D8.2 Development of a policy support tool for the assessment of the impacts of CCAM

WP8 – Deliverable D8.2 – NTUA

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Work package 8, Deliverable D8.2

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Coordinator:	Andrew Morris, Prof – Prof. of Road & Vehicle Safety Loughborough University Ashby Road, LE11 3TU Loughborough, United Kingdom
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Lead contractor for this deliverable:
George Yannis – National Technical University of Athens

Report Author(s):	Ziakopoulos A., Roussou, J., Oikonomou, M., Yannis, G., (NTUA), Greece Hartveit, K. J. L., Veisten, K., Institute of Transport Economics (TOI), Norway

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List of abbreviations

AUSS	Automates Urban Shuttle Service
ADAS	Advanced Driver Assistance Systems
AEB	Autonomous Emergency Braking
AV	Automated Vehicle
CACC	Cooperative Adaptive Cruise Control
CAV	Connected and automated vehicle
CAFE	Corporate Average Fuel Economy
CBA	Cost-benefit analysis
CBR	Cost-Benefit Ratios
CCAM	Cooperative, Connected and Automated Mobility
C-ITS	Cooperative Intelligent Transport Systems
CMF	Crash Modification Factor
CV	Connected Vehicle
DisA	Distraction Alert
DrowA	Drowsiness Alert
ERTRAC	European Road Transport Research Advisory Council
EU	European Union
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
FORS	Fleet Operation Recognition Scheme
GDPR	General Data Protection Regulation
GLOSA	Green Light Optimal Speed Advisory
HSM	Highway Safety Manual
IMA	Intersection Movement Assist
IMF	Impact Modification Factors
ISA	Intelligent Speed Assist
IVS	In-vehicle Signage
LCA	Lane Change Assist
LDW	Lane Departure Warning
LKA	Lane Keeping Assist
MPR	Market Penetration Rate
mUoM	marginal Utility of Money
NHTSA	National Highway Traffic Safety Administration
NRC	National Research Council
PI	Policy Implementation
PST	Policy Support Tool
SAE	Society of Automotive Engineers
SRG	Stakeholder Reference Group
SUC	Sub-Use Case
TA	Turn Assist
TTC	Time to Collision
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to everything
VKT	Vehicle Kilometers Travelled
VOC	Vehicle Operating Cost

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Executive summary

The aim of the LEVITATE project is to prepare a new impact assessment framework to enable policymakers to manage the introduction of cooperative, connected, and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives. As part of this work, the LEVITATE project seeks to forecast societal level impacts of cooperative, connected, and automated mobility (CCAM), by developing an open access web-based Policy Support Tool (PST).

This report specifically focuses on the development of the online PST. The first step was to identify the existing tools and similar projects in order to use them as a template. After analyzing the past and current projects related to CCAM it was found out that none of them proceeded to the development of such a complete impact assessment policy support tool. For this reason the development of the LEVITATE PST, was based on the knowledge base tool developed by ARCADE and on the SafetyCube DSS, which includes both a knowledge and an estimator module. The next step of the PST design was to identify a draft structure and present it to a group of stakeholders in order to make sure it is compliant with the users needs. After adaptations according to the stakeholders' feedback, the impact assessment started and was followed by the development of the online PST, where the results and methods were added. The main obstacles faced during the development of such a complex and unique tool was to certify the transferability of results and the prioritization of sub-use cases and impacts.

The PST comprises two main modules: the Knowledge module (static component) and the Estimator module (dynamic component). The knowledge module aims to provide a searchable static repository through a 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. More specifically, the user is able to search by any parameter, to adjust and customize the search according to preliminary results and to access all background information about any stage of the LEVITATE project. The reports 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 estimator module will provide estimates for different types of impacts and allow comparative analyses. It includes four pillars of analysis: (i) forecasting, serving as the basis of predicting the quantitative and qualitative estimated impacts for different horizons, (ii) backcasting, serving as the basis of acquiring relevant policy targets for each impact area, (iii) cost-benefit analysis, serving as the basis of monetizing costs and benefits of CCAM interventions and (iv) case study examples, serving as a basis for documented applied paradigms of CCAM interventions within real-world environments at a city level.

1 Introduction

1.1 LEVITATE

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

Specifically LEVITATE has four key objectives:

- 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.
- 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 shuttles, passenger cars and freight services.
- 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.
- To incorporate the methods within a **new web-based policy support tool** to enable city and other authorities to forecast impacts of CCAM in urban areas. The methods developed within LEVITATE will be available within a toolbox allowing the impact of measures to be assessed individually. The Policy Support Tool will enable users to apply backcasting methods to identify the sequences of CCAM measures that will result in their desired policy objectives.

1.2 Work package 8 and Deliverable 8.2 within LEVITATE

Within LEVITATE, WP8 is the Work Package responsible for creating and designing the LEVITATE Policy Support Tool, establishing its modules, standardizing the inputs of the different methodologies used within the project in WPs 4-7, and populating the PST with results, case study analyses and impact assessments, and documentation of the methodologies. The objectives of WP8 include:

- Consolidation of the outputs of WPs 4-7 into an overall framework for the assessment of impacts, benefits and costs of CCAM;
- Analysis of user needs for a decision support tool to assist in the analysis of urban policy scenarios and targets;

- Development and implementation of a toolkit and a decision support tool to demonstrate the added value by means of a set of analyzed scenarios for selected cities and use cases;
- Policy recommendations.

The purpose of Deliverable 8.2 is to present the development and testing of the PST, based on the data provided by D8.1 (Ziakopoulos et al., 2021a). The system includes a forecasting and backcasting estimator module, which will provide impact assessment and cost-benefit estimates for various CCAM interventions and a knowledge module (which will include case study and sub-use case results). Confidence intervals or other relevant assessment of the uncertainty in the estimates will be provided. Particular emphasis will be placed on the transparency of the system operation, through access to methodology background information and exhaustive meta-data.

1.3 Earlier work and involvement of other work packages

In the early phases of the project, in D3.1 (Elvik et al., 2019), a taxonomy of potential impacts of connected and automated vehicles at different levels of implementation was presented. From there, methods for predicting and quantifying impacts were surveyed in D3.2 (Elvik et al., 2019). This included a distinction of variables that are direct, systemic and wider impacts. The final list of studied variables in LEVITATE was then determined in various meetings within the consortium and the stakeholders reference group. Based on that taxonomy and on feasible paths of interventions defined by D4.3 (Zach et al., 2020), the estimation, development of techniques and specifications was then done in use-case work packages (urban transport (WP5), passenger cars (WP6) and freight transport (WP7)), in parallel to the development of the general methodology for conducting a CBA for measures handling the new autonomous vehicles.

The deliverable is organized as follows: in the next section a brief review of existing system is presented (section 2.1). Afterwards, the stakeholders' input on the PST modules and the potential user needs are described (section 2.2). The critical issues are presented next (section 2.3). Then, the design of the PST is described, followed by the presentation of the online version of the tool with various screenshots of the different components (section 3).

2 User needs

2.1 Review of existing systems

The development of the LEVITATE PST, was based on the existing web-based tools that support authorities and policy makers. The first step in the development of the PST was therefore to review the existing systems and identify their key features and limitations. Before reviewing the existing systems, it was necessary to identify the projects related to CCAM and examine whether they developed a similar tool. In order to identify the past and current projects related to CCAM, the list of the Automated Driving Roadmap document from ERTRAC (https://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf), was studied, as well as the knowledge base on Connected and Automated Driving developed as part of the Horizon 2020 Action ARCADE (Aligning Research & Innovation for Connected and Automated Driving in Europe - (https://www.connectedautomateddriving.eu), which included all the projects related to CCAM. In the following table (Table 2.1), some of the EU projects on CCAM are presented.

Table 2.1: Past and current EU projects on CCAM

EU Projects on CCAM		
CoEXist 05/2017 – 04/2020	https://www.h2020-coexist.eu/	Focusing on the technological development of microscopic and macroscopic transport modelling tools, CAV-simulators and CAV control logistics and aims to strengthen the capabilities of urban road authorities for the planning and integration of CATS on their networks
AUTOPILOT 01/2017-31/12/2019	http://autopilot-project.eu/	AUTOPILOT brings together relevant knowledge and technology from the automotive and the IoT (internet of Things) value chains in order to develop IoT-architectures and platforms which will bring automated driving towards a new dimension
Connected automated driving.eu **(SCOUT, CARTRE)** Both completed	https://connectedautomateddriving.eu/about-us/	Two projects (SCOUT, CARTRE) that work together with a broad range of international stakeholders to ensure that these technologies are deployed in a coordinated and harmonised manner, which will accelerate the implementation of safe and connected automated driving in Europe.
SCOUT (H20202)	https://connectedautomateddriving.eu/about-us/scout/	Aims to promote a common roadmap of the automotive and the telecommunication and digital sectors

EU Projects on CCAM		
01/07/2016-2018		for the development and accelerated implementation of safe and connected and high-degree automated driving in Europe. It will support identification of deployment scenarios in LEVITATE.
CARTRE (H2020) 01/10/2016-2018	https://connectedautomateddriving.eu/about-us/cartre/	Aims to establish a joint stakeholders forum in order to coordinate and harmonise automated road transport approaches at European (e.g. strategic alignment of national action plans for automated driving) and international level (in particular with the US and Japan).
ARCADE (will continue the work of CARTRE) 01/10/2018-2021	https://connectedautomateddriving.eu/arcade-project/	Aims to coordinate consensus-building across stakeholders in order to enable smooth deployment of connected and automated driving (CAD) on European roads and beyond. EC, Member States and industry are committed to develop a common approach to development, testing, validation and deployment of connected and automated driving.
interACT 01/05/2017-30-04/2020	https://www.interact-roadautomation.eu/	Works towards cooperative interaction of automated vehicles with other road users in mixed traffic environments
L3Pilot 09/2017-2021	http://www.l3pilot.eu/home/	The overall objective of L3Pilot is to test the viability of automated driving as a safe and efficient means of transportation, exploring and promoting new service concepts to provide inclusive mobility (assessment of level 3 & 4 in-vehicle functions).
HADRIAN 12/2019-05/2023	https://hadrianproject.eu/	Investigates and defines the driver role for automated vehicles using a holistic user centered approach that addresses shortcomings of current development and design processes to achieve high impact and wide-reaching acceptance of automated vehicles.
SHOW 01/2020-12/2023	https://show-project.eu/	Aims to advance sustainable urban transport through technical solutions, business models and priority scenarios for impact assessment, by deploying shared, connected, electrified fleets of automated vehicles in coordinated Public Transport (PT), Demand Responsive Transport (DRT), Mobility as a Service (MaaS) and Logistics as a Service (LaaS) operational chains in

EU Projects on CCAM		
		real-life urban demonstrations all across Europe.
AdaptIVe Level1 -level 4 of automation 01/2014-06/2017	https://www.adaptive-ip.eu/	AdaptIVe develops various automated driving functions for daily traffic by dynamically adapting the level of automation to situation and driver status. Further, the project addresses legal issues that might impact successful market introduction.
iTETRIS 2008-2010?	http://www.ict-itetris.eu/simulator/	iTETRIS integrates wireless communications and road traffic simulation platforms in an environment that is easily tailored to specific situations allowing performance analysis of cooperative ITS at city level. The accuracy and scale of the simulations leveraged by iTETRIS will clearly reveal the impact of traffic engineering on city road traffic efficiency, operational strategy, and communications interoperability.
FUTURE-RADAR (H2020) *Jan 2017 – Dec 2020*	https://www.ertrac.org/index.php?page=future-radar POLIS is project partner	Support action for ERTRAC and EGVIA to create and implement the needed research and innovation strategies for a sustainable and competitive European road transport system. ERTRAC has a Working Group on road transport automation.
CIVITAS SATELLITE (H2020) *2002-2020*	https://civitas.eu/ POLIS is project partner	CIVITAS can help to maximise the outreach of LEVITATE results. This includes, among others, making tools available in the online CIVITAS transport tools inventory.
Drive2theFuture (H2020) *2019-2022*	https://www.ait.ac.at/en/research-fields/integrated-mobility-systems/projects/drive2thefuture/	The aim of the Drive2theFuture project is to prepare future "drivers" and travellers for networked, cooperative and automated means of transport and to increase acceptance accordingly.
MAVEN (H2020) *2016-2019*	http://maven-its.eu/ POLIS is project partner	Aims to provide solutions for managing automated vehicles in an urban environment (with signalised intersections and mixed traffic). It develops algorithms for organising the flow of infrastructure-assisted automated vehicles.

EU Projects on CCAM		
STAPLE (CEDR) 2018-2020	AIT is project partner http://www.stapleproject.eu/	Identification of relevant connected and automated driving test sites in Europe and beyond and creation of an online catalogue to be used and further enhanced by the NRAs for further research beyond the project duration Investigation of the relevance of test sites against the NRA core business taking into account the roles and responsibilities of different stakeholders and looking at the areas of road safety, traffic efficiency, customer service, maintenance and construction
CityMobil 05/2006 – 12/2011	http://www.citymobil-project.eu/	Safety applications and technologies: safe speed and safe following, lateral support, intersection safety, active 3D sensor technology for pre-crash and blind spot surveillance.
PICAV 08/2009 – 09/2012	https://cordis.europa.eu/project/rcn/91186/factsheet/en	Passenger transport, urban traffic, car sharing, networking, assisted driving, vulnerable road users.
CATS 01/2010 – 12/2014	https://cordis.europa.eu/project/rcn/93669/factsheet/en	Robotic driverless electric vehicle, passenger transport, transport management, urban transport.
FURBOT 11/2011 – 02/2015	http://www.furbot.eu/	Fully electrical vehicle for freight transport in urban areas, robotics.
V-Charge 06/2011 – 09/2015	http://www.v-charge.eu/	Autonomous valet parking, EVs coordinated recharging, smart car system, autonomous driving, multicamera system, multi-sensor systems.
Cargo-ANTs 09/2013 – 08/2016	https://ict.eu/case/eu-fp7-project-cargo-ants/	Create smart Automated Guided Vehicles (AGVs) and Automated Trucks (ATs) that can co-operate in shared workspaces for efficient and safe freight transportation in main ports and freight terminals.
CityMobil2 09/2012 – 08/2016	http://www.citymobil2.eu/en/	Automated road transport system, automated vehicle, driverless, urban transport, safety, infrastructure, legislation.
PReVENT 02/2004 – 03/2008	https://trimis.ec.europa.eu/project/preventive-and-active-safety-application	Development and demonstration of preventive safety applications and technologies (advanced sensor, communication and positioning technologies).

EU Projects on CCAM		
Have-it 02/2008 – 07/2011	https://cordis.europa.eu/project/rcn/85267/factsheet/en	Automated assistance in congestion, temporary auto-pilot.
ASSESS 07/2009 – 12/2012	https://cordis.europa.eu/project/rcn/91187/factsheet/en	To develop a relevant set of test and assessment methods applicable to a wide range of integrated vehicle safety systems, mainly AEB for car to car. Methods developed for driver behavioural aspects, pre-crash sensing performance and crash performance under conditions influenced by pre-crash driver and vehicle actions.
Digibus Austria (National Austrian Funding) *2018-2021*	https://www.digibus.at/en/ AIT is project partner	Digibus pursues the goal to research and test methods, technologies and models for proofing a reliable and traffic-safe operation of automated shuttles on open roads in mixed traffic in a regional driving environment on automated driving level 3 ("Conditional Automation") and creating foundations for automation level 4 The results form the basis for an Austrian reference model for the real testing and operation of highly or fully automated vehicles in local public transport.
DIGITrans (National Austrian Funding) *2018-2023*	https://www.testregion-digitrans.at/ AIT is project partner	Exploration of needs and cases of application regarding heavy duty and special purpose vehicles Use of automated vehicles in areas of logistics hubs, e.g., inland ports like Ennshafen, airport or company sites Common use of infrastructure for test regions regarding automated driving
auto.Bus - Seestadt (National Austrian Funding) *2017-2020*	https://www.ait.ac.at/en/research-fields/integrated-mobility-systems/projects/autobus-seestadt/	The findings of the project will be: (a) robustness through the use and fusion of modern image processing technology, (b) trust and acceptance-building interactions with passengers and other road users as well as their impact, and (c) planning and design principles. These findings form the central prerequisites to enable a successful use of autonomous buses for public transport covering tomorrow's mobility needs.

As it is demonstrated in Table 2.1, none of the existing projects develop a tool providing an extensive impact assessment on the impacts of CCAM on safety, mobility, environment and society, as the LEVITATE PST. The majority of these projects are focused on safety, or on developing only a knowledge base with no estimation module, or on presenting the results of real-life demonstrations. The LEVITATE project will be the first to provide a complete Policy Support Tool, which includes a knowledge module and an estimator module for the impact assessment of the introduction of CCAM in the urban environment. The development of the LEVITATE PST, was based on the SafetyCube DSS and the ARCADE knowledge base, since it was not possible to find a project more similar to the scope of LEVITATE.

2.1.1 SafetyCube DSS

The SafetyCube DSS (www.roadsafety-dss.eu) is the European Road Safety Decision Support System, which has been produced within the European research project SafetyCube, funded within the Horizons 2020 Programme of the European Commission, aiming to support evidence-based policy making. The SafetyCube Decision Support System provides detailed interactive information on a large list of road accident risk factors and related road safety countermeasures. The SafetyCube DSS includes a knowledge and an estimator module. The knowledge module lists all documents synthesized during the SafetyCube project, regarding the effects of risks and measures, the causes and impacts of serious injuries, and the most common accident scenarios. The calculator module provides the Economic Efficiency Evaluation (E3) of road safety counter measures and allows to combine information about the effectiveness of a measure (i.e. the percentage of crashes or casualties prevented) with the costs of this measure. The calculator also integrates updated information of crash-costs in the European countries, allowing to express all costs and benefits of a measure in monetary values and conducting cost benefit analysis. Select one of the SafetyCube cost benefit analysis examples or perform a cost benefit analysis with the user's input data.

The SafetyCube DSS is a well-developed Decision Support System, including both knowledge and calculator components. This is why it was used by the LEVITATE project as a basis for the design and development of the PST. Nevertheless, the system exclusively features road-safety measures and does not concern the introduction of CCAM.

2.1.2 Knowledge Base of ARCADE

The Knowledge Base on Connected and Automated Driving (CAD) (https://www.connectedautomateddriving.eu) is an important repository for data, knowledge and experiences on CAD in Europe and beyond. The knowledge base was developed as part of the Horizon 2020 action ARCADE (Aligning Research & Innovation for Connected and Automated Driving in Europe) and gathers the scattered information among a broad network of CAD stakeholders to establish a common baseline of CAD knowledge and provide a platform for a broad exchange of knowledge. The ARCADE knowledge base provides information regarding past and current CCAM projects, regulations and policies on a national, EU and world-wide level, strategies and action plans related on the future development of connected and automated driving prepared either individually or jointly, by European Institutions, Member States, the private sector and their representative networks and associations, guidelines and evaluation methodologies and data sharing developed from the CARTRE data exchange platform. This is a very thorough knowledge base regarding the introduction of CCAM, but does not include an estimator component for the impact assessment of CCAM.

2.2 Review of user needs and stakeholders' input

The LEVITATE project aims to create a PST to enable policymakers to manage the introduction of cooperative, connected, and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives. For this reason, in various stages of the project, stakeholders were consulted in order to provide input for the development of the PST and to identify the user needs and adapt the final PST version to them, as well as to contribute to the progress of the project WPs. The consultation of the stakeholders was made through workshops and webinars.

2.2.1 Stakeholders input

The first Stakeholder Reference Group (SRG) workshop was organised at Gothenburg, Sweden on 28th May 2019. The main role of the SRG is to support the project team in ensuring the research continues to address the key issues as well as providing a major route to implementation of the results and consequent impact on mobility and road safety of all travellers. There were 35 participants and 10 Levitate project members.The SRG workshop participants came from various sectors such as municipality, city councils, traffic management, industry and, research. The workshop was organised in the following four sessions each one dedicated to a different part of the LEVITATE project:

- Session 1 – Visions of CCAM futures (current approaches to future planning in order to define important characteristics of short, medium and long term future to take into account in WPs 5, 6 and 7).
- Session 2 – Ideal futures (definition of future goals and indicators needed in order to develop the scenarios in WP4).
- Session 3 – Selecting interventions and activities (feedback on the sub-use cases identified in WPs 5, 6 and 7).
- Session 4 – Feedback on the PST (in fact feed forward) on the initial outline of what the policy support tool (PST) may include, and what features would be beneficial (developed in WP8).

The outcomes of sessions 1 to 3 provided feedback to WPs 4, 5, 6 and 7. The outcomes of session 4 concerning the PST structure were used in WP8. The aim of session 4 was for stakeholders to give their opinion on the proposed PST structure, identify the potential challenges and suggest additional features based on their expectations. The stakeholders consultation took place through the use of Vevox which is a polling and Q&A platform. Questions appeared in the powerpoint presentation during the workshop and the participating stakeholders could answer them using their mobile phones and see the results in real time, leading to increased interaction and engagement in the session. Out of the 35 workshop attendees, 27 took part in the PST dedicated session.

The first question was why stakeholders would use the PST. Stakeholders would write a phrase and then a word cloud (Figure 2.1) was created by presenting in different font sizes the words based on how many participants used them. The most common words were policy, complex measures and decision. The purpose of using the PST based on the stakeholders' answers are to test scenarios before taking political decision and gain insight on the implications of various measures. They also consider that forecasting is always of great importance for city administrations as they need time enough to react and allocate resources, and the PST would give some direction into long term policy planning, in order to achieve the estimate impacts, justify measures and eventually argue investments.

Figure 2.1: word cloud, why stakeholders would use the PST

The second question was about the importance of the knowledge module of the PST. The majority of participants (59%) considered the knowledge module a very important component of the PST, as it would provide guidance in the use of the estimator module as well as cases studies which would help them take the right decisions or at least informed decisions. The other 41% would mostly use the estimator module and do not consider the knowledge module as important as the estimator component. Based on the stakeholders answers the knowledge module will be populated and present all necessary documents in order to satisfy the expectations of the users.

The third question was about the features of the knowledge module that the stakeholders would mostly use. The guidelines and recommendations based on the impact assessment results and the case studies are the most important feature of the knowledge module based on 56% of the participants. The results and the tools documentation would be mostly used by 40% of the participants (20% each). The bibliography of the literature review and the project deliverables would be used by only 4% of the stakeholders. This importance of the guidelines and recommendations feature is explained by the fact that stakeholders would like to gain insight on the implications of their decisions which will be provided by the guidelines and recommendations documents. For this reason, the PST knowledge module will include all documentation regarding the methods and the results of cases studied, but also provide documents that will describe in detail the policy recommendations.

The fourth question was dedicated to the estimator module and stakeholders were asked to choose between the forecasting and the backcasting sub-systems the one that they would mostly use. The backcasting sub-system was selected by 73% of the respondents, since it provides the users the possibility to identify a vision of the future and the backcasting sub-system will suggest the measures to be implemented in order to help achieve the long-term mobility goals and/or to mitigate the potential negative effects of vehicle automation.

In the fifth question stakeholders were asked to suggest what additional features they would like to be added to the PST. The majority of participants would like to see some simulation results and examples of EU or national level interventions to support city plans. This suggestion will be provided at a first stage via the case studies, but also the feature of real-life examples could be added in the future after the end of the project and during the maintenance of the PST if funding is provided. Furthermore, stakeholders would like a FAQ feature and suggestions about the functionality of the PST, which will be provided as part of the knowledge module. Finally, participants suggested that the creation of a community network with links to contacts of trials, contacts of demos and contacts with other cities, that have some experience with CCAM and a forum, would be a helpful component of the PST. This feature could be added in the future when a large number of policy makers would have used the PST and implemented the proposed interventions.

The final question was about the challenges that might be faced for the development of the PST. The outcome of this question (Figure 2.2) helped PST developers prepare for these challenges and come up with proactive solutions. The most important challenge of the PST based on the stakeholders' answers was the high complexity of such a tool. Other challenges also included the difficulty in validating the impact assessment results, especially given the fact that different rules and strategies apply in each country, and this would make it more difficult to convince policy makers that the tool is accurate. In order to overcome, these difficulties a transferability analysis took place after the impact assessment towards the end of the project. The results of the transferability analysis will be presented to the users, so that they would be persuaded of the accuracy of the tool. The case studies that took place in the network of Athens, Manchester and Vienna will also be included in the final version of the PST, in order to provide users with examples of local based evidence.

Figure 2.2: word cloud. PST development challenges

The LEVITATE Stakeholder Reference Group met for the second time in the project's lifetime for a workshop held on 26 November 2019 in Brussels. The workshop provided a preview of the Policy Support Tool to an audience of 37 participants, among them local and regional authorities, national authorities, national road operators and researchers. The main aim of this second meeting of the LEVITATE stakeholder group workshop was to gather feedback from stakeholders on the scope and structure of the policy support tool (PST).

In the first part of the workshop, the main concepts were presented to the audience. The Policy Support Tool (PST) was presented first: its components, what it can and cannot do, what input will be required by the users and what the output might look like. The tool was presented through a mock-up to show the audience how the tool could work in the future. A practical example was used to illustrate the tool's expected functioning in a step by step process. The audience could thus understand how the tool could potentially help public authorities determine the interventions they could take as connected and automated motoring advances.

This demonstration was followed by a presentation of the different CCAM impact areas, and the reasons why they were selected. An overview of the CCAM policy interventions (related to urban transport, economic incentives, access and space allocation) was given. Finally, the backcasting method was presented highlighting that backcasting starts with the city's vision (the targets cities want to achieve). After these presentations, the participants broke up into four smaller groups (of 8/9 people). The group discussions consisted of several rounds to gather opinion about several topics: the PST structure, the backcasting method and the policy interventions.

The PST structure discussion was focused on the PST development, and more precisely on the goals that this tool will assist the stakeholders in achieving, the challenges in the development of the forecasting estimator as well as the suggestions for improvement in the next version of the PST. Thus, workshop participants had the opportunity to provide feedback that could influence the onward development of the PST and its components.

PST usability:
Participants were generally positive concerning the presented PST structure, as it was considered user friendly and a sufficiently comprehensive tool with great potential to support decision-making. They also appreciated the flexibility of the system, that transformed it simultaneously into a communication and planning tool. Nevertheless, they were sceptical about the systems reliability due to the abundance of different parameters.

The main reason why stakeholders would use the PST is to provide cities with the opportunity to prioritise policy interventions contributing in the no regret policy, and eventually to support changes in regulations. Additionally, this tool would offer the possibility of interactive use by comparing different scenarios and reducing uncertainty during the decision making process. The use of PST as evidence base in order to convince for budget requirements, could also, according to participants, contribute in cost saving of consultancy.

PST development challenges:
The participants' first impressions concerning the structure of the PST were optimistic, however they pointed out several challenges that could be faced during the development of the estimator module. The main challenge is the validation of results in order to be reliable, especially given the fact that fully quantified analysis seems somehow uncertain.

Additionally, it is important to identify the limitations of the interventions and the potential for CAV expansion. It was also highlighted that the development of such a complex tool needs important contributions from the scientific research teams. Another challenge identified by the stakeholders is to achieve the transferability of results to different cities.

PST additions and improvements:
Participants proposed various improvements to be included in the final version of the PST. Concerning the knowledge module stakeholders considered the origin of data used in the estimator module, should be added, and a glossary with the terminology of the project would be helpful. Additionally, in order to gain users trust the assumptions should be defined clearly.

Regarding the presentation of analysis results, participants proposed to include the combined effect of different sub-use cases and parameters as well as a sensitivity analysis in order to identify which sub-use case and parameter affects each impact more. The importance of communicating with other projects that are developing tools with similar features, such as the H2020 project FLOW, was highlighted. Another important suggestion was to ensure cooperation with city Macroscopic Transport Models.

Regarding the impacts analysed in the forecasting sub-system of the PST, participants specified that the impact of safety could be a direct impact and that the impact of land use could be included. Additionally, road casualties should be added in order to quantify the road safety impact. The impact of CAV data availability should be taken into account. It was also stated that infrastructure costs (physical and digital) should be included in the analysis and that cost benefit analysis for each impact and for all impacts together would be useful.

The final web PST should be updatable, based on CCAM progress and include the excel file which will be downloadable with the full documentation ("open box"). The user interface of the web tool should be ergonomic and user friendly, including graphs, statistics and distributions. The web PST must offer comprehensive user support, including documentation, training, etc.

The outcomes of both SRG workshops were taken into consideration during the development of the online PST.

2.3 Identification of critical issues

One challenge during the development of a PST offering a complete impact assessment for the introduction of CCAM in urban transport, passenger cars and freight transport, was the complexity of the tool given the fact that there is an abundance of potential interventions and impacts to take into consideration. For this reason, the final sub-use cases to be used in the PST have been developed and refined over multiple steps during the project. As a first step to develop sub-use cases, an overall list was developed from the existing expertise of the project partnership and existing knowledge from scientific literature. This was subsequently refined; their descriptions were clarified, and they were classified into logical categories. Then, during the first SRG workshop a session was dedicated to the consultation with the stakeholders on the prioritization of the proposed sub-use cases. After a predictability assessment and refinement and clustering of the stakeholders input on the sub-use cases were prioritized and selected to be added in the impact assessment of the PST.

One of the key challenges of developing the LEVITATE PST, as was already outlined by the stakeholders, was the validation and transferability of results. Naturally, the 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 or Manchester, partly due to the resource limitations 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 can be 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. 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 Design of the Policy Support Tool

3.1 Design principles and structure

The LEVITATE PST is designed as 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. For the purposes of this project, short-, medium- and long-term impacts would be those defined by D3.1 (Elvik et al., 2019). 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 the urban environment. Following the terminology established in the LEVITATE project, a use case is defined as any high-level area of application of CCAM. The use cases that are considered in the frame of LEVITATE are categorised as urban transport (WP5), passenger cars (WP6) and freight transport (WP7). The detailed description of the LEVITATE sub-use cases is included in D5.2 (Roussou et al., 2021) for the automated urban transport use case, in D6.2 (Haouari et al., 2021) for automated passenger cars and in D7.2 (Hu et al., 2021) for the automated freight transport use case. The outcomes of the impact assessment for all the sub-use cases 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 LEVITATE Policy Support Tool (PST) is envisioned to be the go-to, one-stop-shop to support decisions on CCAM-related interventions. It is expected to be used by city authorities, transport planners and engineers, transport researchers and interested citizens and NGOs. It is designed as an open access, web-based system that will provide interested users with access to LEVITATE methodologies and results. The detailed design will take into account the specific needs of the key stakeholders and it will provide access to related bibliography, project results, documentation of tools and methods, excerpts from CCAM guidelines, as well as a Policy Support Tool with forecasting and backcasting capabilities.

The LEVITATE PST comprises two main modules: the Knowledge module (static component) and the Estimator module (dynamic component). A graphical representation of the Tool, the two modules and the various sub-systems within each module is presented in Figure 3.1. This concept figure was utilized during development to provide direction towards a comprehensive PST; it is not a representation of the final visual interface of the system. The final visual representation of the PST are presented in chapter 4 of this deliverable.

The **Knowledge module** provides access to the knowledge base, repository and guidelines of LEVITATE project, namely:

- the bibliography,
- the project results, including the case studies on the participating cities (scenarios and baseline conditions, results) and the predefined impact assessments,

- the documentation of LEVITATE Tools and methods, to enable cities to explore the expected impacts of CCAM,
- excerpts from CCAM suggested Guidelines and Policy Recommendations.

To create the LEVITATE PST, an approach combining the different methodologies and their results into a single integrated unified system was required. At the same time, the approach has to keep the resulting PST understandable, comprehensive and approachable for the wide array of users that would be potentially interested in using it. A third dimension to be considered is that the system has to be feasible from a coding and software development scope without diluting or distorting the mathematical and scientific content.

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 contributed provided by the activities of WP5, WP6 and WP7, as well as data obtained from the horizontal methodologies implemented within the project (microscopic simulation, mesoscopic simulation, system dynamics, operations research and the Delphi panel method). It includes two sub-systems:

- the **Forecasting sub-system** provides quantified output on the expected impacts of CCAM related policies, using both pre-defined key scenarios and customised scenarios;
- the **Backcasting sub-system** enables users to identify the sequences of CCAM measures that are expected to result in their desired policy objectives.

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.

For the development of the LEVITATE PST, knowledge and expertise from past online decision-support systems was exploited, such as the SafetyCube DSS (www.roadsafety-dss.eu), the PRACT repository (www.pract-repository.eu) and the SafeFITS tool (https://unecetrans.shinyapps.io/safefits/).

A series of steps had to be undertaken to combine and integrate the inputs of the individual contributing methodologies and activities, undertaken in WPs 4 to 7 within LEVITATE, in order to create this interactive tool. These steps are analysed in detail in D8.1 (Ziakopoulos et al., 2021a). Specifically:

1. A common input Excel-based template was devised
2. Common scenarios were established, governed by different MPR progression of CCAM
3. Different methods provided input for each impact across different key MPR mixtures
4. The intermediate points were calculated with linear interpolation, formulating the full PST datasets

5. Capabilities describing the temporal lag of policy intervention introduction were introduced
6. Measure effectiveness and intensity capabilities were introduced
7. Forecasting and backcasting processes could be then conducted
8. CBA modules were created and operated based on the underlying datasets, and on user specification made during the forecasting and backcasting processes as well

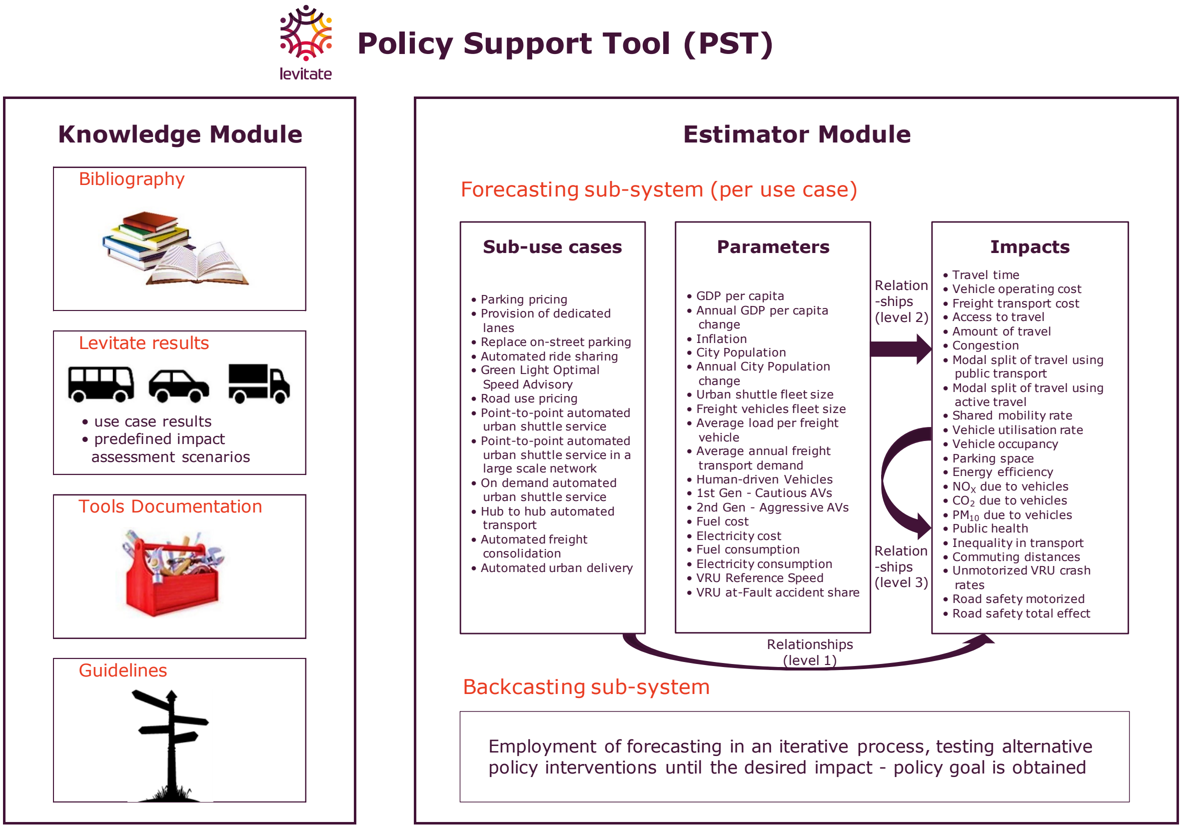


Figure 3.1 Structure of the LEVITATE Policy Support Tool

3.2 Populating the PST

The LEVITATE PST incudes 22 distinct impacts, defined by D3.1 (Elvik et al., 2019), which are calculated based on the respective default initial values as well as the outputs from the different methods (microscopic simulation, Delphi method, mesoscopic simulation and system dynamics) of the WP5, WP6 and WP7 that were selected based on the outcomes of D4.4 (Papazikou et al., 2020). Based on the 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 (WP5), passenger cars (WP6) and freight transport (WP7). The outcomes of the impact assessment were integrated in the LEVITATE PST.

To create the LEVITATE PST, an approach combining the different methodologies and their results into a single integrated system was required. At the same time, the approach has to keep the resulting PST understandable, comprehensive and approachable for the wide array of users that would be potentially interested in using it. A third dimension to be considered is that the system has to be feasible from a coding and software development scope without diluting or distorting the mathematical and scientific content. Therefore, before the Javascript code development, an intermediate step of MS Excel-based templates, using mainly simple functions and formulas to ensure a smoother transition into the online PST version, was adopted and followed. These documents were created for each of the 12 sub-use cases and were termed 'PST-Demo-' files, which were the documents used to receive the inputs of the different methodologies used in WP5-7 for each examined impact and policy intervention.

To successfully conduct impact forecasting and backcasting with the LEVITATE PST, the user has to follow the sequence of steps outlined in the next 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. The input and output process were initially created in the Excel Demo phase as well and depicted in a pseudo-interface presented in D8.1 (Ziakopoulos et al., 2021a). This preparatory phase facilitated the subsequent development of the PST in the fully functional online Javascript version considerably.

Subsequently using the 'PST-Demo-' files of the different sub-use cases, the LEVITATE PST estimator was developed in Javascript code, comprising a highly ergonomic interface, simple and easy to use. It includes a graphical environment (interactive infographics) for presentation of results. Especially regarding the impacts, the graphical presentation of results (e.g. in a suitably designed chart) allows for the visualisation of the time dimension of the impact (in the x-axis of the chart).

It should be mentioned that some snapshots of the various stages of the PST have been presented in international conferences by partners with papers and or posters/ presentations. Indicative references are Ziakopoulos et al. (2020; 2021b; 2021c; 2022).

4 Development of the Policy Support Tool

4.1 Overview of the online tool

The online PST can be found in the link https://www.ccam-impacts.eu/. The introductory page presents the three components that the user can access: the forecasting sub-system, the backcasting sub-system and the knowledge module. The user can choose and navigate into each one of the tools as presented in the following sections.

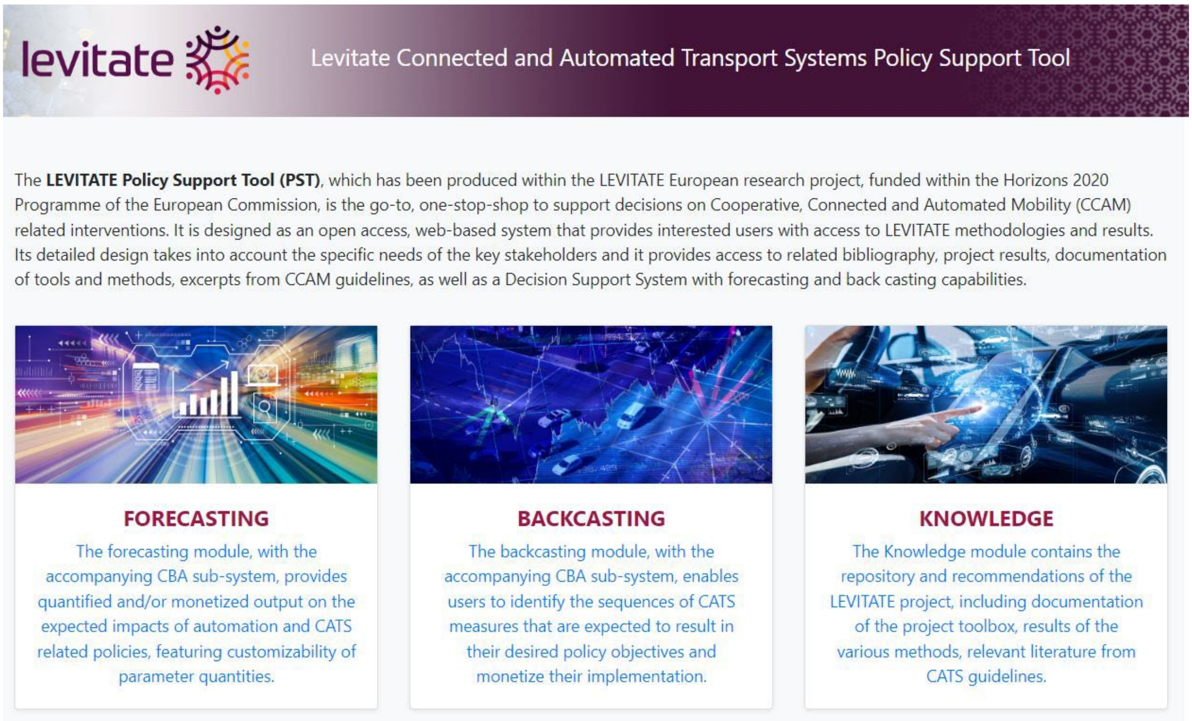


Figure 4.1: Online PST components

The PST serves as an integration of the mathematical tools, approaches, data and results summarized in detail in D8.1 (Ziakopoulos et al., 2021a).

4.2 Forecasting sub-system

The forecasting sub-system provides quantified and/or monetized output on the expected impacts of CCAM related policies, featuring customizability of parameter quantities. The PST user has to follow several steps in order to provide the required inputs, as shown in Figure 4.2.

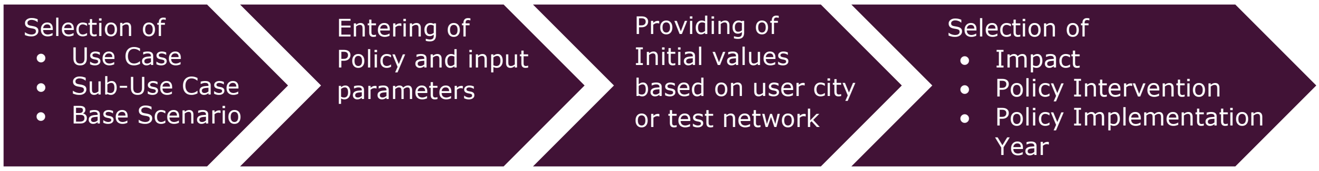


Figure 4.2: User inputs of forecasting module flowchart

More specifically, the first step of the impact assessment is for the user to choose a use case, between urban transport, passenger cars and freight transport in the form of drop-down menu. Then, the user is asked to choose a sub-use case, which is a CCAM intervention related to the selected use case, and to define the base CCAM deployment scenario to be assessed (no automation, pessimistic, neutral and optimistic) in the form of drop-down menus. The user can also define the intensity of the policy intervention between the years 2020-2050, which refers to what lies within the control of the authorities, such as route frequency for shuttle buses as well as the policy effectiveness, which refers to what the authorities can measure, observe or expect but cannot directly control, such as public acceptance, regulation obedience or similar aspects of the network and, most importantly, the behavior of the network users. These quantities are predefined in case the user does not want to adapt them.

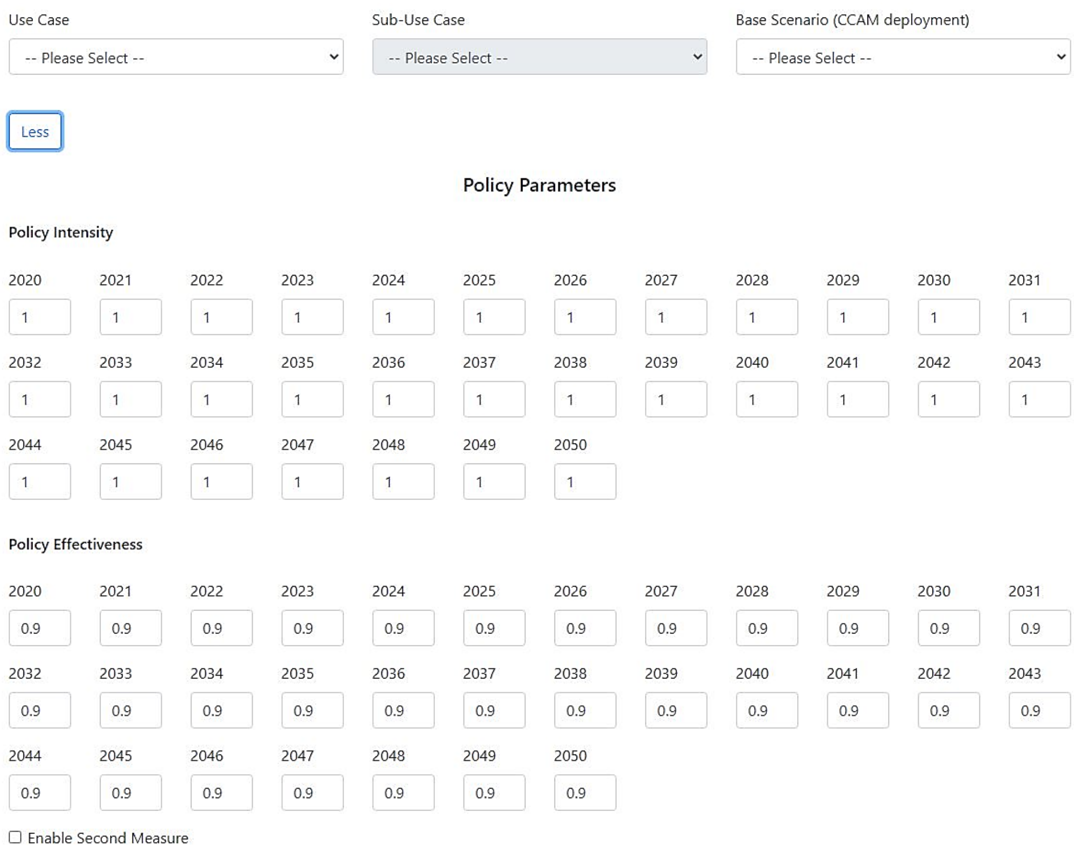


Figure 4.3: policy intervention selection

The user is also given the possibility to combine two CCAM measures (sub-use cases) for the impact assessment. For the second measure the user should similarly to the first, define the use case, the sub-use case and the policy parameters.

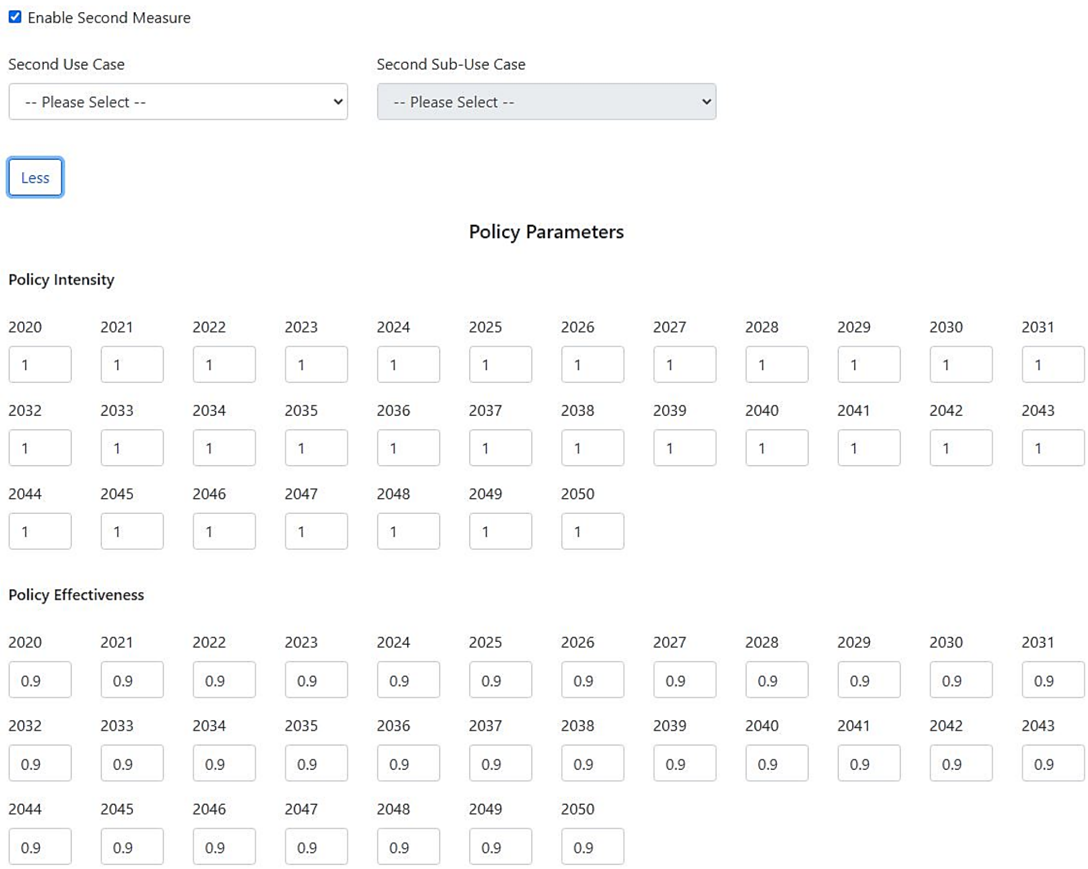


Figure 4.4: forecasting second measure definition

In case of selection of the "City Tolls" sub-use case related to the "PASSENGER CARS" use case and the "On Demand Shuttle Bus Service" sub-use case related to the "URBAN TRANSPORT" use case, the user is prompted to enter some additional details that are required. More specifically, these are details of economic situation of agents, which is the selection of the "Marginal utility of money" for both sub-use cases and the "Selection of the pricing level (€)" only for the "City Tolls" sub-use case, as shown in Figures 4.5 and 4.6.

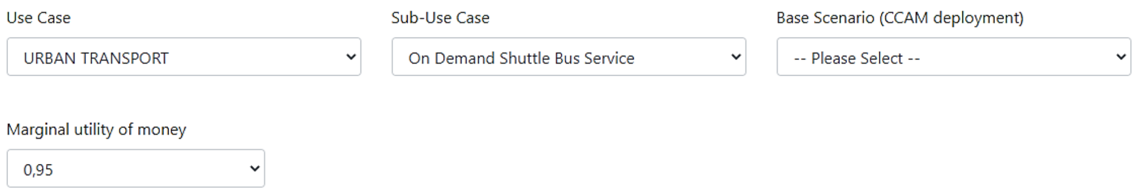
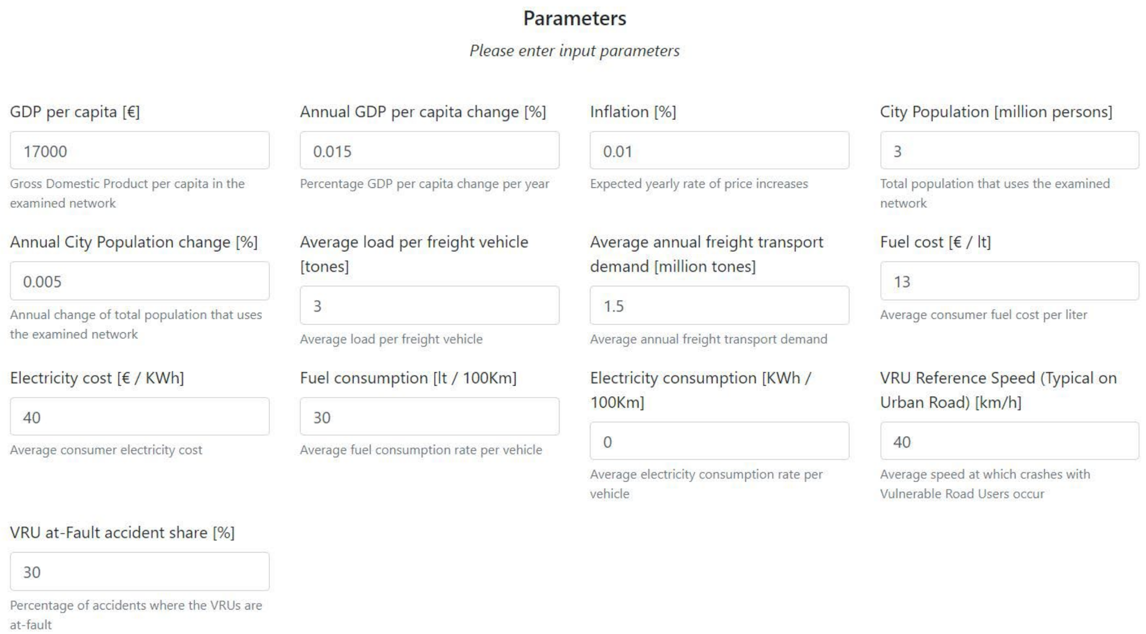


Figure 4.5: Selection of economic situation for On Demand Shuttle Bus Service sub-use case


Use Case
PASSENGER CARS
Sub-Use Case
City Tolls
Base Scenario (CCAM deployment)
-- Please Select --
Marginal utility of money
0,95
Selection of the pricing level (€)
0

Figure 4.6: Selection of economic situation for City Tolls sub-use case

After selecting the sub-use cases and the scenarios to be assessed, the user is asked to define the system parameters, which include predefined values, but can be adapted by the user to reflect more the user's region where the CCAM intervention will be implemented.


Parameters

Please enter input parameters

GDP per capita [€]
17000
Gross Domestic Product per capita in the examined network

Annual GDP per capita change [%]
0.015
Percentage GDP per capita change per year

Inflation [%]
0.01
Expected yearly rate of price increases

City Population [million persons]
3
Total population that uses the examined network

Annual City Population change [%]
0.005
Annual change of total population that uses the examined network

Average load per freight vehicle [tones]
3
Average load per freight vehicle

Average annual freight transport demand [million tones]
1.5
Average annual freight transport demand

Fuel cost [€ / lt]
13
Average consumer fuel cost per liter

Electricity cost [€ / KWh]
40
Average consumer electricity cost

Fuel consumption [lt / 100Km]
30
Average fuel consumption rate per vehicle

Electricity consumption [KWh / 100Km]
0
Average electricity consumption rate per vehicle

VRU Reference Speed (Typical on Urban Road) [km/h]
40
Average speed at which crashes with Vulnerable Road Users occur

VRU at-Fault accident share [%]
30
Percentage of accidents where the VRUs are at-fault

Figure 4.7: forecasting parameters predefined values

Finally, the user can also define the current values of the studied impacts, the starting values of the impact assessment. These are predefined but can be changed to reflect the user's city.

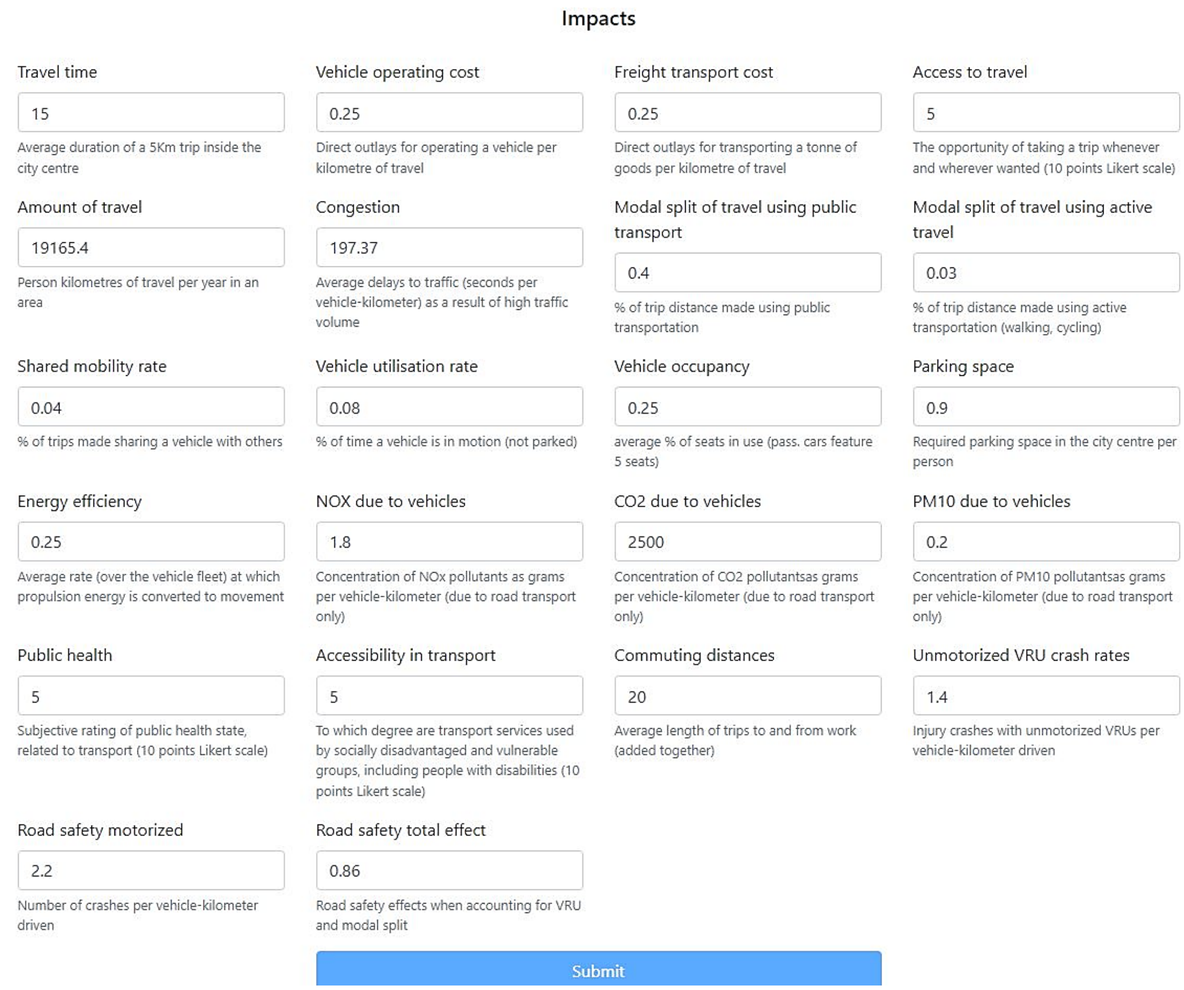


Figure 4.8: forecasting module impacts values definition

After defining the use case, the sub-use case, the scenario, the parameters and the impacts values the user can 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.

Figure 4.9: forecasting impact assessment graph selections

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.

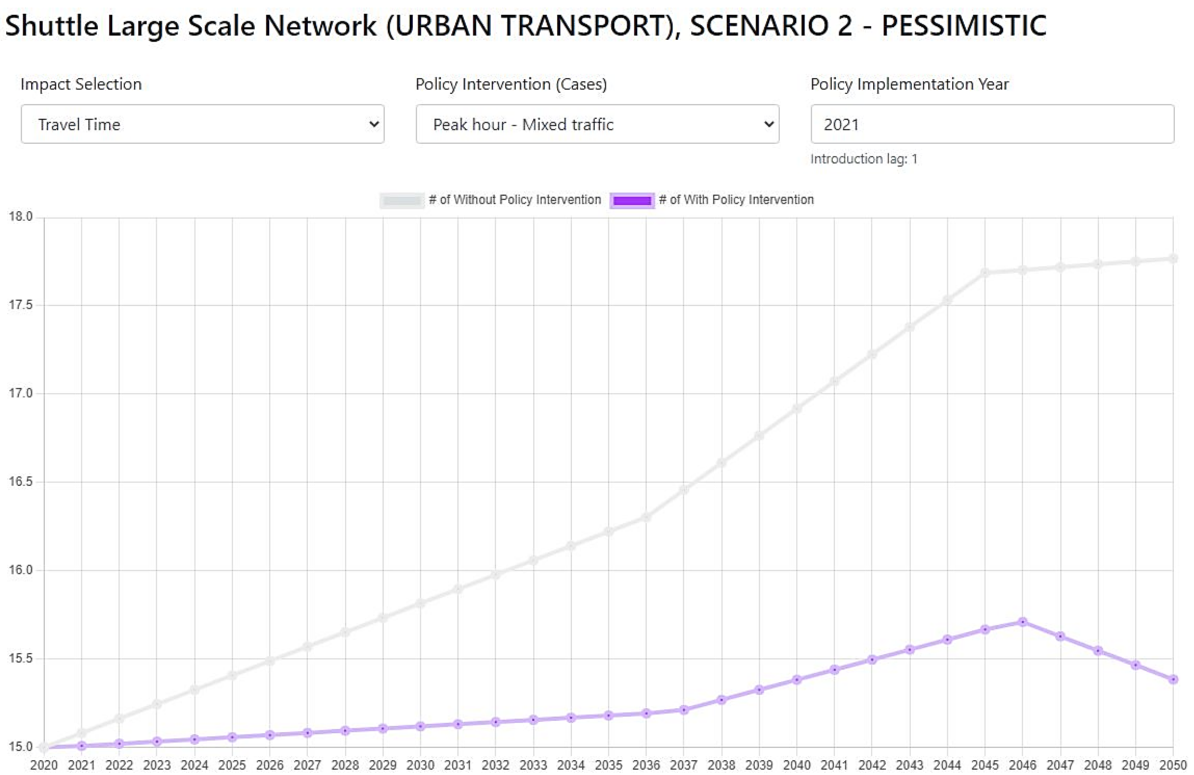


Figure 4.10: forecasting impact assessment graph

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.

Figure 4.11: forecasting impact assessment graph selections when combining two measures

Then, the graph presents, how the selected impact is affected by the introduction of the two policy interventions.

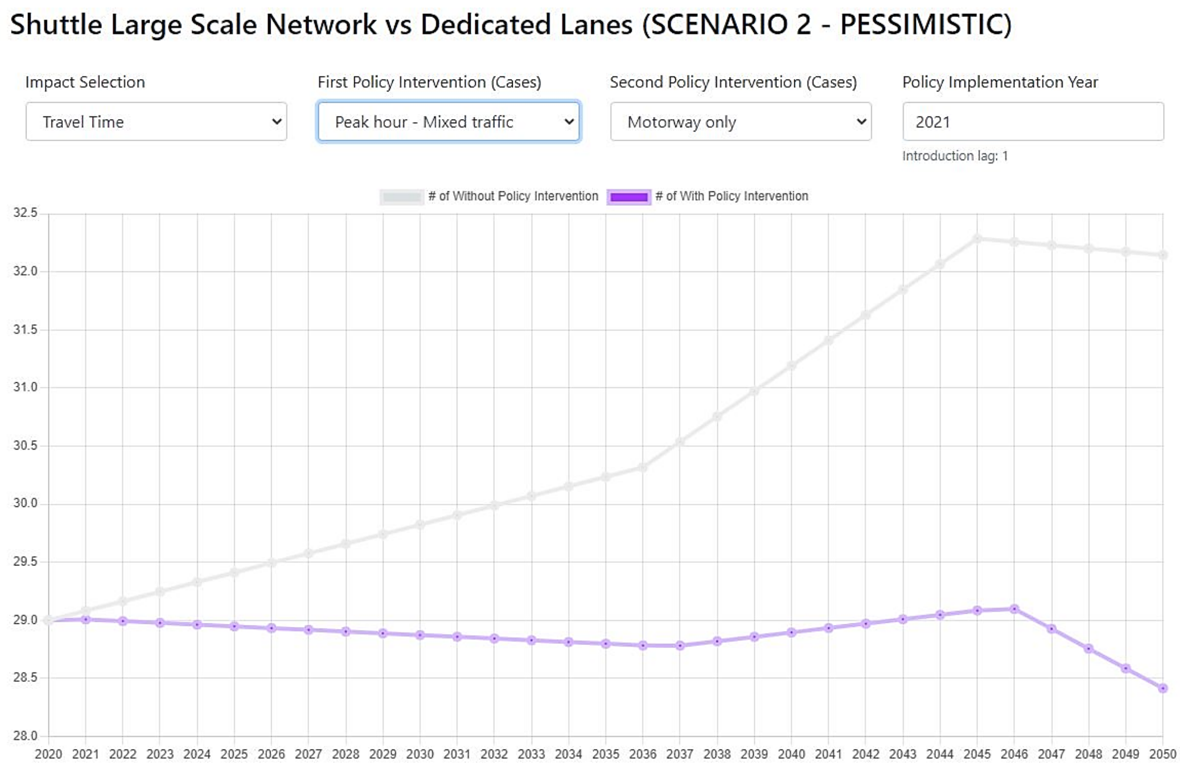


Figure 4.12: forecasting impact assessment graph when combining two measures

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.

Without Policy Intervention

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 4.13: forecasting impacts descriptions and results

Without Policy Intervention

	Measurement Unit	2020	2021	2022	2023	2024
) public transportation	%	0.4	-0.24%	-0.47%	-0.71%	-0.95%
) active transportation (walking, cycling)	%	0.03	-0.21%	-0.42%	-0.63%	-0.84%
iicle with others	%	0.04	0.04%	0.08%	0.12%	0.17%
on (not parked)	%	0.08	0.27%	0.53%	0.80%	1.07%
ss. cars feature 5 seats)	%	0.25	0.10%	0.20%	0.29%	0.39%
e city centre per person	m2/person	0.9	-0.15%	-0.31%	-0.46%	-0.61%
e fleet) at which propulsion energy is converted to movement	%	0.25	0.19%	0.37%	0.56%	0.74%
ints as grams per vehicle-kilometer (due to road transport only)	g/veh-km	1.8	-2.18%	-4.36%	-6.53%	-8.71%
ntsas grams per vehicle-kilometer (due to road transport only)	g/veh-km	2500	-2.09%	-4.19%	-6.28%	-8.37%
tantsas grams per vehicle-kilometer (due to road transport only)	g/veh-km	0.2	-1.74%	-3.48%	-5.22%	-6.97%
alth state, related to transport (10 points Likert scale)	-	5	0.06%	0.13%	0.19%	0.26%

Figure 4.14: forecasting impact assessment numerical results

4.2.1 Forecasting Cost-benefit analysis extension

The Cost-Benefit Analysis sub-system (CBA module) is set up as an extra module in the PST (Hartveit & Veisten, 2021). After receiving the forecasting impact assessment results the user will be able to continue with the Cost-Benefit Analysis. In the CBA, some additional default values will have to be considered by the PST user, e.g. the costs related to the selected policy scenario (policy implementation costs). The objective of the CBA module is to convert the "physical" effects (travelling time, emissions, etc.) simulated and estimated in the PST to monetary terms and to provide socio-economic results. One key contribution from the CBA module is a set of valuations and guidelines for monetizing physical effects. The monetized impacts and results from the CBA will be presented on various levels: a net benefit estimate and a cost-benefit-ratio in total, results for each infrastructure user group (transport modes), the policy entity (which carries out the policy scenario) and the surrounding community, as well as a sensitivity analyses and a break-even analysis.

4.2.2 Numerical example

The 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:

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

Figure 4.15: forecasting sub-system example use case, sub-use case and CCAM scenario selection

4) Definition of parameters based on the data from the user's city, to ensure that the final results will be relevant and transferable. In this example the city parameters aredifferent from the default values are the following:
   GDP per capita: 25000
   Annual GDP per capita change: 0.020
   City population: 5
   Average load per freight vehicle: 2
   Fuel cost: 15
   Fuel consumption: 25

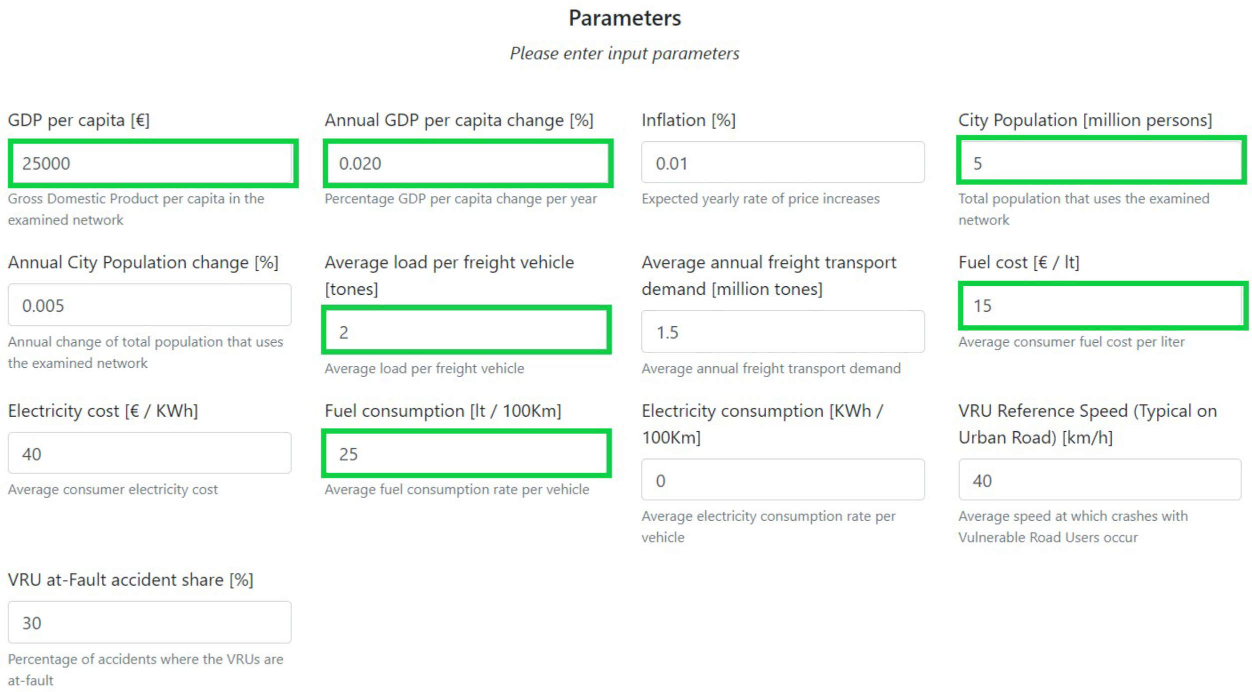


Figure 4.16: forecasting sub-system example city parameters definition

5) Definition of impact values, based on the user's city data. In this example the impact values different from the default values are the following:
Travel time: 10min
CO2 due to vehicles: 2000gr/vehkm

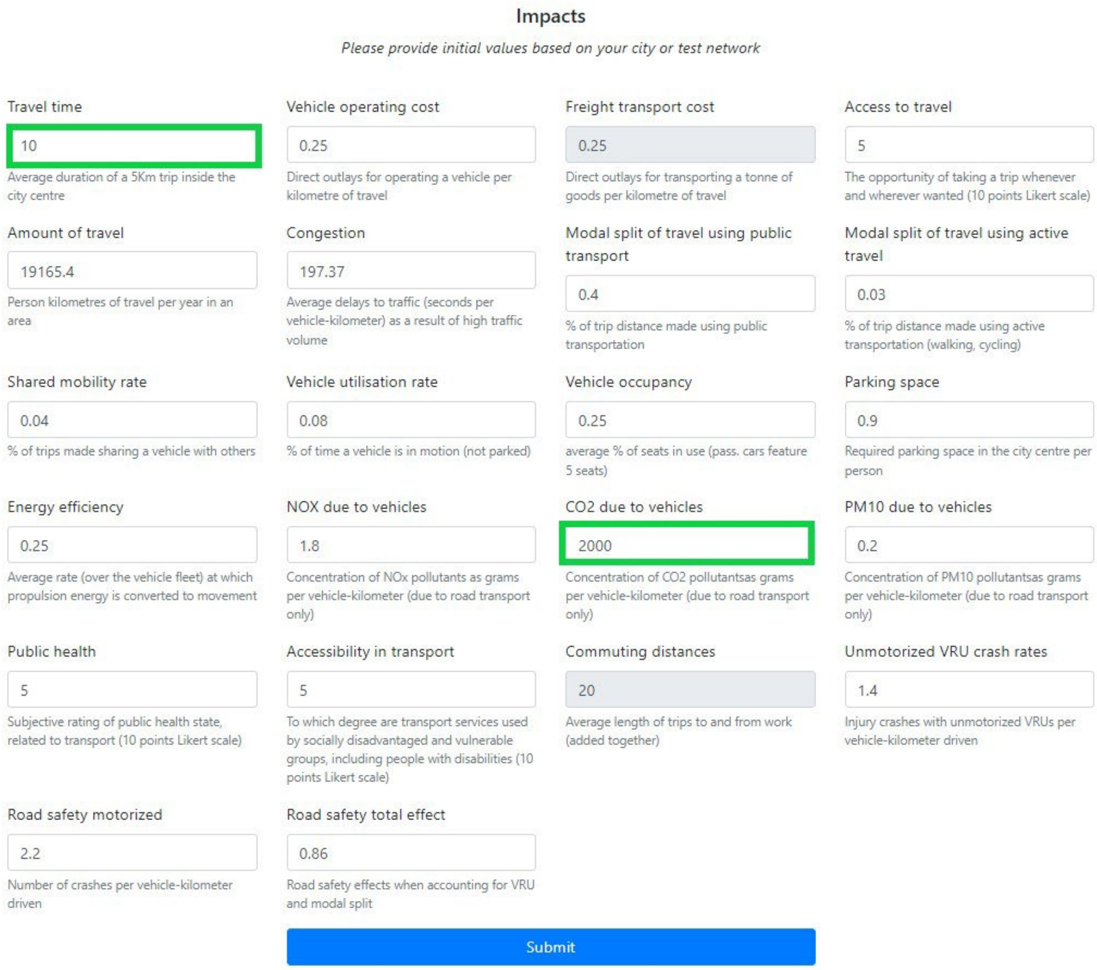


Figure 4.17: forecasting sub-system example impact starting values definition

6) Submit the selection and proceed to the results page.
7) In the results page the user will select the impact to see the graphical representation of results.
8) Select the scenario from the policy intervention drop-down menu, in this case the dedicated lanes on a “Motorway and A road”.
9) Definition of the implementation year of the policy intervention, in this example the year 2025 is selected.
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.

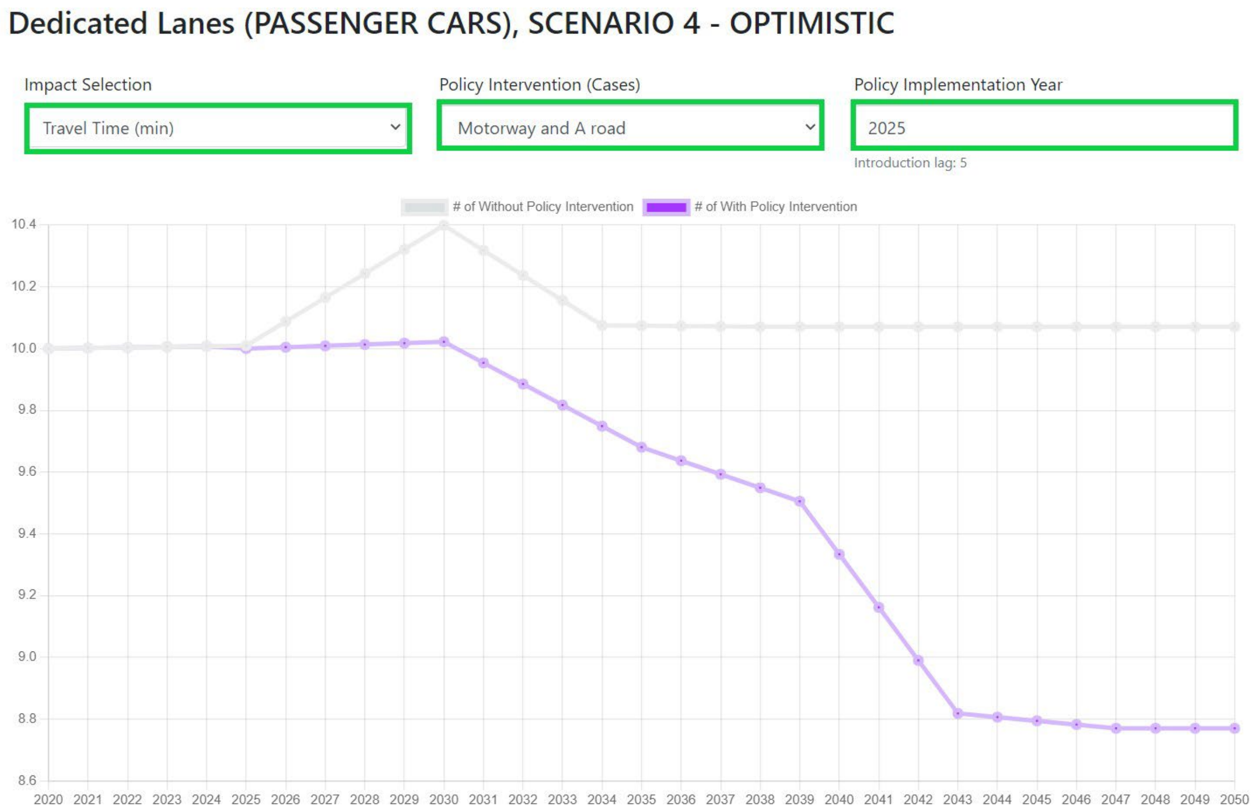


Figure 4.18: forecasting sub-system example praph results

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.

With Policy Intervention - Motorway and A road

Type	id	Impact	Description	Measurement Unit
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 4.19: forecasting sub-system example results table

With Policy Intervention - Motorway and A road

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0.04%	0.09%	0.13%	0.18%	0.22%	-0.46%	-1.15%	-1.83%	-2.51%	-3.19%
0.83%	1.66%	2.49%	3.32%	4.15%	3.37%	2.59%	1.81%	1.03%	0.25%
-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%
1.43%	2.87%	4.31%	5.74%	7.17%	6.59%	6.01%	5.42%	4.84%	4.25%
1.07%	2.14%	3.20%	4.27%	5.34%	5.00%	4.65%	4.31%	3.97%	3.63%
0.42%	0.84%	1.26%	1.68%	2.10%	2.22%	2.34%	2.46%	2.57%	2.69%
-0.64%	-1.28%	-1.92%	-2.56%	-3.19%	-3.53%	-3.88%	-4.22%	-4.56%	-4.90%
0.04%	0.09%	0.13%	0.18%	0.22%	-0.46%	-1.15%	-1.83%	-2.51%	-3.19%
0.83%	1.66%	2.49%	3.32%	4.15%	3.37%	2.59%	1.81%	1.03%	0.25%
1.22%	2.44%	3.66%	4.88%	6.10%	5.71%	5.32%	4.93%	4.54%	4.15%

Figure 4.20: forecasting sub-system example results table percentages

4.3 Backcasting sub-system

The backcasting module enables the users to identify the sequence of CCAM measures that are expected to result in their desired policy objectives. The PST user has to follow several steps in order to provide the required inputs, as shown in Figure 4.21.

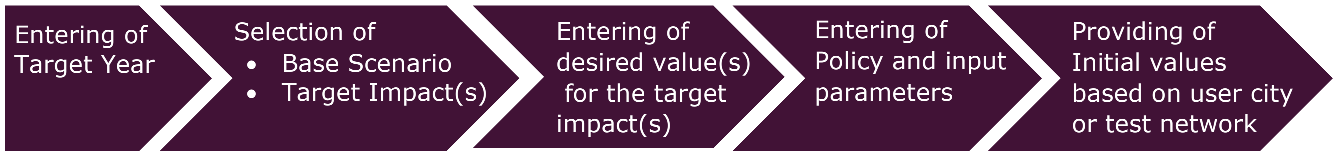


Figure 4.21: User inputs of backcasting module flowchart

More specifically, the first step of the backcasting is to identify the target parameters regarding the city's vision. The user is asked to indicate the target year, the CCAM deployment scenario (no automation, pessimistic, neutral, optimistic) and the target impact or impacts (5 maximum) along with the desired value to be reached in the target year.

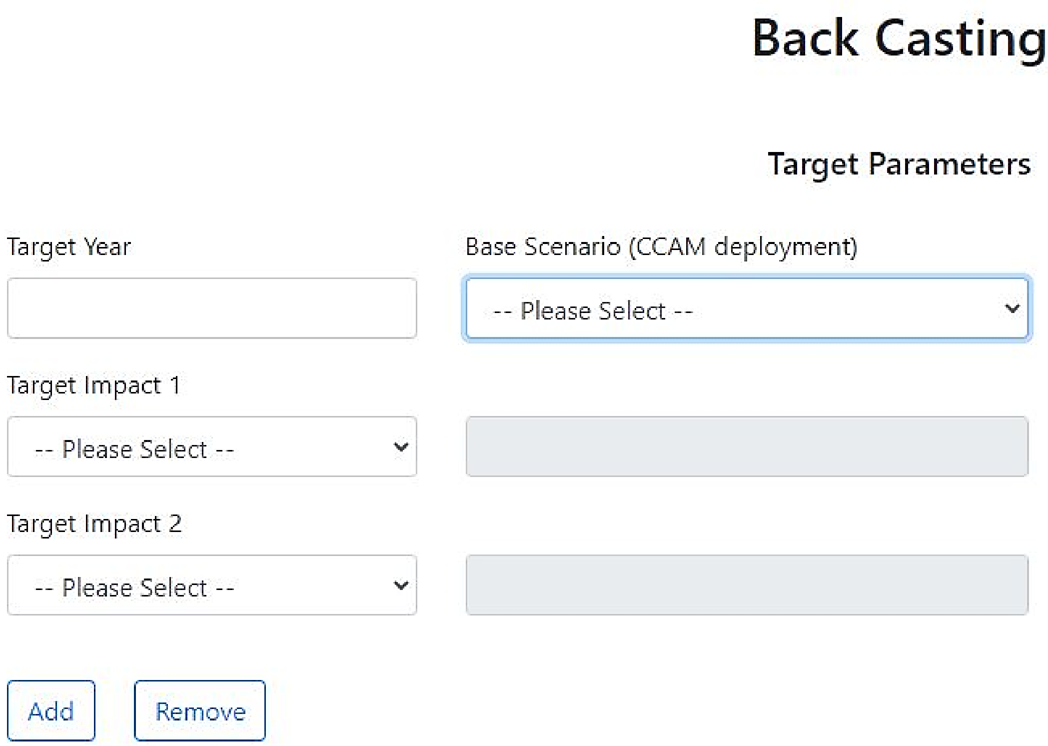


Figure 4.22: backcasting target parameters definition

Similarly to the forecasting module, the user can define the network and city parameters as well as the current impact values. Then the user can submit the selection in order to initiate the assessment.

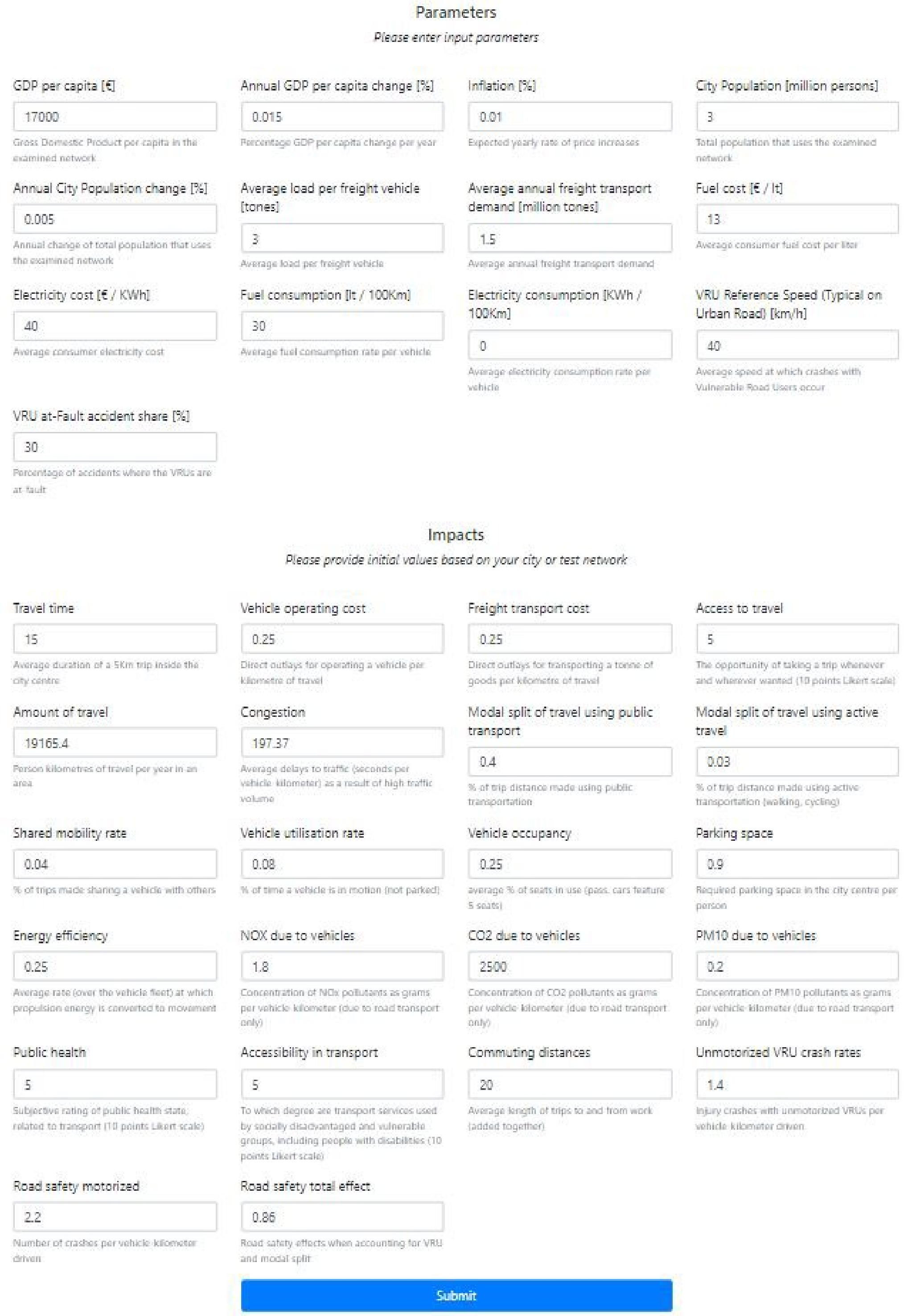


Figure 4.23: backcasting parameters and impacts values definition

The backcasting results present the list of scenarios that can lead to the desired impact values.

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 4.24: backcasting results

4.3.1 Numerical example

The example concerns the desirable future vision of decreasing congestion from 197 delay seconds per vehicle-kilometer 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.
2) Define the CCAM deployment scenario, the low deployment scenario is the scenario 2 from the drop-down menu, the "PESSIMISTIC" scenario
3) Select the specific impacts that the user wishes to include in the backcasting analysis. There is the possibility of selecting up to 5 different impacts. For this example, only the "congestion" will be selected from the drop-down options.
4) Define the desired future value of the selected impact(s). In this example the future value of congestion is 197.

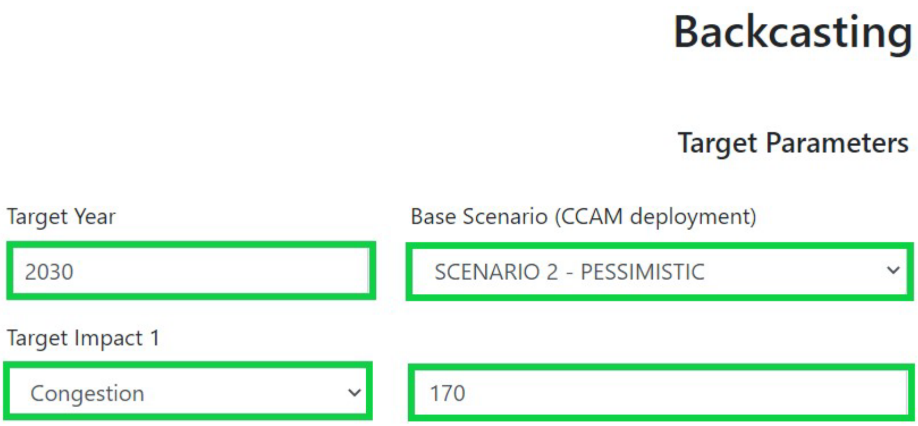


Figure 4.25: backcasting sub-system example target year, CCAM scenario, impacts selection and desired values definition

5) Define the parameters based on the data from the user's city, to ensure that the final results will be relevant and transferable. In this example the city parameters different from the default values are the following:
   GDP per capita: 25000
   Annual GDP per capita change: 0.020
   City population: 5
   Average load per freight vehicle: 2
   Fuel cost: 15
   Fuel consumption: 25

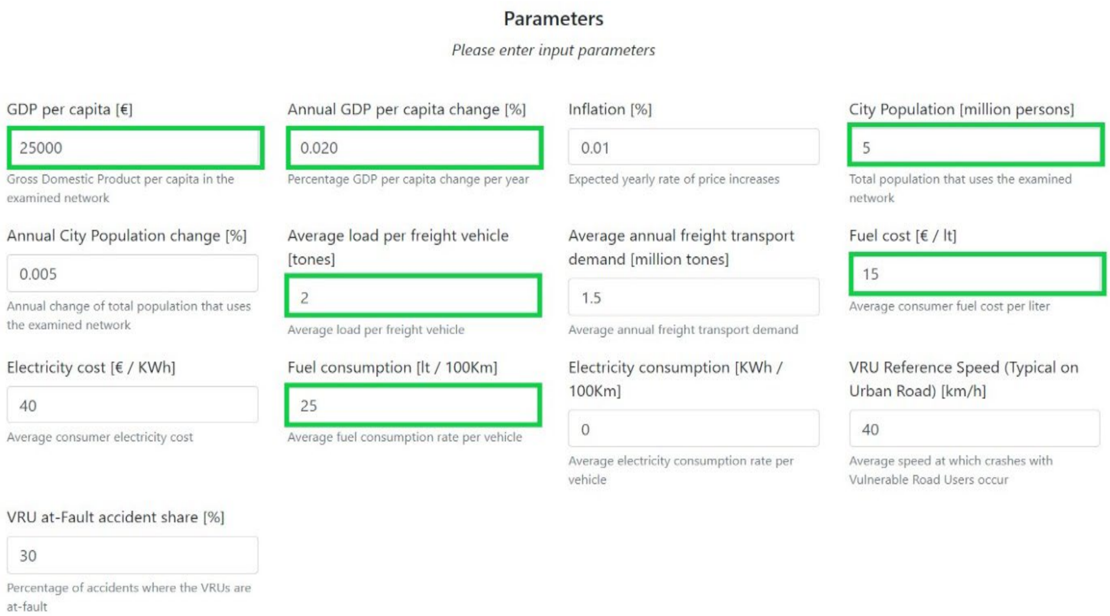


Figure 4.26: backcasting sub-system example city parameters definition

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.

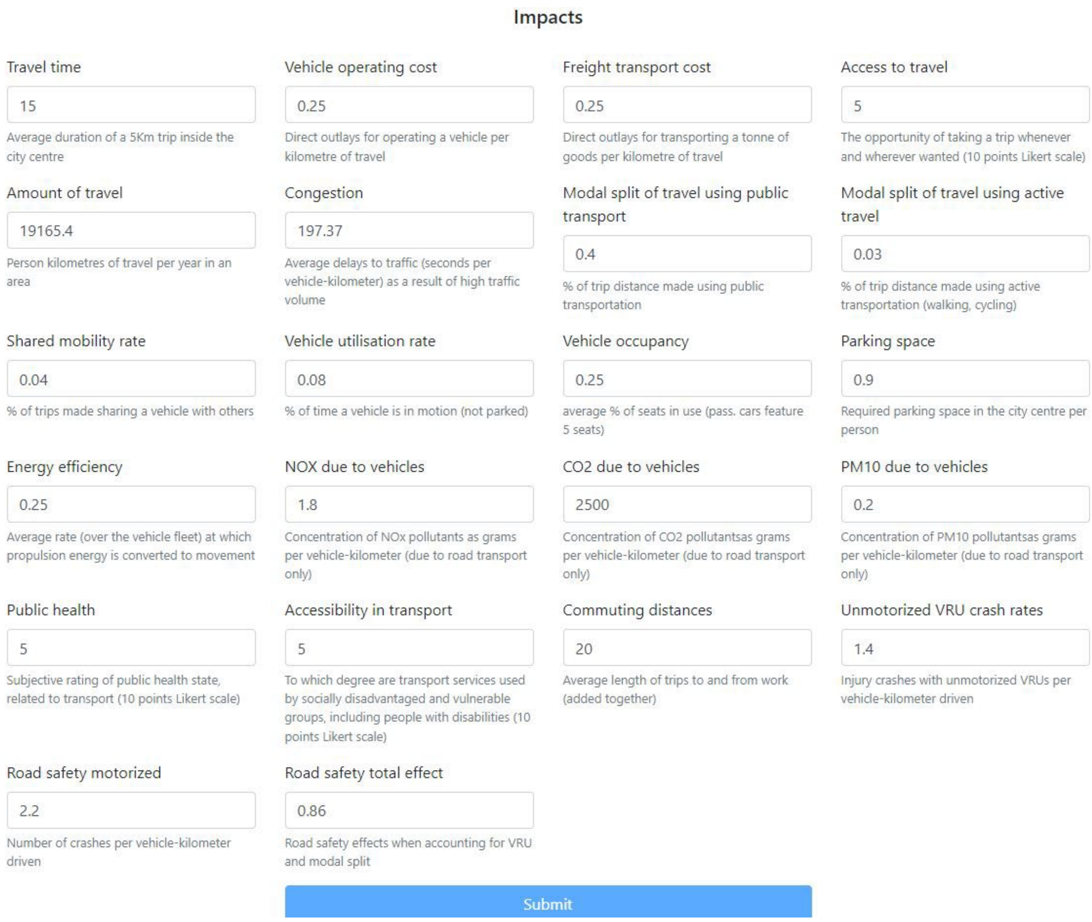


Figure 4.27: backcasting sub-system example impact starting values definition

7) Submit the selection and proceed to the results page.
8) In the results page 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. 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	Difference from inpu
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Baseline	true	0.00000385725622
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Manual consolidated delivery	true	0
Congestion	FREIGHT TRANSPORT	Automated Consolidation	Automated consolidated delivery	false	0
Congestion	PASSENGER CARS	Glosa	Baseline	true	2.51899575153e-7
Congestion	PASSENGER CARS	Glosa	GLOSA on 1 Intersection	false	0
Congestion	PASSENGER CARS	Glosa	GLOSA on 3 Intersections	true	0
Congestion	PASSENGER CARS	Glosa	GLOSA on 2 Intersections	false	0
Congestion	FREIGHT TRANSPORT	Automated Delivery	Baseline	true	0.00000385725622
Congestion	FREIGHT TRANSPORT	Automated Delivery	Semi-automated delivery	true	0
Congestion	FREIGHT TRANSPORT	Automated Delivery	Fully-automated night delivery	false	0

Figure 4.28: backcasting sub-system example table results

4.4 Knowledge module

The knowledge module aims to provide a searchable static repository through a fully detailed and flexible concise repository. The concise reports aim to inform the user in the most essential and summarizing way, offering the necessary information. More specifically, the user is able to search by any parameter, to adjust and customize the search according to preliminary results and to access all background information about any stage of the project. The reports 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:

- Bibliography: the bibliography of all relevant literature concerning impact assessments of CCAM,
- Project results: the project results, including the case studies on the participating cities (scenarios and baseline conditions, results) and the predefined impact assessments,
- 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),
- Guideline excerpts: Guidelines and policy recommendations regarding CCAM.

In the online PST the user will select in the initial page the "Knowledge Module". The user has access to 6 different types of documents seen in the following figure.

Figure 4.29: Knowledge module contents

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 Toolbox 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 Results 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 Results 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.

4.5 Transferability of results / uncertainty of results

The analyses of the generalizability and transferability of results have also been performed within the Levitate project, as detailed in "Transferability of results within the Levitate Project" (Sha et al., 2022). The approach used include both qualitative and quantitative comparisons where qualitative comparisons include the identification of the key characteristics of the study networks used within the project while the quantitative comparisons involve various experiments, which are performed to test the transferability of results under different methods used within the project including microscopic simulation, mesoscopic simulation, system dynamics, and operations research.

5 Conclusions and future work

5.1 Conclusions

The development of the LEVITATE PST followed several steps in order to make sure that its structure and contents will be addressing the users' needs. After two Stakeholder Reference Group workshops, the potential users needs and desired features have been identified. The PST comprises two main modules: the Knowledge module (static component) and the Estimator module (dynamic component). The estimator module provides a forecasting and a backcasting sub-system, including a CBA sub-module, and a backcasting sub-system. The results and methods of the impact assessment have been added in the online tool. The development of the online tool followed the stakeholders' requests and in order to verify that the purpose and use of the PST are clear to the users, stakeholders will also be asked to take part in training sessions. The limitations concerning the development of such a complex tool have been mostly connected with the fact that various impact assessment methods have been used, and it was necessary to ensure the transferability of results. Finally, a vast number of impacts and interventions have been identified and a prioritization took place in order to select the most important to be analysed and added in the PST.

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. 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 practictioners 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.

5.2 Future work

Further work to be carried out in WP8 includes the following tasks:

a. Finalize the project case studies using the methodologies developed by the harmonization of results within the LEVITATE PST. The application of the LEVITATE PST on these selected cases studies will be the content of deliverable D8.3 in terms of task 8.4.

b. Promote and exploit the LEVITATE PST with road authorities, interested stakeholders and the scientific community, as part of the task 8.2 as well as the ongoing works of WP2, which focusses on the exploitation and dissemination of the project outcomes throughout the whole duration of LEVITATE.
c. Develop the synthesis of the key messages and outputs of the project, in order to provide the most important policy recommendations which will derive from the outputs of the LEVITATE PST for different types of stakeholders, and for optimal use of the methodologies. These policy recommendations will be in detail developed in deliverable D8.4 (Chaudhry, A. et al., 2022), as part of the task 8.5 and will be included in the knowledge module of the LEVITATE PST.
d. Present key LEVITATE results in academic publications in scientific journals and conferences, promoting the project and increasing the audience to which the overall work within LEVITATE is promoted and disseminated.

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