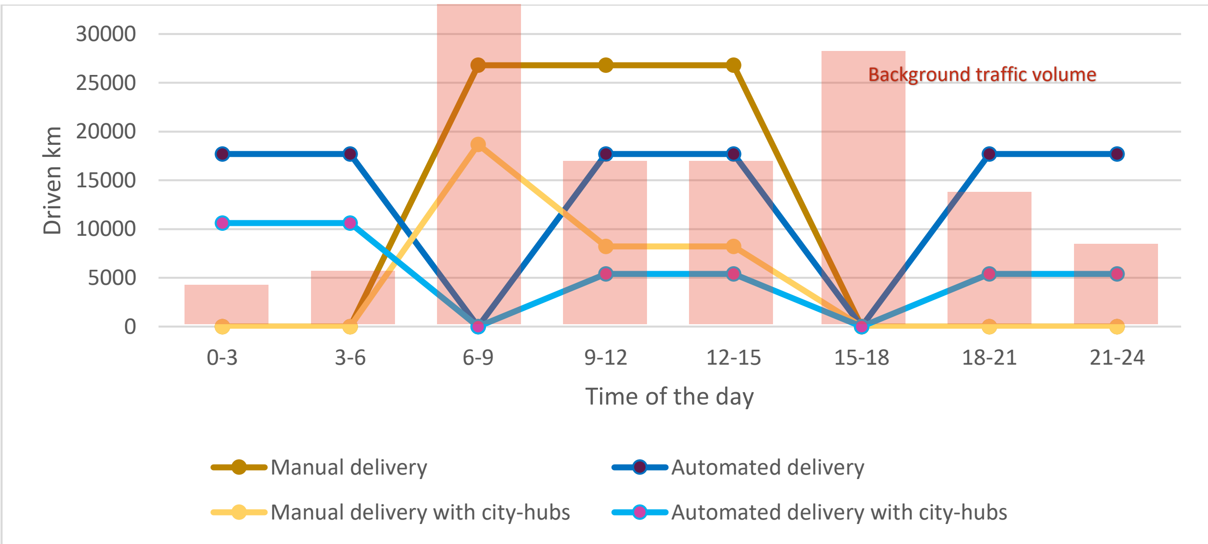


Figure 3.15: Chart for mileage (km) for each delivery scenario and breakdown to time of the day

Another goal of this study was to address the transferability of the methodology. When considering the primary output to be the total mileage, we want to identify the key factors that influence the output most. These are shown in Figure 3.16, which illustrates a qualitative chart of dependencies.

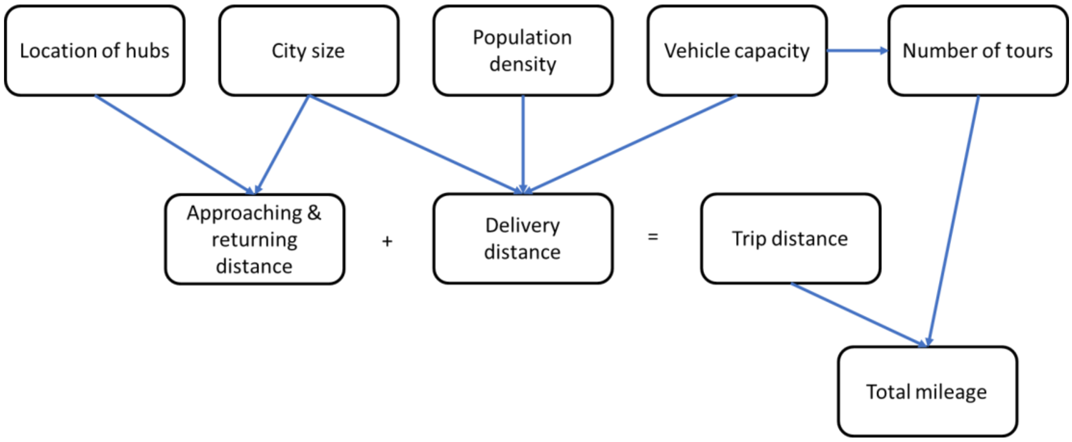


Figure 3.16: Key factors for transferability in automated delivery

The approaching & returning distance is the route of a delivery vehicle from the origin (distribution centre or city hub) to the delivery area and back, which directly depends on the location of the hubs and the city size. The delivery distance is the driven km within the delivery area, from the first parcel to the last one. This primarily depends on the size of the delivery are, the population / parcel density, and the vehicle capacity. Finally, the trip distance of each vehicle is the sum of its approaching & returning distance and the delivery distance. The sum of all trip distances results in the total mileage.

Following the correlations, a simplified transferrable approach can be summarised as the following steps:

1. Estimate the parcel demand
2. Identify the distribution centres and potential city-hub locations
3. Subdivide the city / region into areas (e.g., districts or postal codes)
4. Calculate the average approaching distance to the delivery areas
5. Estimate the average delivery distance w.r.t. population density for each area
6. Multiply average trip lengths with the number of trips for each area

This results in an approximation for the total delivery mileage, without the necessity to apply the tour calculations in detail.

3.6.6 Platooning on urban highway bridges

Automated driving enables the formation of truck platoons, with several trucks driving synchronously and using small vehicle distances (headways) in order to take advantage of the lower aerodynamic resistance of this formation. The traffic loads that are considered in the design of new bridges are derived from measured sequences of axle loads using statistical evaluations and extrapolating assumptions that consider future traffic. With traffic flows changed by the introduction of automated driving and truck platooning, the question arises, whether the load models used in bridge design are appropriate to represent the traffic loads in the new conditions. Another urgent question that arises with the introduction of truck platooning, is whether the existing bridges that were designed using current traffic load models can safely carry the new traffic flows.

The urban traffic simulated in this case study produces maxima of bridge internal forces, which were much less critical than with the previously simulated intercity traffic. For the most relevant limit states of bending moments (Figure 3.17) and shear forces in main girders, the results are optimistic. However, the effect of truck platooning on bridge internal forces is still significant and may cause an increase of their expected maxima. The results are optimistic in the sense that this increase is not likely to exceed the level of LM1 requirements, for which the bridges are designed. The situation is different in case of braking forces (Figure 3.18), where structural measures would be needed.

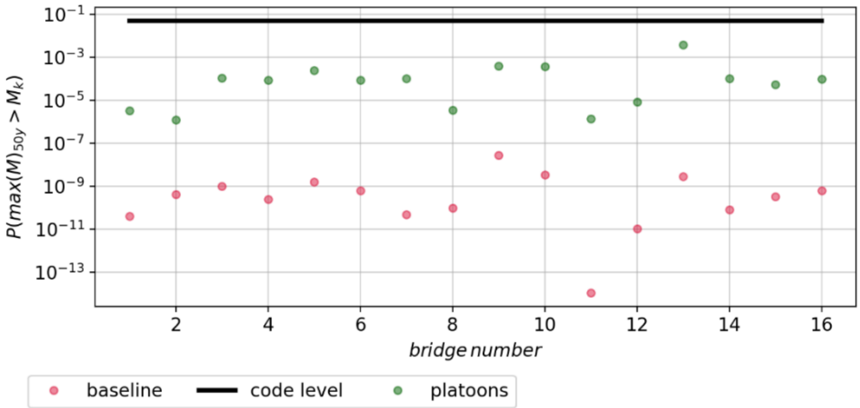


Figure 3.17: Probability that the 50-year-extreme of bending moment exceeds M_k

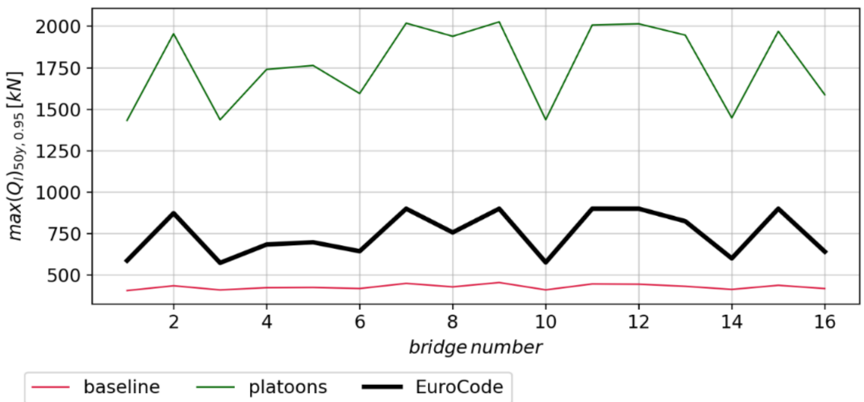


Figure 3.18: 95%-quantiles of 50-year-extremes of horizontal braking force

3.6.7 Associated deliverables

Table 3.10: List of deliverables that contributed to section 3.6.7.

D8.3	Application of the Decision Support Tool on Selected Use Cases	Continuation of the city dialogues in D4.3 with a quantitative evaluation of city measures as case studies.	All case study reports are summarised in this deliverable, which are more specific and detailled than the SUCs in WP5,6,7. They showcase the capabilities of the Levitate methodologies.

3.7 Transferability of Results

The generalizability/transferability of results produced within the Levitate project was examined through various experiments performed under different methods used within the project including microscopic simulation, mesoscopic simulation, system dynamics and operations research. The analyses provide useful insights towards transferability of results and can serve as guidelines on using them for different cities or study areas. To present an overarching view on the transferability of results within Levitate, the key findings from different methods are summarized as follows.

The experiments under microscopic simulation method showed that the results (on the impacts of AVs) can be considered transferable under homogeneous traffic composition with passenger vehicle fleets. Whereas, when results on AV impacts were analysed under mixed traffic composition (including passenger cars, freight, and public transport vehicles), the results were found to be not transferable under mixed traffic condition. Even under mixed traffic compositions, the trends were found to be generalisable; however, the percentage change/difference in results can be different among different networks due to network characteristics and demand composition.

Transferability of results analysis under system dynamics method was performed through investigating the validity of results by significantly changing one or the several of the model parameters. In this context, comparisons were made between 'original scenario' as used in the PST (based on SD model results) vs. 'shifted scenario' where shifted scenarios included considering (i). low modal split of public transport (was generated by doubling the value of travel time) (ii). High modal split of public transport (generated by doubling the travel costs for private car trips). The comparisons were made to reflect:

a. How the variables develop with increasing AV penetration rate (baseline), and
b. The influence of applying certain sub-use cases, also with increasing AV penetration rate.

In both cases, the impact (influence) of increasing AV rate as well as of the two policy interventions considered was not found to change very much for the shifted scenario. This result increases the confidence into PST predictions, where typically smaller shifts in the initial values would be expected. Further comparison between SD and PST results on shifted scenario also indicated that quantitative predictions of PST can only be trusted in a certain range of parameter values, deviating not too much from the default values.

The transferability experiments under operations research method, on cities of Vienna and Manchester, showed less than 2% error compared to the detailed results achieved by operations research. Even though, the calibration was performed based on these two cities, the accuracy of results on other cities is predicted to be 90-95%.

The transferability approaches used under different methods in this working paper are alternative to performing detailed calculations. Within a short amount of time, these approaches can estimate the results for other cities.

3.8 Cost Benefit Analysis

Cost-benefit analysis (CBA) is included in the PST as an add-on module. The CBA module applies the PST information, the matrices of initial impact values and annual changes over the period of 2020-2050; the matrices produced for the PST user-selected deployment scenario and its baseline scenario. The CBA adds monetary valuations to changes in impacts, valuing the changes from baseline to policy (Hartveit & Veisten, 2022). Transport kilometrage is a key driver of the CBA module; the CBA does not work without it. All valuations of impacts are either stated originally as €/km (most often €/vkm), or they are transformed from, e.g., original €/hour to €/km. The CBA module estimates the valuation of changes per "agent"; these agents comprise transport mode users, transport service providers, external effects (other infrastructure users and the community), and a "policy entity" to which the costs of policy implementation are allocated. The policy entity also collects tolls/fees and administrates land use. The calculations per agent and transport mode is a necessity, as all valuations are transport-mode specific and often different for consumers and providers. It adds complexity to the module, but it also adds more information about distributional effects of the selected scenario deployments. The CBA module yields monetised assessment of single impacts, e.g., the net present value (NPV) of travel time and delay changes. It also produces NPV for each specified agent. A virtue of the CBA is that it also estimates the overall NPV of the deployment scenario, for a given set of inputs, predicted changes, and valuations. Hence, the CBA can assess all impacts together on a common monetary scale.

The overall NPV of a project can be stated in a simplified way as: "The present value is a sum over the project period, in which the benefits and costs in future years are discounted. If the discounted monetised impacts are positive and greater than the discounted implementation costs, the NPV of the project is positive. The NPV expression above is for the whole period, but NPV can also be calculated per year or, in our transport project case, per vehicle km (vkm)." As indicated, when the PST user initiates the CBA module, it will provide a CBA for the selected deployment scenario in the PST (a single scenario or a combined scenario). Firstly, the CBA will present a simple NPV result emphasizing the agent(s) that the deployment scenario targets, e.g., automated urban shuttles, passenger cars, and/or freight delivery vehicles. The next result is a break-even analysis, showing how annual net benefits and cumulative net benefits develop over the period. Finally, the CBA module shows the distributional NPV results, per year and per vkm, distributed across impacts and across agents. The CBA module includes most of the impacts described in sub-chapter 4.1. But some impacts present in the PST are not quantified in a manner easily applicable to monetisation; e.g., access to travel, public health, and accessibility in transport. These impacts, and possibly others, might have had some weight in the CBA if included in monetary terms.

When looking at the NPV for particular impacts, we will expect that the CBA shows a fairly similar pattern to those presented in sub-chapter 4.1. Yet, the relative valuations of the different policy impacts, as well as the costs of implementing the deployment scenarios, will be of importance for the CBA results. Even if various impacts show a positive NPV, their relative value can be outweighed by other negative NPV impacts; and vice versa. And even if all impacts of a deployment scenario are positive, the costs of implementing the scenario might surpass the present value of all the benefits. The CBA module does not include a complete set of default costs of implementation; what is included comprises the hub costs for freight consolidation and hub-to-hub. Costs of implementation are not the same as negative impacts, the "negative benefits". Implementation costs are the costs of initiating the policy, e.g., the planning and preparation (labour costs) and, for some deployments, technical installations. In hypothetical examples shown below, most scenarios include a fixed start-up (investment) cost of €1 million and annual management/monitoring costs of €10,000 (in the EU-28 Euro value of 2020, EUR2020, 30,500 GDP/capita). The implementation costs do not comprise costs of vehicles; these are part of the impacts, more precisely the vehicle operating and ownership costs (voc).

3.9 Backcasting

One of the methodological pillars of LEVITATE is the backcasting framework that has been described in detail in the Deliverables of WP4 (Zach et al., 2019). In the context of this Deliverable, the main ideas are summarized in brief, and an outline of using the LEVITATE results for a backcasting perspective is given. The backcasting approach can be considered as assembly of the following basic steps: 1. Our starting point is to estimate the impacts of CCAM for various impact dimensions. 2. Coming from the opposite direction, a strategic "vision" of a city / region can also be broken down into quantified targets belonging to various dimensions (as has been discussed in section 2.1). 3. The intersection between such strategic vision and the possible CCAM impacts defines the policy goals where CCAM is expected to contribute and has been represented in the LEVITATE indicator framework – which is the base for the quantified impacts shown in the PST. 4. A second level of impact estimation is added now to steer the CCAM deployment by policy Interventions – on the left side in Figure Figure 4.1: various sub-use cases and policy interventions that have been considered for LEVITATE impact assessment. 5. Given that all these relationships and impacts (white arrows) have been quantitatively assessed, a conclusion from a defined vision (set of policy goals) to the most promising policy interventions gets possible (indicated by the red arrow) – this is the essence of the backcasting process.

4 Policy Support Tool

4.1 Associated deliverables

Table 4.1: List of deliverables that contributed to section 4.

D8.1	Integration of outputs of WP4-7	Decomposition of estimated impacts per different scenario, use case and time horizon along with integration of the impacts within combined use cases.	Development of an enhanced repository of impacts, costs and benefits, forming the basis of the knowledge module of the PST, as well as models, algorithms and other estimation tools bringing together the results of individual case studies in a combined way and enabling their feeding into the estimator module.
D8.2	Development of a decision support tool for the assessment of the impacts of CAV	Presentation of the PST development and testing, based on the data provided by D8.1.	Development of a system including a forecasting and backcasting estimator module, which provides impact assessment and cost-benefit estimates for various CCAM interventions and a knowledge module, which included case study and sub-use case results.
D8.3	Application of the decision support tool on selected use cases	PST application to specific examples in order to acquire quantifications of the expected impacts of specific CCAM interventions.	Specific use cases, which have been identified through the so-called backcasting city dialogues were considered in detail analysing the (future) city goals, then elaborating the influencing factors, and finally identifying the corresponding policy measures in order to reach the desired goals.
D8.4	Policy recommendations	Summary of key findings based on the impact assessment of CCAM technologies and services, performed within the project.	Identification of key factors with implications for future policymaking and recommended areas for deeper consideration to policymakers.

4.2 Description and main functions

The LEVITATE Policy Support Tool (PST) is an **open access, web-based system** that provides future users with access to LEVITATE methodologies and results. The PST comprises **two main modules**: the Knowledge module (static component) and the Estimator module (dynamic component). The knowledge module provides a static repository through fully detailed and flexible concise reports. The concise reports aim to inform the user in the most essential and summarizing way, offering the necessary information on CCAM impacts. The estimator module will provide estimates for different types of impacts and allow comparative analyses. It includes four pillars of analysis:

1. **Forecasting**, serving as the basis of predicting the quantitative and qualitative estimated impacts for different horizons,
2. **Backcasting**, serving as the basis of acquiring relevant policy targets for each impact area,
3. **Cost-benefit analysis**, serving as the basis of monetizing costs and benefits of CCAM interventions and
4. **Case study examples**, serving as a basis for documented applied paradigms of CCAM interventions within real-world environments at a city level.

The online PST is operational and can be found on the following **link**: https://www.ccam-impacts.eu/. The user can choose and navigate into each of the three PST components: the forecasting sub-system, the backcasting sub-system and the knowledge module of the tools, as presented in Figure 4.1

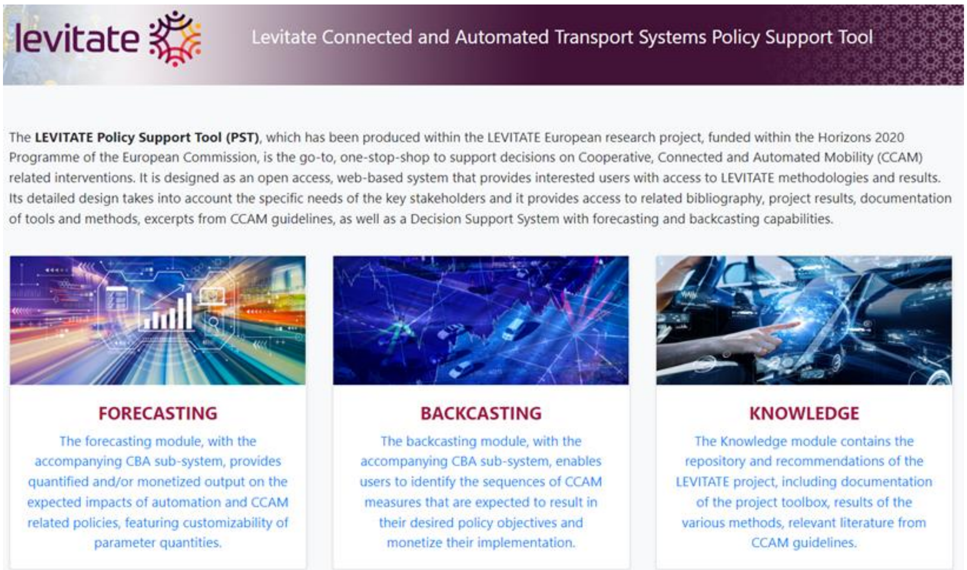


Figure 4.1: Online LEVITATE PST Home Page

The PST serves as an **integration** of the mathematical tools, approaches, data and results summarized in detail in D8.1 (Ziakopoulos et al., 2021), while the **development and testing** of the tool is discussed in D8.2 (Ziakopoulos et al., 2022). The LEVITATE PST is designed as a dynamic and interactive policy support tool, which can be used to support decision making related to the introduction of CCAM in the urban environment, and hence **short-, medium- and long-term impacts** (22 in total) that defined in D3.1 (Elvik et al., 2019) are comprised. Based on that taxonomy and on feasible paths of interventions defined by D4.3 (Zach et al., 2019) the impact assessment took place for the introduction of CCAM in urban transport, passenger cars and freight transport. The outcomes of the impact assessment are integrated in the LEVITATE PST.

The impacts have been estimated and forecasted using appropriate assessment methods suggested by D3.2 (Elvik et al., 2019). The **methods used** are the microscopic simulation, mesoscopic simulation, system dynamics, operations research and the Delphi method. The details of the methods and the impact assessment results for each use case are presented in the deliverables of WPs 5, 6 and 7. The short, medium and long-term impacts of CCAM on urban transport are presented in D5.2 (Roussou et al., 2020), D5.3 (Roussou et al., 2021) and D5.4 (Roussou et al., 2021), respectively. The detailed results of impact assessment in the sub-use cases of the automated passenger cars are presented in D6.2 (Haouari et al., 2021), D6.3 (Sha et al., 2021) and D6.4 (Chaudhry et al., 2021). Finally, the short, medium and long-term impacts of CCAM on freight transport are in detail presented in D7.2 (Hu et al., 2021), D7.3 (Hu et al., 2021) and D7.4 (Hu et al., 2021) respectively.

In order to enable the impact assessments, predefined **base scenarios** are established as per the PST development process, concerning the temporal distribution of the market penetration rates (MPRs) of connected and autonomous vehicles throughout the study period, which is from 2020 to 2050. These scenarios are part of the assumptions that have been made within PST development and attempt to identify the conditions of the area, which the PST user wishes to examine. It should be noted that these scenarios refer to the advent of CAVs in the traffic of the network regardless of any policy interventions that are or are not adopted by authorities. The base scenarios are the No automation, Pessimistic, Neutral and Optimistic and their visualization is displayed on Figure 4.2.

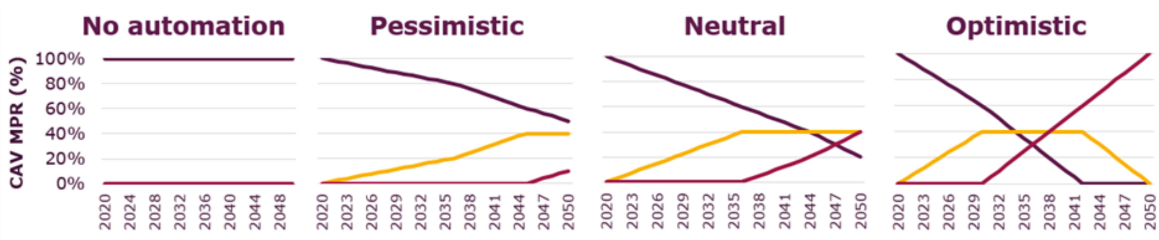


Figure 4.2: MPR development over time for each base scenario

Focusing on the LEVITATE PST components, the **Knowledge module** provides access to the knowledge base, repository and guidelines of LEVITATE project. The reports of the module differ in the documentation categories that essentially are the contents of the module as well as in different levels namely the cross project and use-case or sub-use case level. The **contents of the module** are the following:

1. Bibliography: the bibliography of all relevant literature concerning impact assessments of CCAM,
2. Project results: the methodology-obtained project results, including the overall transferable results and the case studies on the participating cities (scenarios and baseline conditions, results), as well as the predefined impact assessments,
3. Documentation of tools: the documentation about the toolbox of methods developed in LEVITATE, to enable cities to explore the expected impacts of CCAM in the users’ circumstances (including underlying models, data and impact assessment methods)

Figure 4.3: Knowledge module contents

In the online PST the user is has access to **six different types of documents** seen in Figure 4.3. Each section includes different documents. This categorization was decided in order to facilitate the access of the potential users. The "Project-level Documentation" includes documents referring to the whole project and the terminology developed in the first stages of the project. The "Impact Documentation" includes reports for the three categories of impacts studied in the project; direct, systemic and wider. The "Methodological Documentation" includes reports for the different impact assessment methods used throughout the project; microsimulation, mesoscopic simulation, Delphi, operations research, system dynamics and CBA. The "Use-case Bibliography Documentation" includes the outcomes of the literature review conducted before the impact assessments for each use-case; urban transport, passenger cars and freight transport. The "Sub-use Case Level Documentation", includes the literature review findings, as well as the characteristics of each sub-use case studied in the project and presented in the PST. Finally, the "Case Study Documentation" section includes the results of the case studies that took place to verify the PST results. When the user selects one of these sections, all the related documents are presented and can be directly downloaded.
The **Estimator module** provides estimates for different types of impacts (including cost-benefit ratios) and allows comparative analyses. The foundation of the estimator module was required to contain the databases from which the LEVITATE PST essentially draws inputs to conduct the calculations. These databases include data obtained from the horizontal methodologies implemented within the project (microscopic simulation, mesoscopic simulation, system dynamics, operations research and the Delphi panel method). The module includes two sub-systems:

1. **Forecasting sub-system**:
   - The main purpose of the forecasting sub-system is to provide quantitative estimates to users about the future impacts of policy interventions.

- In the forecasting sub-system, the user is able to select a policy intervention, define the required CCAM factors and the module provides quantified and/or monetized output on the expected impacts.
- In the sub-system, the capability of an intervention combination is also made based on a methodological basis drawn from the Crash Modification Factor (CMF) approach highlighted in the Highway Safety Manual and the respective CMF clearinghouse repository of the US Federal Highway Administration.

2. Backcasting sub-system:

- The main purpose of the backcasting sub-system is to provide a conclusion from a defined vision (set of policy goals) to the most promising policy interventions, given that all these relationships and impacts have been quantitatively assessed.
- A primary goal of the backcasting sub-system is to estimate the impacts of CCAM for various impact dimensions.
- Coming from the opposite direction, a strategic "vision" of a city/region can also be broken down into quantified targets belonging to various dimensions in the backcasting sub-system.

Both sub-systems include **Cost-Benefit analysis** estimators, which will quantify the efficiency of the selected policy interventions, in terms of changes in infrastructure user surplus, external costs, and the income change minus implementation costs (plus tax financing cost) for policy-making entities, which implement each considered policy scenario.

The PST user has to follow several steps in order to provide the **required inputs**, as shown in Figure 4.4 and Figure 4.5 of the forecasting and backcasting module, respectively.

Figure 4.4: User inputs of forecasting module

Figure 4.5: User inputs of backcasting module

In case of the forecasting module, the online **system output** are: a graphical representation of how the selected impact is affected by the introduction of the selected policy interventions (Figure 4.6), as well as tables including the detailed results for all the impacts and for all the studied years (2020-2050).

Figure 4.6: PST outputs of forecasting module

In case of the backcasting module, the online system output is a list of scenarios that can lead to the desired impact values (Figure 4.7)

BackCasting results for SCENARIO 2 - PESSIMISTIC (target year: 2040)

Without Policy Intervention

Impact ▲	Use case	SubUse case	Target achiev...	Difference
Travel time	FREIGHT TRANSPORT	Automated Consolidation	true	11.938
Travel time	PASSENGER CARS	Glosa	true	11.983
Travel time	FREIGHT TRANSPORT	Automated Delivery	true	11.938
Travel time	FREIGHT TRANSPORT	Hub2Hub	true	11.938
Travel time	URBAN TRANSPORT	On Demand Shuttle Bus Service	true	11.872
Travel time	PASSENGER CARS	On Street Parking	true	11.988
Travel time	PASSENGER CARS	Parking Price	true	11.965
Travel time	URBAN TRANSPORT	Shuttle Bus Service	true	11.872
Travel time	URBAN TRANSPORT	Shuttle Large Scale Network	true	11.872
Travel time	PASSENGER CARS	Automated Ride Sharing	true	11.983

Figure 4.7: PST outputs of backcasting module

4.3 Result interpretation

The LEVITATE PST is a **user-friendly, dynamic and interactive policy support tool**, which can be used to support decision making related to the introduction of CCAM in the urban environment. The online tool offers an easy-to-use and neat interface. Both forecasting and backcasting modules are available in the online mode and therefore not any download is required. Additionally, the tool provides the possibility of interactive use by comparing different aspects and reducing uncertainty during the decision making process.

In addition, the system is flexible transformed it simultaneously into a communication and planning tool, as the user is able to **customize multiple parameters** in order the results to be in-line with the test network or city. These parameters provide an initial basis for the formulation of the city network and they provide important finetuning capabilities to the PST user in order to **make the results relevant and transferable** to the area, which the PST user wishes to examine. Predefined values for each parameter not influenced by an intervention are available and the user is be able to change these values if needed. These default initial values do not explicitly represent any specific city network, however they give a preliminary attempt to identify the related parameters and suggest a respective range of values for each parameter. It should be mentioned that default initial values allow users to have an informed start, and an idea of what the range of inputs is expected to be for the PST.

To successfully conduct impact forecasting and backcasting with the LEVITATE PST, the user has to follow the sequence of steps outlined in the previous chapter. This entailed a process of several inputs, in the form of drop-down or free entry menus, and a 'Submit' execution order, in order to prompt the system to provide the desired output. In the **output process of the forecasting sub-system**, the user is able to submit the selection and initialize the impact assessment. In the impact assessment page, the user can choose the impact to be presented in a graph, along with the policy intervention scenarios and the policy implementation year. The graph presents the progress of the impact throughout the years with and without the policy intervention, so that the user can compare the results. In case that the user has chosen two measures, it will be necessary to select the first and the second policy intervention scenarios as well as their implementation year. In this case, the graph presents how the selected impact is affected by the introduction of the two selected policy interventions. Apart from the graph, the tool gives access to the user to the detailed results for all the impacts and for all the studied years (2020-2050). In the **results page of the backcasting sub-system**, a table is presented with all the studied policy interventions. If the desirable target for each impact is achievable for the target year, the system specifies it as "true" for the respective policy intervention, while in the opposite case, a "false" message is given.

The LEVITATE PST offers also the **necessary information** (Knowledge module) to the user in the most essential and summarizing way through fully detailed and flexible concise reports. As it is intended, the tool is designed as a sufficiently comprehensive tool with great potential to support decision-making. Policy makers, stakeholders as well as practitioners would use the PST in order to provide cities with the opportunity to prioritise policy interventions contributing in the no regret policy, and eventually to support changes in regulations. Finally, it is intended for specialist users to support city-level transport and mobility policy-making.

Finally, one of the key challenges of developing the LEVITATE PST is the **validation and transferability of results**. Naturally, the impact assessment approach adopted within LEVITATE has some limitations. A certain degree of uncertainty is underlying in every method, while this quantity is inherently different for each method. Additionally, each quantitative method has different parameters and is applied in a different city model, for example, the microscopic simulation considers the AIMSUN model for Athens or Manchester. Therefore, a series of case studies are also conducted within LEVITATE project in order to validate the methodologies and to demonstrate the system. Their results are part of the PST Knowledge module. In addition, the question of transferability of the identified impacts of autonomous vehicles derived from microscopic simulations is also addressed. A general framework for evaluating the impacts of CAVs in road networks is conducted and presented in a LEVITATE report of the PST knowledge module (Tympakianaki et al., 2022). The main contribution of the proposed approach was the applicability and transferability of the results to other networks.

4.4 Applying the PST

In this section, **numerical examples** of the forecasting and backcasting sub-systems described on the previous sections are given in order to clarify their operations.

The **forecasting sub-system example** concerns the impact assessment of the introduction of dedicated lanes of Connected and Automated passenger cars for a high CCAM deployment. The steps that the user will follow are the following:

1. Select the "PASSENGER CARS" use case from the drop-down options (FFigure 4.8).
2. Select the specific CCAM policy intervention as the "Dedicated Lanes" in the Sub-use Case drop-down options (Figure 4.8).
3. Define the CCAM deployment scenario, the high deployment scenario is the scenario 4 from the drop-down menu, the "OPTIMISTIC" scenario (Figure 4.8).

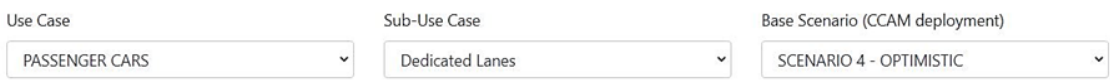


Figure 4.8: Forecasting sub-system example use case, sub-use case and CCAM scenario selection

4. Define parameters based on the data from the user city, to ensure that the results will be relevant and transferable.

In this example, the city parameters are different from the default values (Figure 4.9) and are the following:

- GDP per capita: 25000 €
- Annual GDP per capita change: 0.020%
- City population: 5 million persons
- Average load per freight vehicle: 2 tones

- Fuel cost: 15 €/lt
- Fuel consumption: 25 lt/100Km

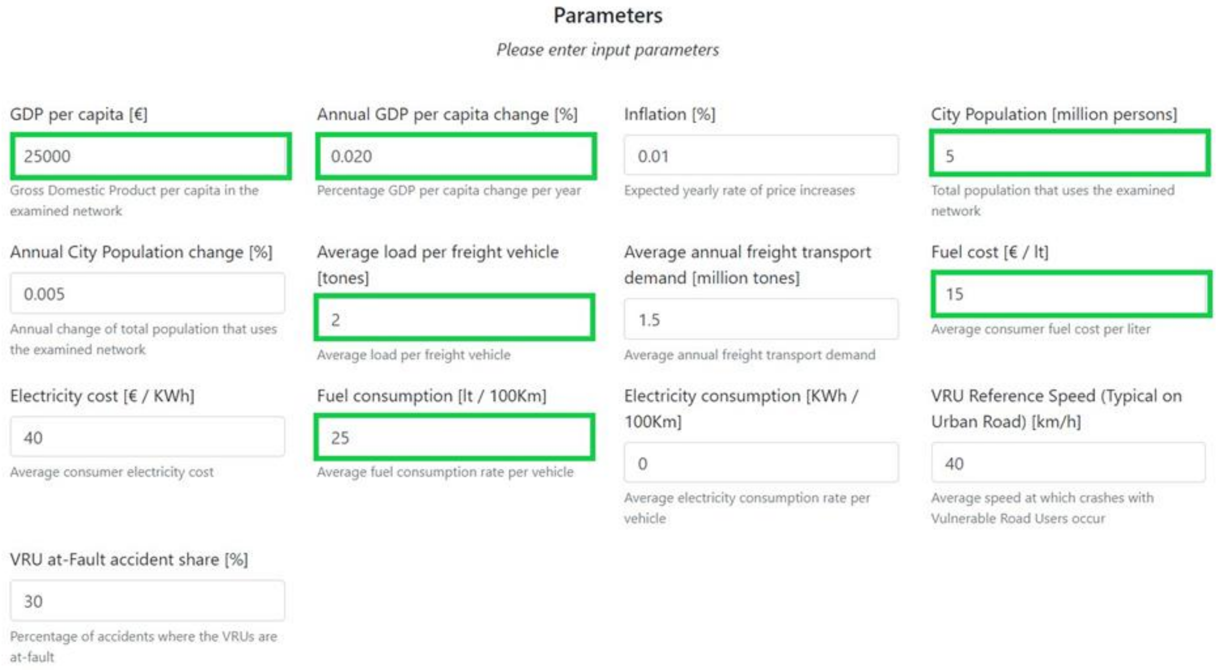


Figure 4.9: Forecasting sub-system example city parameters definition

5. Define the impact values based on the user city data.

In this example, the impact values different from the default values (Figure 4.10) are the following:

- Travel time: 10 min
- CO_2 due to vehicles: 2000 gr/vehkm

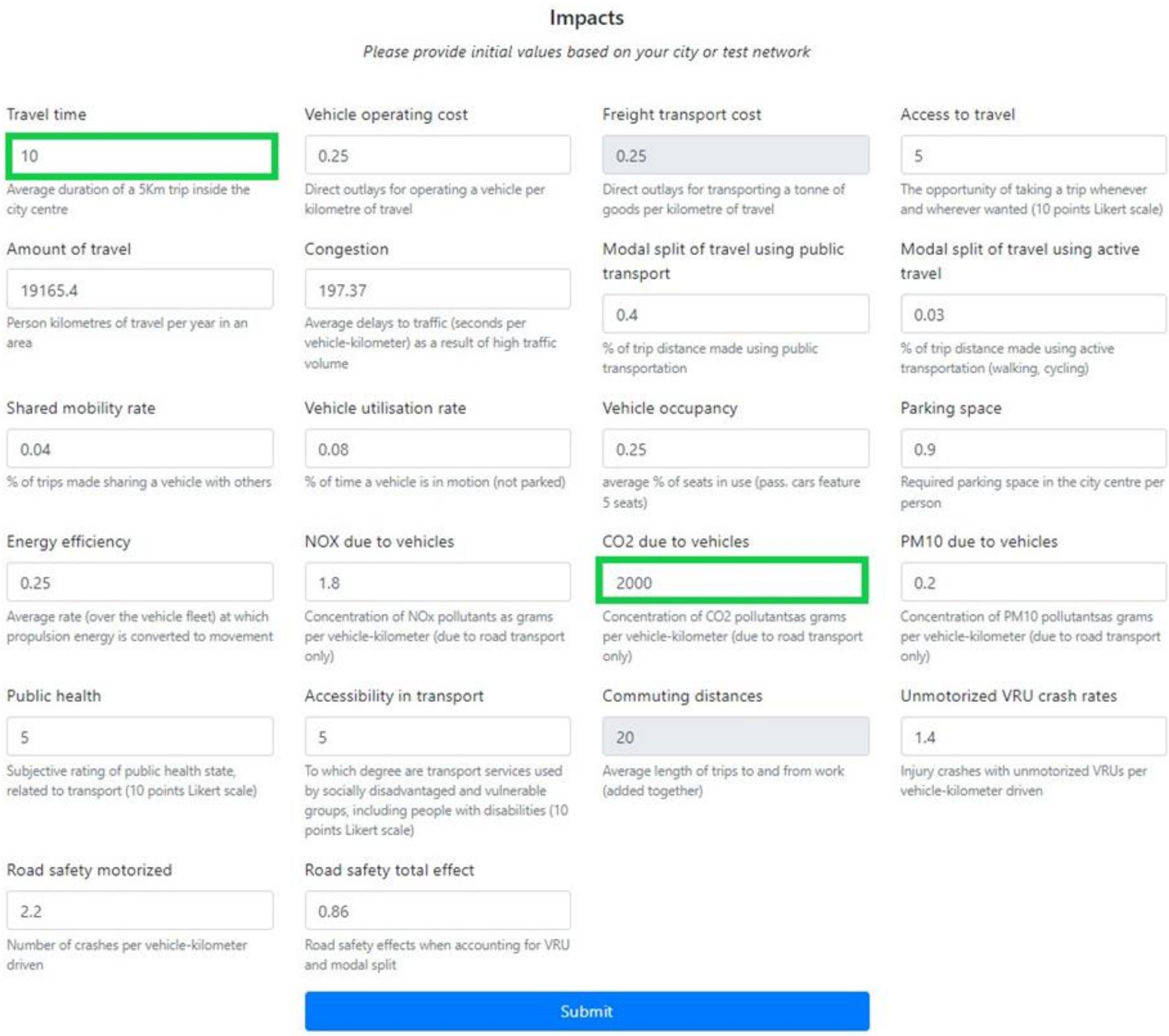


Figure 4.10: Forecasting sub-system example impact starting values definition

6. Submit the selection (Figure 4.10) and proceed to the results page.
7. In the results page the user will select the impact to see the graphical representation of results (Figure 4.11).
8. Select the scenario from the policy intervention drop-down menu, in this case the dedicated lanes on a “Motorway and A road” (Figure 4.11).
9. Define the implementation year of the policy intervention, in this example the year 2025 is selected (Figure 4.11).
10. In the graph, the user can compare the forecasted impacts on travel time of the baseline, without intervention, which is the grey line with the outcome of the selected policy intervention in the purple line (Figure 4.11).

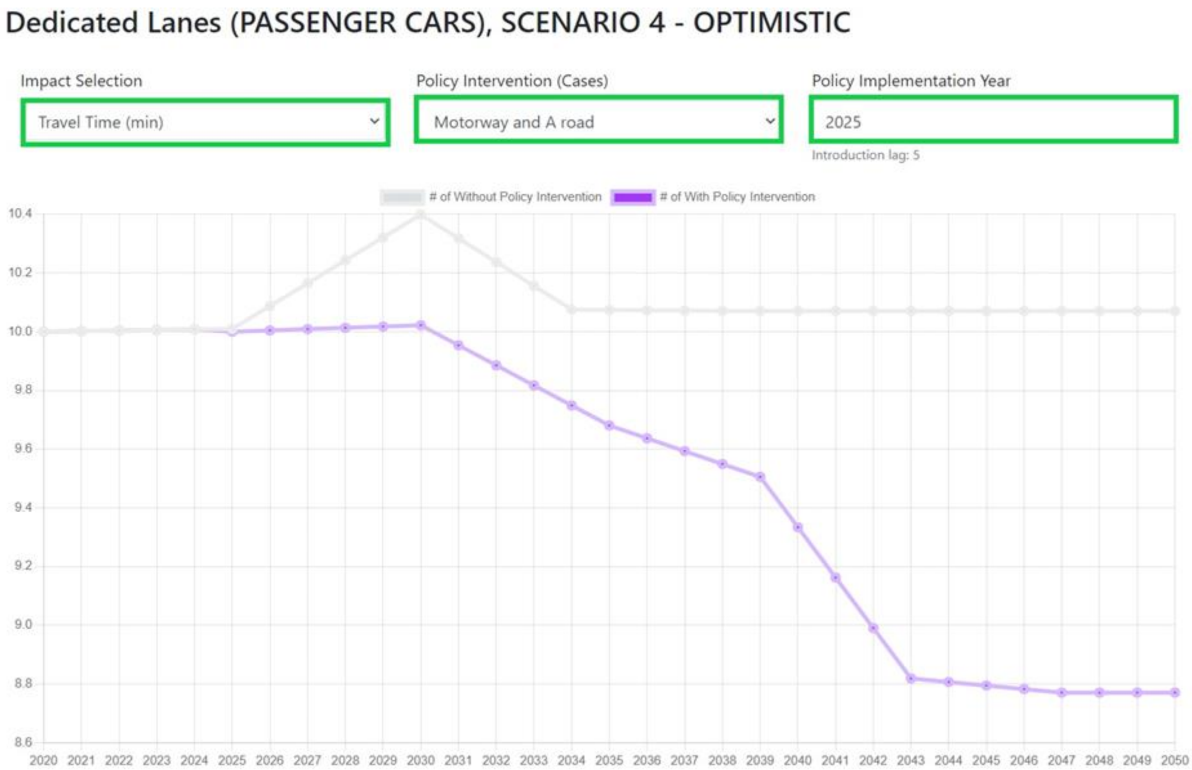


Figure 4.11: Forecasting sub-system example graph results

11. For more quantitative information, the user can look at the tables that show all impacts examined in LEVITATE and describe the percentage change of each impact from the initial value for each year in the 2020 to 2050 time-horizon (Figure 4.12).

With Policy Intervention - Motorway and A road

Type	id	Impact	Description	Measurement Uni
Direct impacts	1	Travel time	Average duration of a 5Km trip inside the city centre	min
Direct impacts	2	Vehicle operating cost	Direct outlays for operating a vehicle per kilometre of travel	€/Km
Direct impacts	3	Freight transport cost	Direct outlays for transporting a tonne of goods per kilometre of travel	€/tonne.Km
Direct impacts	4	Access to travel	The opportunity of taking a trip whenever and wherever wanted (10 points Likert scale)	-
Systemic impacts	5	Amount of travel	Person kilometres of travel per year in an area	person-km
Systemic impacts	6	Congestion	Average delays to traffic (seconds per vehicle-kilometer) as a result of high traffic volume	s/veh-km
Systemic impacts	7	Modal split of travel using public transport	% of trip distance made using public transportation	%
Systemic impacts	8	Modal split of travel using active travel	% of trip distance made using active transportation (walking, cycling)	%
Systemic impacts	9	Shared mobility rate	% of trips made sharing a vehicle with others	%
Systemic impacts	10	Vehicle utilisation rate	% of time a vehicle is in motion (not parked)	%
Systemic				

Figure 4.12: Forecasting sub-system example results table

The **backcasting sub-system example** concerns the desirable future vision of decreasing congestion from 197 delay seconds per vehicle-kilometre to 170 by the year 2030 for low CCAM deployment. The steps that the user will follow are:

1. Define the target year; in this case, the user will type "2030" in the corresponding cell (Figure 4.13).
2. Define the CCAM deployment scenario, the low deployment scenario is the scenario 2 from the drop-down menu, the "PESSIMISTIC" scenario (Figure 4.13).
3. Select the specific impacts that the user wishes to include in the backcasting analysis. There is the possibility of selecting up to five different impacts. For this example, only the "congestion" is selected from the drop-down options (Figure 4.13).
4. Define the desired future value of the selected impact(s). In this example, the future value of congestion is 197 seconds per vehicle-kilometre (Figure 4.13).

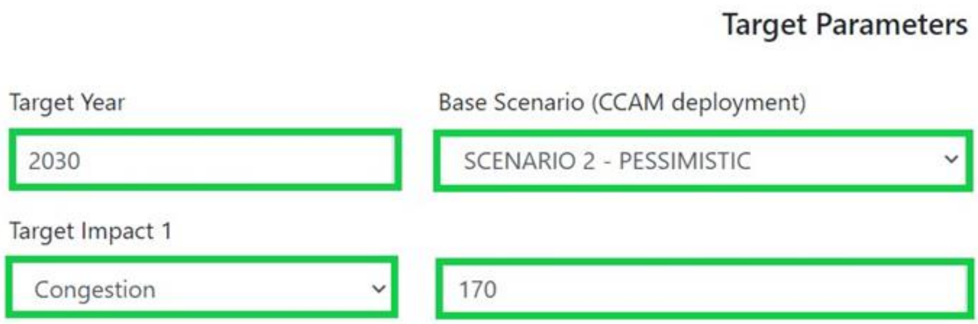


Figure 4.13: Backcasting sub-system example target year, CCAM scenario, impacts selection and desired values definition

5. Define the parameters based on the data from the user's city, to ensure that the results will be relevant and transferable.

In this example the city parameters different from the default values (Figure 4.14) are the following:

- GDP per capita: 25000 €
- Annual GDP per capita change: 0.020%
- City population: 5 million persons
- Average load per freight vehicle: 2 tones
- Fuel cost: 15 €/lt
- Fuel consumption: 25 lt/100Km

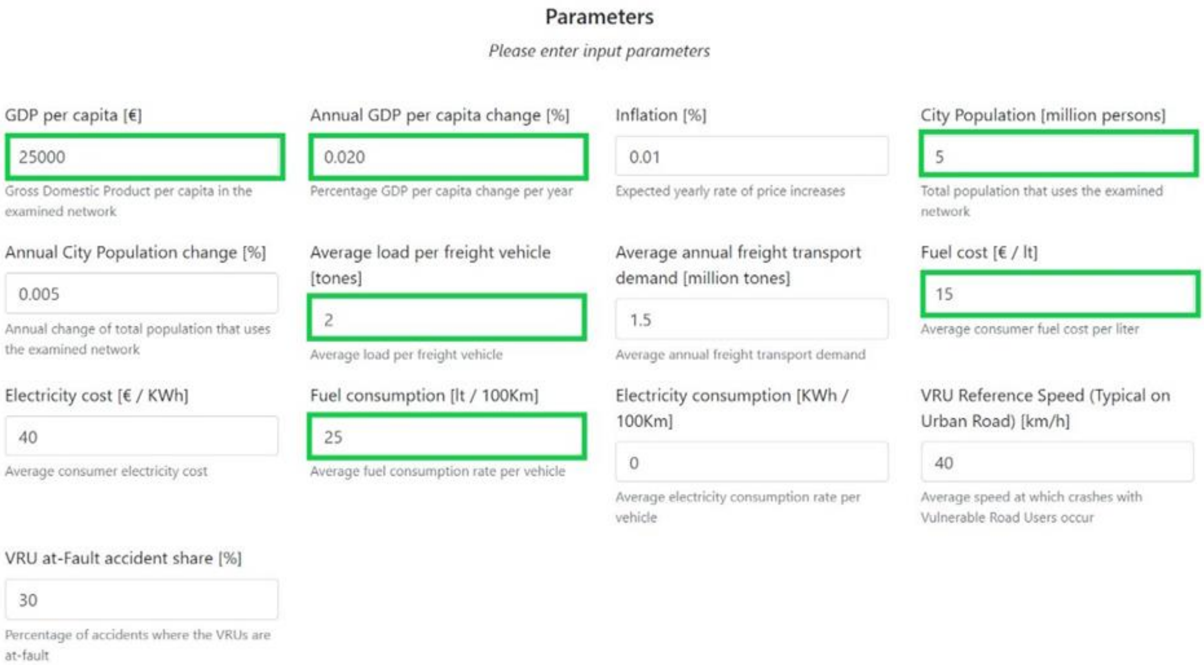


Figure 4.14: Backcasting sub-system example city parameters definition

6. Definition of initial impact values based on the user's city data. In this example, the initial impact values are not different from the default values (Figure 4.15).

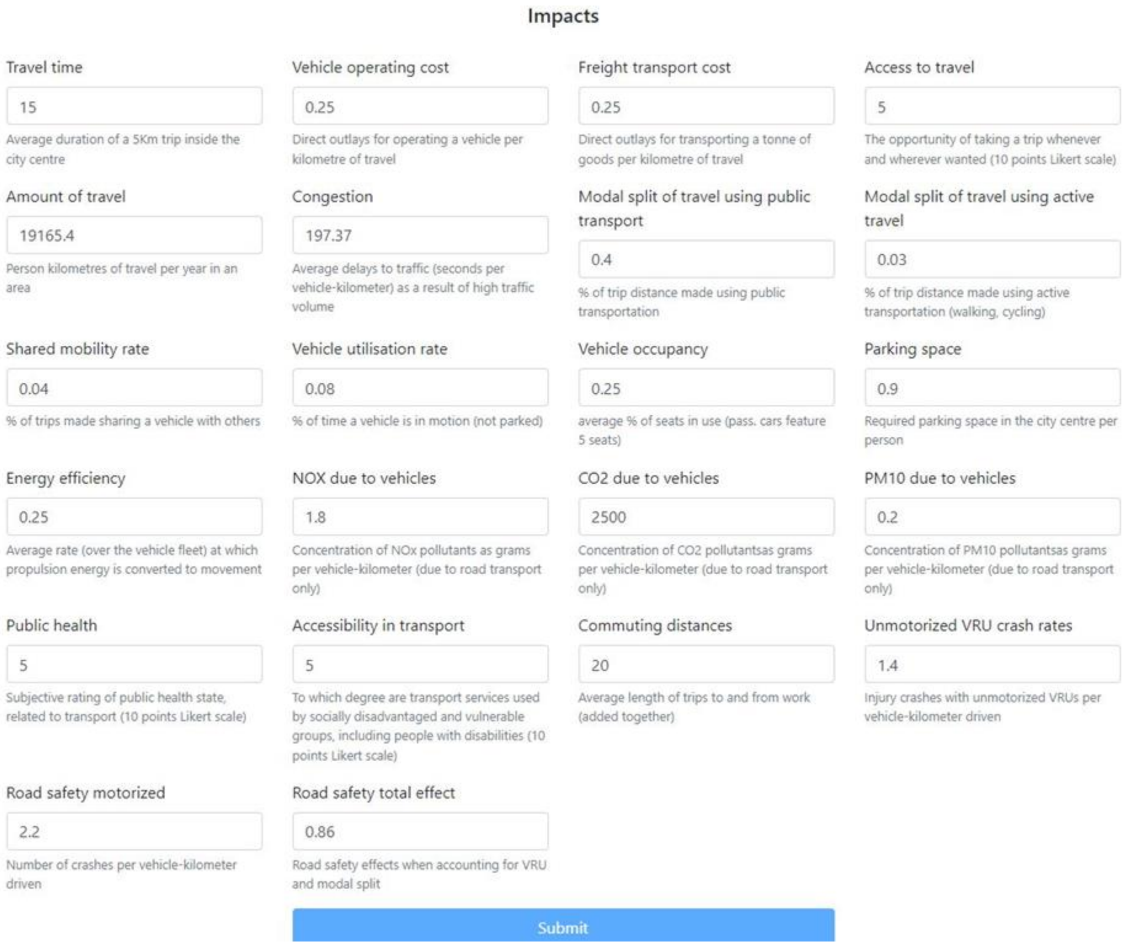


Figure 4.15 :Backcasting sub-system example initial impact values

7. Submit the selection and proceed to the results page (Figure 4.16).
8. In the results page a table is presented with all the studied policy interventions (4.16). If the desirable target for each impact is achievable for the target year, the system specifies it as "true" for the respective policy intervention, while in the opposite case, a "false" message is given. For instance, the targeted congestion can be achieved, with the baseline and GLOSA on 3 intersections (but not on 1 or 2). Looking at a different policy, the target is reached for the baseline as well as for the semi-automated Automated Freight Delivery but not the fully automated night delivery.

BackCasting results for SCENARIO 2 - PESSIMISTIC (target year: 2030)

Impact ▲	Use case	SubUse case	Policy intervention	Target from input
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Baseline	true
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Manual consolidated delivery	true
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Automated consolidated delivery	false
Congestion	PASSENGER CARS	Glosa	Baseline	true
Congestion	PASSENGER CARS	Glosa	GLOSA on 1 Intersection	false
Congestion	PASSENGER CARS	Glosa	GLOSA on 3 Intersections	true
Congestion	PASSENGER CARS	Glosa	GLOSA on 2 Intersections	false
Congestion	FREIGHT TRANSPORT	Automated Delivery	Baseline	true
Congestion	FREIGHT TRANSPORT	Automated Delivery	Semi-automated delivery	true
Congestion	FREIGHT TRANSPORT	Automated Delivery	Fully-automated night delivery	false

Figure 4.16:Backcasting sub-system example table results

5 Policy implications of CCAM

5.1 Associated deliverables

Table 5.1: List of deliverables that contributed to section 5.

D8.4	Policy Recommendations for Conected, Cooperative, and Automated Mobility	This deliverable presents the summary of key findings based on the impact assessment of Cooperative, Connected, and Automated Mobility (CCAM) technologies and services, performed within the Levitate project.	Purpose was to identify key factors, based on the findings, with implications for future policy making and recommends areas for deeper consideration to policymakers.

5.2 Policy implications

The following summarises the broader implications of various CCAM related policy measures, the key influencing factors for ensuring the effective and sustainable implementation, and hence, enables the selection of suitable policy options while minimising any adverse impacts. The detailed discussions can be found in the LEVITATE deliverable on Policy Recommendations for CCAM (LEVITATE D8.4, Chaudhry et al, 2022).

General issues

- CCAM services with similar names and broad approach may have very different impacts depending on the manner in which they are implemented.
- Future CCAM services and technologies may have a mixture of positive and negative societal impacts. Policy measures should be based on a full impact assessment in order to identify improved opportunities to achieve city policy goals or set measures to mitigate negative impacts. Depending upon network characteristics and fleet compositions, the early phases of CAV deployment with a mixed fleet of automated vehicles and vehicles with human drivers in the transport system can result in marginal decrease and in some cases increased conflicts and collisions. Local and national policies will be essential to monitor and mitigate these detrimental impacts during the transition phase.
- As advanced automated vehicles form the largest part of the vehicle fleet, it is anticipated that crash rates will reduce substantially below the current levels. When these vehicles meet or exceed the performance of humans it is expected that traffic impacts may improve beyond existing levels.
- Early generations of automated vehicles, which operate below the level of human driven vehicles with increased headways, highly cautious sensitivity to the detection of other road users– so increased stops - and therefore slower travel and increased delays, are expected to reduce the capacity of cities for traffic. City policies will be required to mitigate these impacts.
- The magnitude of the impacts of CCAM services and technologies is broadly in line with the fleet penetration. Small scale deployments are unlikely to result in a large impact at network level as these impacts remain dominated by the background traffic.

- Several policy measures that have been examined can bring positive environmental impacts; however, powertrain electrification has an overwhelmingly larger impact on emissions compared to the studied policy interventions
- Commonly any improvement in passenger car mobility through the increased automation will have the effect to reduce the use of public transport and active travel. Similarly, improvements in public transport will reduce personal car use and active travel. Automated ride sharing as well as last mile shuttle services are likely to negatively impact active travel with respect to the baseline scenario due to providing pick-ups and drop-offs closest to the origins and destinations of passengers, where last mile shuttles can potentially have much stronger impact on active travel than automated ride sharing.
- Close monitoring of the manner in which CAVs moved, their interactions within the transport network and a calibration of the societal impacts is essential to improve future impact forecasts and to prepare more effective interventions so that city goals can be achieved.
- The Levitate project has shown the benefits of conducting detailed impact forecasts based on a broad spectrum of modelling methods. The methods can be applied to other CCAM interventions and can also be adapted to evaluate real-world trials of CCAM services and technologies.

Economic cost-benefit analysis
All single interventions have been tested in cost-benefit analysis, applied to a hypothetical case area. Although lacking input about the costs of implementing the policy interventions, the following summarises the overall results in net present value (NPV).

- There is a considerable variation in NPV between the interventions and between the various implementation methods.
- Automated urban shuttle services, automated freight delivery and the implementation of GLOSA show routinely positive NPV, given relatively limited costs of implementation.
- Automated ride sharing (ARS) and the replacement of on-street parking show variable NPV results, in the case of ARS the proportion of the total demand and the willingness to share are critical factors.
- The introduction of road pricing within a CAV traffic environment will result in negative NPV; the gains in external environment and health impacts do not outweigh the increased costs to private car users, under the given assumptions.
- Even without policy measures, automation in freight transport will likely gain popularity once the technology is mature and the operating costs become cheaper than the costs nowadays.

Specific interventions
- **Road use pricing** can be a promising option for improving use of active modes and public transport with increasing prevalence of CAVs. The benefits from Road Use Pricing policy may be slower but will potentially lead to sustainable benefits. It is expected to lead to a number of additional benefits over the baseline impacts: better energy efficiency (dynamic toll more than static toll or empty km pricing), higher vehicle occupancy rate, and lower parking space demand.

- The implementation of **Dedicated Lanes for CAVs** shows small benefits for traffic until CAVs comprise the majority of vehicles in the fleet. The use of the innermost lane provides the greatest traffic and safety benefits.
- The optimum parking behaviour of CAVs can be managed by adjusting the **price of parking**. The scenario where a CAV drops passengers off then parks locally minimises impacts on travel time and congestion. Other scenarios where a CAV may return to base or park remotely will increase impacts because of the additional distance travelled.
- CAV parking that is remote from the drop-off location enables **on-street parking** to be replaced by public spaces or cycle lanes with associated benefits to travel delay and speed.
- **Green Light Optimised Speed Advisory (GLOSA)** systems in general showed small improvements in traffic impacts when used with fixed time controllers. Increasing the number of GLOSA controlled intersections on arterial roads resulted in small additional improvements in traffic impacts. The impacts need to be carefully assessed when human-driven vehicles comprise the largest proportion of traffic.
- The impact of **Automated Rideshare Services** depends heavily on the proportion of total demand fulfilled by the service and also the passengers' willingness to share with others. When fulfilling low levels of demand there are low, adverse impacts on traffic indicators and there are many empty journeys but, when there is a high willingness to share and a large part of the total demand are covered, traffic impacts become positive.
- Under all of the deployment scenarios examined the impacts of **Automated Urban Shuttle Services** were relatively low as the vehicles routinely formed only a small part of the total fleet. Most societal impacts were positive. However, care should be taken to prevent the anticipated unwanted impacts of these services, for example on the use of active travel modes. Anticipatory research and anticipatory and flexible planning approaches are recommended to prevent these negative developments.
- Freight vehicles also tend to be a small proportion of the total fleet nevertheless **Automated Urban Freight Delivery** services provide many positive benefits. Automated freight vehicles that enable night-time deliveries to be made produce additional benefits to travel time and congestion. Automation alone will most likely lead to an increase in freight mileage (because of smaller and cheaper freight vehicles), so corresponding policy measures in favour of freight consolidation should be considered to mitigate this trend. Fortunately, automation is expected to facilitate the consolidation process.
- A focused assessment of the impact on bridges of truck platooning has identified the need to improve the structural resistance of bridges over 55m span in bending and over 60m span in shear. Alternatively, increased forward headways must be imposed.

Other key remarks

- To govern new forms of smart mobility and automated urban transport, public authorities will need to cooperate with many new partners and assume new roles in the process of governance. Although many ideas and plans for new forms of mobility may come from private companies, public authorities should promote preferred directions of innovation by setting up strategic agendas and by establishing suitable standards, regulations and guidelines.

- However, care should be taken to prevent the anticipated unwanted impacts of these services, for example on equal accessibility of travel and on the use of active travel modes. Anticipatory research and anticipatory and flexible planning approaches are recommended to prevent these negative developments.
- Given the potential that increasing automation may attract part of public transport users and/or pedestrians/cyclists to switch to a private automated vehicle it is recommended that city planners and managers enhance the public transport network, by providing point-to-point Automated Urban Shuttle Services as well as on-demand AUSS, in order to promote the reduction of the use of private cars.
- Clear communication to transport users and other road users is necessary to clearly explain new transport operations, to explain what users and other road users can expect and to prevent idealised expectations. The effectiveness of specific interventions may be very sensitive to changes in mobility behaviour.
- In decisions about new forms of automated transport, waiting time, travel time, travel costs, comfort, safety and security should play a dominant role in setting policy goals, as these are likely to determine long-term and wider acceptance once the novelty value wears off.
- In future projects the long-term planning of successive implementation phases is recommended, for example going from operator to remote operator operations, and from simple to complex traffic environments.
- Although new forms of automated urban transport may be operated and controlled by private companies, it is recommended that these are developed to complement the public transport system in useful ways, for example by providing their services in regions not served by the public transport, usually outside the city centre, or by providing automated shuttles connecting different existing public transport stations.
- Guidelines - including ethical guidelines - and lists of impacts for future automated urban mobility and transport have been formulated, within LEVITATE and generally by the transport research community, and should be partly or fully adopted in strategic plans to facilitate successful implementation of new transport services.
- Multimodality and synchro modality are important factors to aim towards a sustainable logistic supply chain.
- All the above points require homogenous and shared data among operators, which is perhaps the most difficult challenge due to the competition between service providers as well as freight operators.

The many different scenarios of CCAM, the many different potential policy options and its interdependencies show a very complex pattern of effects. However, the effects of CCAM on cities and society largely depend on the regulatory framework in which CCAM is deployed. It is up to policy makers to define a regulatory framework supporting the goals of the respective Smart City Strategies, SUMPs (Sustainable Urban Mobility Plans), Climate Strategies etc. while avoiding adverse effects.

6 Project Conclusions

The Levitate project has conducted a major piece of research that will enable cities to prepare for the increasing fleet penetration of automated vehicles and the introduction of new services and technologies that are enabled by connectivity. The project has evaluated the societal impacts of a wide range of CCAM technologies and services that have been identified by the cities to be of major interest. In parallel the project has evaluated the impact of increasing automation and an increasing fleet composition of automated vehicles. All of the results have been documented in detail but, to enable ready access by users and to support the principles of open data, all results have been incorporated within the new Policy Support Tool along with a knowledge base and a toolbox of methods.

The cities and other stakeholders have closely supported the development of the PST throughout so that it directly addresses the CCAM technologies and services of most importance to the cities. The analytic results have been fed back to cities via webinars, workshops and 1:1 meetings, so a high level of validation has been conducted.

The outcomes of the research and the availability of the new PST have been described as a valuable new resource for cities that are preparing long-term strategic plans which may directly address mobility or where citizens mobility may affect other policy goals. Sustainable Urban Mobility Plans may typically have a time horizon of 15 or more years which are directly comparable to the likely timescales for the introduction of CCAM technologies and services. The PST and Levitate results will assist cities when developing new strategies by ensuring that scenario planning incorporates the most appropriate mix of targets and is based on the best knowledge of CCAM interventions.

The PST also supports cities when developing specific mobility schemes since the impacts can already be identified although there may be a need for further customization. The methods deployed in Levitate can also be used to support scheme appraisal and optimisation by examining the outcomes of alternative deployments of CCAM technologies.

The Levitate project team has already started to exploit the project results by promoting application of the PST to the cities that are members of the Stakeholder Reference Group. Through further dissemination activities beyond the completion of the project it will share the results with wider groups of cities and other industry stakeholders to encourage them to use Levitate to support strategic decision making by optimizing the benefits of future CCAM technologies and strategies.

7 List of deliverables with links

LEVITATE Dissemination strategy (D2.1)
LEVITATE project leaflet (D2.2)
LEVITATE Initial exploitation plan (D2.3)
Intermediate exploitation plan (D2.4)
Intermediate report on innovation & business model development (D2.5)
Visualization of PST (D2.6)
LEVITATE Policy Recommendations Brochure (D2.7)
A taxonomy of potential impacts of connected and automated vehicles at different levels of implementation (D3.1)
Methods for forecasting the impacts of connected and automated vehicles (D3.2)
Converting impacts of CAVs to monetary terms (D3.3)
Methods for cost-benefit analysis to support decision making (D3.4)
Definition of Quantified Policy Goals (D4.1)
Definition of Desirable Scenarios (D4.2)
Feasible paths of interventions (D4.3)
Detailed list of forecast scenarios, applicable forecasting methodologies and necessary output variables (D4.4)
Defining the future of urban transport (D5.1)
Short term impacts of CCAM in urban transport (D5.2)
Medium term impacts of CCAM in urban transport (D5.3)
Long term impacts of CCAM in urban transport (D5.4)
Guidelines and recommendations for future policy of automated urban transport (D5.5)
Defining the future of passenger car transport (D6.1)
Short-term impacts of CCAM on passenger transport (D6.2)
Medium term impacts of CCAM on passenger transport (D6.3)
Long-term impacts of CCAM on passenger transport (D6.4)
Guidelines and recommendations for future policy of cooperative and automated passenger transport (D6.5)
Defining the future of freight transport (D7.1)
Short term impacts of CCAM on freight transport (D7.2)
Medium term impacts of CCAM on freight transport (D7.3)
Long term impacts of cooperative, connected and automated mobility on freight transport (D7.4)
Guidelines and recommendations for future policy of cooperative and automated freight transport (D7.5)
Integration of outputs of WP4-7 (D8.1)
Development of a decision support tool for the assessment of the impacts of CATS final (D8.2)
Application of the Decision Support Tool on Selected Use Cases (D8.3)
Policy Recommendations (D8.4)

7.1 List of Other Documentation produced within the Project

7.1.1 Working Papers

Behavioural Parameters for Connected and Automated Vehicles within the LEVITATE Project
Road Safety Working Paper
Transferability Working Paper

7.1.2 SUC Definition and Documentation

On-demand Automated Urban Shuttle Service
Point-to-Point Automated Urban Shuttle Service Connecting Two Modes
Provision of Dedicated Lanes for CAVs on Urban Highways—passenger cars
Parking space regulation through replacing on-street parking with driving lanes, cycle lanes, public places and pick-up/drop-off points – passenger cars
Parking Behaviours through Parking Price Policies – passenger cars
Automated Ride Sharing – passenger cars
Green Light Optimal Speed Advisory (GLOSA) System – passenger cars

7.1.3 Case Studies Documentation

Green Light Optimal Speed Advisory (GLOSA) System- Case Study
Automated Delivery and Automated Consolidation
Automated Ride Sharing Services
Automated urban shuttle services – Last mile shuttles Vienna
Road-use pricing- Model implementation Vienna
Truck Platooning on Urban Highway Bridges

7.1.4 Synopsis

Direct Impacts Synopsis
Systemic Impacts Synopsis
Long-Term/Wider Impacts Synopsis
Cost Benefit Analysis Impact Synopsis
Road Safety Impacts Synopsis

8 Table of dissemination activities with links

The following table presents the record of dissemination activities performed during the project duration. These include webinars, workshops, newsletters, press release, scientific conference presentations, and scientific journal publications. In addition to the following table, several articles have been submitted to upcoming dissemination platforms (conferences) such as Transport Research Arena (TRA) scheduled to be held in November 14-17, 2022, International System Dynamics Conference scheduled to be held in July 18-22, 2022 and others.

Table 8.1: Dissemination activities with links

Type of dis-semination activity	Dissemination activity	Part-ner(s) respon-sible	Date	Location	Type of audience	Type of audience	Size of audience	Description	Organised by	Website
Journal Publications										
Scientific publication	Publication	TOI	7/15/2020	Elsevier - Economics of Transportation	(5) Policy Makers		50	The demand for automated vehicles: A synthesis of willingness-to-pay surveys		https://doi.org/10.1016/j.ecotra.2020.100179
Non-scientific and non-peer-reviewed publication (popularised publication)	Article published	LOUGH, AIT	8/15/2020	Website	(4) General Public		50	Article about System Dynamics	LOUGH, AIT	https://levitate-project.eu/2020/08/18/1265/
Scientific publication	Publication in scientific conference proceedings (full paper with review)	NTUA	9/22/2020	Proceedings of the 23rd IEEE International Conference on Intelligent Transportation Systems, ITSC 2020, virtual, (20-23 September 2020)	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	30	Impacts of Autonomous Shuttle Services on Traffic, Safety and Environment for Future Mobility Scenarios	NTUA	https://doi.org/10.1109/ITSC45102.2020.9294576
Scientific publication	Publication	WP7	12/31/2020	Austria	(1) Scientific Community (Higher Education, Research)	(2) Industry		Article (in German) for the yearbook of Logistics Research Austria	AIT	https://www.lra.at/
Scientific publication	Publication	Tonji University	Feb-21	Transportation Research Part C: Emerging Technologies				Calibration and Evaluation of the Responsibility-Sensitive Safety Model of Autonomous Car-Following Maneuvers Using Naturalistic Driving Study Data		https://doi.org/10.1016/j.trc.2021.102988

Scientific publication	Publication	Tonji University	Apr-21	Transportation Research Part C: Emerging Technologies				Calibration and evaluation of responsibility-sensitive safety (RSS) in automated vehicle performance during cut-in scenarios		https://doi.org/10.1016/j.trc.2021.103037
Scientific publication	Publication	NTUA	6/11/2021	Transportation Letters	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	-	Impacts of autonomous on-demand mobility service: A simulation experiment in the City of Athens	NTUA	https://doi.org/10.1080/19427867.2021.2000571
Scientific publication	publication	SWOV/ TOI	8/31/2021	online	(1) Scientific Community (Higher Education, Research)			Paper on impact assessment methodology	Open platform Europe	https://open-research-europe.ec.europa.eu/articles/1-104/v1
Scientific publication	Publication	Tonji University	Sep-21	Accident Analysis & Prevention				Operational Design Domain of Autonomous Vehicles at Skewed Intersection		https://doi.org/10.1016/j.aap.2021.106241
Scientific publication	Publication	Tonji University	Sep-21	Accident Analysis & Prevention				Feasibility Study of Highway Alignment Design Controls for Autonomous Vehicles		https://doi.org/10.1016/j.aap.2021.106241
	Publication	AIT	12/31/2021	Sustainability 14(1), 428				Integration of different mobility behaviours and intermodal trips in MATSim		https://www.mdpi.com/2071-1050/14/1/428
Scientific publication	Publication	TOI	21-Jan	Danish Journal of Transportation Research	(1) Scientific Community (Higher Education, Research)			Can the impacts of connected and automated vehicles be predicted?	TOI	https://doi.org/10.5278/ojs.djtr.v3i1.6113

Scientific publication	Publication	Tonji University	Mar-22	Accident Analysis & Prevention				Operational Design Domain of Automated Vehicles for Crossing Maneuvers at Two-Way Stop-Controlled Intersections		https://doi.org/10.1016/j.aap.2022.106575
Scientific publication	Publication	Tonji University	Mar-22	Accident Analysis & Prevention				Towards Human-Like Speed Control in Autonomous Vehicles: A Mountainous Freeway Case		https://doi.org/10.1016/j.aap.2022.106566
Scientific publication	Publication in scientific journal (full paper with review)	Aimsun, NTUA	22-May		(1) Scientific Community (Higher Education, Research)	(1) Scientific Community (Higher Education, Research)	20	Transportation Research Record	Aimsun	https://journals.sagepub.com/doi/10.1177/03611981221090507
Non-scientific and non-peer-reviewed publication (popularised publication)	Publication	NTUA	6/8/2022	8th Road Safety & Simulation International Conference (RSS) 2022, Athens, Greece, 8-10 June 2022				RSS2022 Contribution on Safety Impacts of Dedicated Lanes	NTUA	https://www.nrso.ntua.gr/rss2022/wp-content/uploads/2022/06/RSS2022_paper_161.pdf
Scientific publication	Publication	AIT	6/8/2022	Athens	(1) Scientific Community (Higher Education, Research)			RSS2022 Contribution on VRU Impacts Method	NTUA	https://www.nrso.ntua.gr/rss2022/wp-content/uploads/2022/06/RSS2022_paper_65.pdf

Scientific publication	AIT	WP4	21-Sep	Online	(1) Scientific Community (Higher Education, Research)		500	Levitate mentioned and cited in an ITF report about mobility transition	AIT	https://www.itf-oecd.org/travel-transitions-policy-makers-respond-mobility-trends
Scientific publication	Publication	TOI	20-Nov	Under review	(1) Scientific Community (Higher Education, Research)			Risk analysis for forecasting cyberattacks against connected and autonomous vehicles	TOI	https://levitate-project.eu/wp-content/uploads/2021/11/Meyer2021_Cyberattacks.pdf
Scientific publication	Publication	NTUA	16/10/2021	Elsevier-Transport Policy	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	-	Quantifying the implementation impacts of a point to point automated urban shuttle service in a large-scale network	NTUA	https://doi.org/10.1016/j.tranpol.2021.10.006
Scientific publication	Publication	LOUGH			(1) Scientific Community (Higher Education, Research)			Paper on impacts of automation	Lough,	
Scientific publication	Publication in scientific journal (full paper with review)	NTUA		Forthcoming, Expected submission within the summer 2022	(1) Scientific Community (Higher Education, Research)	(1) Scientific Community (Higher Education, Research)	-	Simulating crashes from conflicts in an increasingly automated environment	NTUA	

Conference Proceedings										
Organisation of a Conference	TRB Annual meeting 2020	LOUGH	1/16/2020	Washington DC, USA	(5) Policy Makers		500	LEVITATE's most recent piece of simulation work on parking pricing policies in the Connected and Automated Vehicle era was presented in the Freeway and CAV Simulation subcommittee	LOUGH, NTUA, AIMSUN	https://levitate-project.eu/2020/03/26/levitate-in-trb-annual-meeting-2020/
Scientific publication	Publication in scientific conference proceedings (full paper with review)	Tonji University	Jan-21	Transportation Research Board 100th Annual Meeting, Washington D.C., USA,				Examining Causal Factors of Traffic Conflicts at Intersections Using Vehicle Trajectory Data		
Scientific publication	Publication in scientific conference proceedings (full paper with review)	Tonji University	Jan-21	Transportation Research Board 100th Annual Meeting, Washington D.C., USA,				Performance and Safety Evaluation of Responsibility-Sensitive Safety in Freeway Car-Following Scenarios Using the Intelligent Driver Model and Model Predictive Control		
Scientific publication	Publication in scientific conference proceedings (full paper with review)	Tonji University	Jan-22	Transportation Research Board 101th Annual Meeting, Washington D.C., USA,				Operational Design Domain of Autonomous Vehicles in Merging Sections of Freeway Entrance Terminals		

Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	Tonji Universi ty	Jan-22	Transportation Research Board 101th Annual Meeting, Washington D.C., USA,				Developing an Improved Automatic Preventive Braking System Based on Safety Critical Car-Following Events from Naturalistic Driving Study Data		
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	Tonji Universi ty	Jan-22	Transportation Research Board 101th Annual Meeting, Washington D.C., USA,				Analysis of Left-turn Vehicle Operation Characteristics at Intersection Using Trajectory Data		
Organisation of a Conference	LEVITATE final event	ALL PARTN ERS	22-May						POLIS	https://levitate-project.eu/2022/05/31/levitate-final-conference-on-may-25th/
Non-scientific and non-peer-reviewed publication (popularised publication)	Publication in scientific confer ence proceedings (full paper with review)	NTUA	6/8/2022	8th Road Safety & Simulation International Conference (RSS) 2022, Athens, Greece, 8-10 June 2022				RSS 2022 Contribution on Safety Impacts of GLOSA (won best safety idea award)	NTUA	https://www.nrso.ntua.gr/rss2022/wp-content/uploads/2022/06/RSS2022_paper_99.pdf
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA	6/9/2022	8th Road Safety & Simulation International Conference (RSS) 2022, Athens, Greece, 8-10 June 2022	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		Methodological framework of creating the Levitate Policy Support Tool for Connected and Automated Transport Systems	NTUA	
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA		10th International Congress on Transportation Research (ICTR) 2021, Rhodes, Greece, 2-3 September 2021	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	20	Impacts of autonomous transit services on urban networks: The case of Athens, Greece	NTUA	

Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA		10th International Congress on Transportation Research (ICTR) 2021, Rhodes, Greece, 2-3 September 2021	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	20	Forecasting impacts of Connected and Automated Transport Systems within the LEVITATE project	NTUA	
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA		10th International Congress on Transportation Research (ICTR) 2021, Rhodes, Greece, 2-3 September 2021	(1) Scientific Community (Higher Education, Research)	(1) Scientific Community (Higher Education, Research)	20	Identifying KPIs for safety assessment of autonomous vehicles Through traffic microsimulation	NTUA	
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA		Transport Research Arena (TRA) 2022, Lisbon, Portugal, 14-17 November 2022	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		The LEVITATE Policy Support Tool of Connected and Automated Transport Systems	NTUA	
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	AIT, NTUA		Transport Research Arena (TRA) 2022, Lisbon, Portugal, 14-17 November 2022	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		The impacts of automated urban delivery and consolidation	AIT, NTUA	
Scientific publication	Publication in scientific confer ence proceedings (full paper with review)	NTUA, Aimsun		Transportation Research Board (TRB) 101st Annual Meeting 2022, Washington, D.C, 9–13 January 2022	(1) Scientific Community (Higher Education, Research)	(1) Scientific Community (Higher Education, Research)	20	Passenger Car Unit Values of Connected Autonomous Vehicles in Urban Road Networks	NTUA	

Presentations and Workshops										
Participation to an Event other than a Conference or a Workshop	Presentation at a scientific workshop	NTUA	5/17/2019	Athens, Greece	(5) Policy Makers		250	Special focus was put on future impact of automation on safety with LEVITATE project findings in key presentation, followed by a vivid Expert Panel discussion regarding new perspectives and horizons of road safety in the digital and automated era in Europe and worldwide with focus on the future of automation related safety policy interventions	NTUA	https://levitate-project.eu/2019/06/10/digitalisation-and-road-safety-research-workshop-athens/
	Presentation	Tongji	10/28/2019	Shanghai, China			100	Use of Driving Simulators to Evaluate Driver Behaviours in the Changing Transportation Landscape: Measures and Countermeasures	Tongji, Transportation Research Board	http://www.tjsafety.cn/NewsContent.aspx?YNID=&ID=1174
	Presentation	Tongji	1/12/2020	Washington D.C., U.S.			200	Transportation Research Board 99th Annual Meeting	Transportation Research Board	

Participation to an Event other than a Conference or a Workshop	Participation at IEEE ITSC 2020	LOUGH , NTUA	9/1/2020	Online	(5) Policy Makers		100	LEVITATE contribute to this conference with a special session: Advances in Connected and Autonomous Mobility: From Data to Models, Impacts and Enablers for Adoption.	NTUA	https://levitate-project.eu/2020/02/17/advances-in-connected-and-autonomous-mobility-ieee-itsc-2020/
Participation to an Event other than a Conference or a Workshop	Presentation	NTUA	10/21/2020	Online	(5) Policy Makers		50	"Automation and public transport", at Sustainable Cities – Viewpoints of the Pioneer Alliance: IoT for Smart Cities School, organised by the European Commission	NTUA	https://www.nrso.ntua.gr/geyannis/conf/cp434-automation-and-public-transport/
Participation to an Event other than a Conference or a Workshop	Presentation	TOI	11/13/2020	Online	(2) Industry			Sikringsrisikoanalyse for cyberangrep mot autonome transportsystemer	SAMS fagdykk	https://sams-norway.no/event/fagdykk-sikringsrisikoanalyse-for-cybersikkerhet-hos-autonome-kjoretoy/
Other	Participation to a workshop organised by ARCADE	LOUGH	11/23/2020	Online	(1) Scientific Community (Higher Education, Research)		76	Arcade EU CAD workshop Common Evaluation Methodology	TNO innovation for life	https://connectedautomateddriving.eu/event/workshop-on-common-evaluation-methodology-for-automated-driving-tests/

Participation to an Event other than a Conference or a Workshop	Presentation	NTUA	12/1/2020	Annual POLIS Conference 2020, Virtual Event, 30 November – 3 December 2020	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		LEVITATE – Development of a Policy Support Tool to assess Societal Level Impacts of Connected and Automated Vehicles	NTUA	https://www.polisnetwork.eu/wp-content/uploads/2020/12/8B_Apostolos-Ziakopoulos-National-Transport-University-of-Athens.pdf
Organisation of a Conference	Presentation in session: Planning for automated vehicles	NTUA, POLIS	12/3/2020	Online	(4) General Public		80	POLIS Conference 2020	POLIS	https://www.polisnetwork.eu/2020-annual-polis-conference/
	Presentation	Tongji	1/25/2021	Online			150	Transportation Research Board 100th Annual Meeting	Transportation Research Board	
Participation to an Event other than a Conference or a Workshop	Presentation at a scientific workshop	LOUGH	5/19/2021	Online	(1) Scientific Community (Higher Education, Research)		7	Robomobility - Third annual grand Rendezvous of the robomobile life future workshop	French Ministry for Ecological Transition	https://hopin.com/events/3e-grand-rendez-vous-annuel-de-la-vie-robomobile
Participation to an Event other than a Conference or a Workshop	Presentation	NTUA	5/20/2021	Innovation in Road Safety Research Workshop, online, 20 May 2021	(1) Scientific Community (Higher Education, Research)		40	Societal Level Impacts of Connected and Automated Vehicles	NTUA	
Scientific publication	Presentation (non-peer reviewed)	SWOV	9/16/2021	Portoroz, Slovenia	(1) Scientific Community (Higher Education, Research)		20	Presentation at Young researchers Seminar about road safety impacts of CCAM	SWOV	https://www.ectri.org/activities/young-researchers-seminar-2021/

Participation to an Event other than a Conference or a Workshop	Presentation	NTUA	10/13/2021	ITS World Congress, Hamburg, Germany, 11-15 October 2021	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers	100	Forecasting impacts of Connected and Automated Transport Systems within the LEVITATE project	NTUA	
Scientific publication	Presentation	WP7	11/10/2021	Online	(1) Scientific Community (Higher Education, Research)	(2) Industry	500	Abstract and Presentation on the Automated delivery SUC	AIT	https://www.ubivent.com/register/1/EARPA-FORM-FORUM-2021
Participation to an Event other than a Conference or a Workshop	Presentation	NTUA	12/2/2021	Annual POLIS Conference 2021, Gothenburg, Sweden, 1-2 December 2021	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		The Levitate Connected and Automated Transport Systems Policy Support Tool	NTUA	https://levitate-project.eu/2021/12/14/levitate-at-polis-conference-in-gothenburg/
	Presentation	Tongji	1/9/2022	Washington D.C., U.S.			200	Transportation Research Board 101th Annual Meeting	Transportation Research Board	
	Acceptance for presentation and inclusion in the conference program	LOUGH	1/9/2022	Washington D.C., U.S.				Evaluating the Network-level Road Safety Impacts of Connected and Automated Vehicles in Mixed Traffic using Traffic Microsimulation Methods (Transportation Research Board 101th Annual Meeting)	Transportation Research Board	

Other	Presentation (non-peer reviewed)	Aimsun	21-Jan	Online	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		TRB Freeway and CAV Simulation Subcommittee - Title of presentation: Multi-Resolution Simulation Modelling Framework for Autonomous Vehicles	TRB	
Organisation of a Conference	Presentation	LOUGH	22-Mar	H2020 RTR conference 2022	(1) Scientific Community (Higher Education, Research)		200	LEVITATE presentation	EC	https://levitate-project.eu/2022/04/11/h2020rtr21-conference-automated-driving-and-the-users/
	Presentation	LOUGH	1-Jun-22	In-person				ITS World Congress, Toulouse, France Paper: Evaluating GLOSA in mixed traffic with connected and automated vehicles		
	Presentation	Loughborough University	6/17/2022	Online - OECD Virtual Global Conference on on Governance Innovation						

Organisation of a Conference	Presentation	Aimsun	21-Jun	Online	(1) Scientific Community (Higher Education, Research)			8TH INTERNATIONAL SYMPOSIUM ON TRANSPORT NETWORK RELIABILITY (INSTR) - Title of extended abstract: A Framework for Assessing Network Performance Impacts of Autonomous Vehicles in Urban Networks	KTH Royal Institute of Technology	
Organisation of a Conference	Presentation (non-peer reviewed)	Aimsun	21-Jun	Online	(1) Scientific Community (Higher Education, Research)			7th International IEEE Conference on Models and Technologies for Intelligent Transportation Systems - Title of presentation: Multi-resolution assessment framework of connected and autonomous mobility services for strategic planning	Special Session on Transport modelling in European Research projects (organised by CERTH + UCL)	
Scientific publication	Presentation and publication (peer reviewed)	AIT	7/19/2022	International System Dynamics Conference, Frankfurt & online	(1) Scientific Community (Higher Education, Research)	(1) Scientific Community (Higher Education, Research)		Assessing systemic and wider impacts of cooperative, connected and automated mobility		https://systemdynamics.org/conference-schedule/

Organisation of a Conference	Presentation and publication (non-peer reviewed)	AIT	9/7/2022	AET - European Transport Conference, 07.-09.Sept 2022, Milan				Autonomous urban shuttle services in inner-city and suburban operation: impact assessment from simulation case studies in Vienna	AIT	https://aetransport.org/etc
Organisation of a Workshop	Presentation	Aimsun	21-Nov	Online	(1) Scientific Community (Higher Education, Research)	(5) Policy Makers		Workshop on Traffic Simulation and Connected and Automated Vehicle (CAV) Modelling - Title of abstract: Modelling Framework of Connected and Automated Vehicles For Multi-Resolution Simulation Models	Transportation Research Board	
Organisation of a Webinar	Presentation	LOUGH	18/10/2021	Online				LEVITATE webinar on policy options	POLIS	https://levitate-project.eu/2021/09/09/policy-interventions-webinar/
Organisation of a Workshop	Stakeholder engagement	POLIS	5/28/2019	Gothenburg, Sweden	(9) Local/regional/national authorities	(1) Scientific Community (Higher Education, Research)	40	First SRG meeting to introduce the project to the Stakeholder Group	POLIS	https://levitate-project.eu/2019/05/28/stakeholder-reference-group-workshop-in-gothenburg/
Press release	SRG workshop	POLIS	6/1/2019	Gothenburg, Sweden	(6) Media		150	Press release about the first SRG workshop	POLIS	

Participation to an Event other than a Conference or a Workshop	Invited Talk	AIT	10/2/2019	Vienna, Austria	(4) General Public		100	Invited talk at "Forum Automatisierte Mobilität 2019"	Austrian Ministry of Climate Action and Energy	https://www.austriatech.at/assets/Uploads/Fokusseiten/Kontaktstelle-Automatisierte-Mobilitaet/Dokumente/78478fe112/Programm-Forum-AM.pdf
Organisation of a Workshop	Stakeholder engagement	POLIS	11/26/2019	Brussels, Belgium	(9) Local/regional/national authorities	(1) Scientific Community (Higher Education, Research)	40	Second SRG meeting to get feedback about project deliverables	POLIS (side event of POLIS Conference)	https://levitate-project.eu/2019/12/10/2nd-stakeholder-reference-group-workshop-takes-place-in-brussels/
Organisation of a Workshop	RSS 2022	NTUA, LOUGH, AIT	6/7/2022	Athens, Greece	(5) Policy Makers	(1) Scientific Community (Higher Education, Research)	20	Road Safety and Simulation Conference 2022	NTUA	
Organisation of a Workshop	Panel discussion	AIT	21-Oct	Turkey	(5) Policy Makers	(9) Local/regional/national authorities	50	Invited guest for the panel discussion on "Re-thinking local green policy with data" of the Marmara Urban Forum 2021	AIT	https://online.marmaraurbanforum.org/Program/Detail/106

Non-scientific and non-peer-reviewed publication (popularised publication)	Stakeholder engagement	LOUGH	11/10/2021	Online	(5) Policy Makers	(5) Policy Makers	20 + Unknown web audience streamed	Presentation to European Parliament AIDA-TRAN Hearing on AI and Transport	LOUGH	https://multimedia.europarl.europa.eu/en/webstreaming/aida-tran_20211011-1345-COMMITTEE-AIDA-TRAN
Non-scientific and non-peer-reviewed publication (popularised publication)	Stakeholder engagement	LOUGH	21-Oct	Online	(5) Policy Makers	(5) Policy Makers	15	Project presentation to Centre for Connected and Automated Vehicles, UK Department for Transport	LOUGH	
Webinars										
Website	Dissemination of Deliverables	WP3-4-5-6-7	11/25/2019		(4) General Public		100	Dissemination of D3.1, 4.1, 5.1, 6.1 7.1	POLIS (all partners)	https://levitate-project.eu/2019/11/25/defining-the-future-of-urban-passenger-car-and-freight-transport/
Organisation of a Webinar	Dissemination of project results	POLIS	4/23/2020	Online	(4) General Public		80	LEVITATE webinar about automation in freight transport (WP4)	POLIS (VIL + ALICE)	https://levitate-project.eu/2020/03/12/webinar-the-future-impacts-of-automation-in-freight-transport/

Organisation of a Webinar	Dissemination of project results	POLIS	6/11/2020	Online	(4) General Public		65	LEVITATE webinar about automation in urban transport - featuring local strategies (WP5)	POLIS (TfGM)	https://levitate-project.eu/2020/05/07/2nd-levitate-webinar-the-impacts-of-automation-in-urban-transport-featuring-local-urban-strategies/
Participation to an Event other than a Conference or a Workshop	Dissemination of progress on ongoing work	LOUGH	9/30/2020	Online	(1) Scientific Community (Higher Education, Research)		20	Trilateral Impact assessment sub group meeting where researchers involved in impact assessment projects come together to discuss ongoing work.	VTT, DoT (US) and Japan	
Participation in activities organized jointly with other H2020 projects	Dissemination of project results	POLIS	10/15/2020	Webinar online	(9) Local/regional/national authorities			Webinar about the impact assessment of automated vehicles	POLIS (LOUGH)	https://levitate-project.eu/2020/10/01/webinar-impact-assessment-of-automated-vehicles/
Organisation of a Webinar	Dissemination of project results	POLIS	5/27/2021	online	(4) General Public		100	LEVITATE webinar about road safety impacts	POLIS (SWOV, LOUGH, AIT contributed)	https://levitate-project.eu/2021/06/01/levitate-webinar-on-road-safety-assessment-of-cats/

Organisation of a Webinar	Dissemination of project results	AIT	1/31/2022	Online				LEVITATE freight webinar	POLIS	https://levitate-project.eu/2022/02/02/levitate-freight-case-studies-webinar/
Organisation of a Webinar	Dissemination of project results	AIT	22-Apr	Online				LEVITATE City Dialogues webinar	POLIS	https://levitate-project.eu/2022/04/11/watch-now-levitate-city-dialogues-webinar-introduces-pst/
Organisation of a Webinar	Dissemination of project results	LOUGH, NTUA, AIT	21-Nov	Online				LEVITATE impact assessment methodologies webinar	Polis	https://levitate-project.eu/2021/11/07/levitate-webinar-automated-road-transport-impact-assessment-methodologies/
Newsletters										
Social Media	1st LEVITATE Newsletter	POLIS, SWOV	6/15/2019	Online	(4) General Public		150	Electronic newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS, SWOV	

Social Media	2nd LEVITATE Newsletter	POLIS, SWOV	5/15/2020	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS, SWOV	https://levitate-project.eu/2020/05/14/automated-vehicles-and-covid-19-what-we-can-learn-from-it/
Social Media	5th LEVITATE Newsletter	POLIS, SWOV	5/15/2021	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	SWOV Newsletter	WP2	8/30/2021	Online	(1) Scientific Community (Higher Education, Research)		200	English Newsletter of SWOV covered the project	SWOV	https://mailchi.mp/739ecfde2e38/save-the-date-8033229?e=e0c607b84b
Social Media	8th LEVITATE Newsletter	POLIS, SWOV	22-Mar	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	3rd LEVITATE Newsletter	POLIS, SWOV	20-May	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	9th LEVITATE Newsletter	POLIS, SWOV	22-May	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	

Social Media	6th LEVITATE Newsletter	POLIS, SWOV	21-Jun	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	4th LEVITATE Newsletter	POLIS, SWOV	20-Oct	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	7th LEVITATE Newsletter	POLIS, SWOV	21-Nov	Online	(4) General Public		200	Newsletter including project milestones, activities, events and related articles, partner in the spotlight	POLIS SWOV	
Social Media	NTUA's Newsletter	NTUA	continuous	Online	(4) General Public		300	NTUA continuously includes project activities and events in their international Newsletter	NTUA	https://www.nrso.ntua.gr/levitate-2nd-newsletter-societal-impacts-of-connected-and-automated-vehicles-2019/
Social Media	SWOV International Newsletter	SWOV	continuous	Online	(4) General Public			SWOV continuously includes project activities and events in their international Newsletter	SWOV	

Others										
Exhibition	Exhibition booth	POLIS	6/24/2019	SUMP Conference, Groningen, Netherlands	(9) Local/regional/national authorities		400	Exhibition booth including leaflets about Levitate	POLIS	
Exhibition	Exhibition booth	POLIS, SWOV	10/11/2021	Hamburg, Germany	(2) Industry		50	Booth at ITS World Congress 2021 exhibiting several projects	POLIS, NTUA	
Exhibition	Exhibition booth	POLIS	11/27/2019	POLIS Conference, Brussels	(9) Local/regional/national authorities		500	Exhibition booth including leaflets about Levitate	POLIS	
Video/Film	Introduction of the project	SWOV	10/17/2019	Gothenburg, Sweden	(9) Local/regional/national authorities		150	Introductory video of the project	SWOV	https://levitate-project.eu/2019/12/10/video-levitate-project-introduction/
Participation in activities organized jointly with other H2020 projects	Launch of EC's CCAM platform	POLIS	6/25/2019	Brussels, Belgium	(5) Policy Makers		500	The platform is made up primarily of Member States and approximately 30 associations, including LEVITATE partner Polis.	POLIS	https://levitate-project.eu/2019/08/20/launch-of-ecs-ccam-platform/
Social Media	LinkedIn Group	POLIS	continuous	Online	(4) General Public		87	Engaging the SRG Group with project activities	POLIS (SWOV)	https://www.linkedin.com/groups/8742258/
Social Media	Twitter account	POLIS	continuous	Online	(4) General Public		5000	Tweeting about all project related activities	POLIS (SWOV)	https://twitter.com/ProjectLevitate

Exhibition	Virtual booth	POLIS	9/22/2020	Online	(4) General Public		400	Virtual booth at Science is Wonderful! (EU Research&Innovation Days)	POLIS (all partners)	https://levitate-project.eu/2020/09/28/a-virtual-experience-with-kids-citizens-and-stakeholders-at-the-siw-exhibition/
Flyer	Visualization of the PST (D2.6)	POLIS, SWOV	9/1/2020	Online	(4) General Public		400	Visualization of the current state of the Policy Support Tool	POLIS, SWOV	https://levitate-project.eu/wp-content/uploads/2022/01/Levitate-D2.6_Visuallization-of-PST.pdf
Social Media		CARRS-Q	continuous	Online		(4) General Public	156 engagements (900+ followers)	LinkedIn post advertising 18 October webinar	CARRS-Q	CARRS-Q LinkedIn profile
Social Media		CARRS-Q	continuous	Online		(4) General Public	1600 followers	Retweets of Levitate tweets advertising 18 October webinar and retweet of other Levitate tweets throughout this period	CARRS-Q	CARRS-Q twitter profile
Flyer	Project leaflet	SWOV	2/1/2019		(4) General Public		500	Introductory leaflet to disseminate the project during events		https://levitate-project.eu/wp-content/uploads/2019/04/LEVITATE-project-leaflet.pdf

Website	Promotion	AIMSUN	26/11/2018	Online	(8) Customers	(1) Scientific Community (Higher Education, Research)	36	Promotion of start of project	AIMSUN	https://www.aimsun.com/latest/levitate/
Website	Promotion	AIMSUN	20/01/2021	Online	(8) Customers	(1) Scientific Community (Higher Education, Research)	43	Promotion of project output	AIMSUN	https://www.aimsun.com/latest/levitate-passenger-cars-microsimulation-sub-use-cases-findings/

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