Methodological framework of creating the Levitate Policy Support Tool for Connected and Automated Transport Systems

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Abstract

Connected, Cooperative and Automated Mobility (CCAM) are expected to be introduced in increasing numbers over the next decade based on the rapidly developing capability of modern technologies. The need for policies around the introduction of CCAM is starting to arise, based on the evaluation of the likely impact of different technologies, with the aim to capture the benefits of automation and ensure that new technologies contribute to wider policy objectives. The Horizon 2020 Levitate project aims to investigate the potential short, medium and long term impacts of CCAM, through an innovative multi-disciplinary impact assessment methodology, which will be incorporated within a new web-based policy support tool to enable city and other authorities to forecast impacts of CCAM on urban areas. The aim of the present paper is to provide an insight on the development of the Levitate Policy Support Tool (PST), the use cases, parameters and impacts considered and the methodologies applied for the estimation of relationships and impacts of connected and automated transport systems. This policy support tool will comprise a knowledge and an estimator module and will include forecasting and backcasting systems providing estimates for different types of impacts and allowing comparative analyses. The Policy Support Tool will integrate the methodologies and findings of the Levitate project, in order to develop an overall framework for the assessment of impacts, benefits and costs of CCAM for different automation and penetration levels and on different time horizons, as well as a public toolkit and a decision support system allowing the testing of various policy scenarios on the basis of the needs of relevant stakeholders.

Keywords: connected and automated transport systems; policy support tool; impact assessment; forecasting; backcasting

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1. Introduction

The introduction of Connected, Cooperative and Automated Mobility (CCAM), in increasing numbers over the next decades, has attracted the public imagination and raised high expectations in terms of safety, mobility, environment, society and economy. The introduction of automated driving of levels 3, 4 and 5 is expected to bring significant safety benefits, especially as the level of automation increases and the human error (factor) will be gradually eliminated. According to Logan et al. (2017), the US Federal Highway Administration predicted that 50-80% of highway crashes could be eliminated with the adoption of Automated Highway Systems. Since connected and automated vehicles are less likely to crash; changes in vehicle design could include using lighter, less energy demanding materials for building the vehicles, this would allow energy saving gains (KPMG & Center for Automotive Research, 2012). In addition, since connected systems can optimize traffic flow and reduce the distance required for safety between vehicles, there may be an increase in the capacity of travel lanes and a reduction in congestion and thus improve fuel consumption. Finally, the wide adoption of automated passenger vehicles is expected to have a profound and prolonged impact on land use (Bagloee, Tavana, Asadi, & Oliver, 2016).

Even though automation is expected to be highly beneficial, potential disbenefits may arise especially during the transition period when automated and conventional vehicles will share the urban roads. The transition phase to high automation may last decades, with a wide variation of automation and connectivity levels across the vehicle fleet and across traffic infrastructure. Potential new safety risks introduced by inadequate control systems, transfer of control between human and vehicle and malfunctioning infrastructure create wide-spread concern. Furthermore, it is probable there will be an impact on employment where service, assembly and driving professions may reduce in line with an increase in software related positions. Additionally, it is expected that, while vehicle automation may bring an improvement in mobility for people with disabilities, it could have the effect of increasing traffic and road use by up to 14% (Corey et al., 2016) with a related additional environmental impact.

Within the above context, the aim of the European Commission supported Horizon 2020 project, LEVITATE (Societal Level Impacts of Connected and Automated Vehicles), is to develop a new impact assessment framework to enable policy makers to manage the introduction of CCAM, maximize the benefits and utilize the emerging technologies to achieve societal objectives. Policy Support Tools (PST) are introduced to assist in the decision making process for challenging projects and for the implementation of difficult measures (Perimenis et al., 2011). These system contain primarily computational methods, with the purpose of assisting decision makers by analyzing information and identifying the most appropriate solutions. Their goal is to link computational information to the judgement ability of the decision maker (Shim et al., 2002). The LEVITATE PST will specifically focus on municipalities, regional authorities and national governments that wish to prepare for the increasing prevalence of connected and automated systems, need to understand the implications for mobility policies and wish to identify the most effective measures to achieve wider societal objectives. This will be achieved by developing an open access web-based PST, which will include both forecasting and backcasting capabilities, as well as a rich knowledge module containing policy recommendations and case studies.

The objective of the present paper is to provide an insight on the methodological framework of developing the LEVITATE PST, the use cases, and the impacts considered, as well as the methods applied for the estimation of the impacts of the introduction of CCAM in the urban environment. Specifically, in this paper, an outline of the contents of the PST will be presented starting by the impact assessment methodologies and followed by the structure of the PST. Subsequently, the four pillars of analysis namely: (i) forecasting, (ii) backcasting, (iii) cost-benefit analysis and (iv) case study examples, will be presented. The paper will conclude with a discussion of the limitations and future research possibilities.

2. Methodology

2.1. Use cases and sub-use cases

The LEVITATE PST will provide estimates of the impacts of CCAM through a multi-disciplinary impact assessment methodology. Impact assessments will be derived by comparing forecasts of mobility with a potential intervention against forecasts with no intervention apart from the introduction of CAVs in different Market Penetration Rates (MPRs). These interventions named sub-use cases, are subcategories of the LEVITATE main use cases; namely automated urban transport, automated passenger cars and automated freight transport. A list of sub-use cases of interest from the perspective of CCAM has been developed. This list has been prioritized and refined within subsequent tasks in the project to inform the interventions and scenarios related to the use cases. The prioritization of the sub-use cases mainly took into account the following three input directions into account:

- Scientific literature/studies: 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.
- Stakeholder Reference Group Workshop: containing first hand feedback for the sub-use cases, but might only reflect the opinions of organisations and people who participated.

The selected sub-use cases that will be included in the LEVITATE PST are listed in Table 1.

Table 1: LEVITATE use cases and sub-use cases

Levitate Use Cases	Sub-Use cases
Automated Urban Transport	Point-to-point Automated Urban Transport Services (AUSS) Autonomous mobility on-demand
Automated Passenger Cars	Road use pricing Green Light Optimised Speed Advisory Automated ridesharing Parking pricing policies Parking space regulations Dedicated lanes on urban highways
Automated Freight Transport	Automated urban delivery Automated freight consolidation Hub-to-hub automated transport Truck platooning on urban highway bridges

2.2. Parameters

Parameters represent aspects of the transport system that are influenced by policy interventions or themselves influence impacts, and are therefore important for the impact assessments, yet they are not required to be displayed as impacts. The input parameters used in the LEVITATE PST are presented in Table 2.

Table 2: PST parameters

Parameters	Unit of measurement
GDP per capita	€
Annual GDP per capita change	%
Inflation	%
City Population	million persons
Annual City Population change	%
Urban shuttle fleet size	no. of vehicles
Freight vehicles fleet size	no. of vehicles
Average load per freight vehicle	tones
Average annual freight transport demand	million tones
Human-driven Vehicles	%
1st Gen - Cautious AVs	%
2nd Gen - Aggressive AVs	%
Fuel cost	€ / lt
Electricity cost	€ / KWh
Fuel consumption	lt / 100Km
Electricity consumption	KWh / 100Km
VRU Reference Speed (Typical on Urban Road)	km/h
VRU at-Fault accident share	%

2.3. Impacts

An important step of a successful impact assessment is the identification of potential impacts. In order to provide a structure to assist in understanding how CCAM impacts will emerge in the short, medium and long-term, a taxonomy of the potential impacts of CCAM was developed by Elvik et al. (2019). This process involved identifying an extensive range of potential impacts which may occur from the future expansion of CCAM. Impacts were classified into three categories: direct impacts, systemic impacts and wider impacts (Table 3). Direct impacts are changes that are noticed by each road user on each trip. These impacts are relatively short-term in nature and can be measured directly after the introduction of intervention or technology. Systemic impacts are system-wide impacts within the transport system. These are measured indirectly from direct impacts and are considered medium-term. Wider impacts are changes occurring outside the transport system, such as changes in land use and employment. These are inferred impacts measured at a larger scale and are result of direct and system wide impacts. They are considered to be long-term impacts.

Table 3: PST impacts

Impacts	Description
	Short term / direct impacts
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)
	Medium-term / systemic impacts
Amount of travel	Person kilometres of travel per year in an area
Congestion	Average delays to traffic (seconds per vehicle-kilometer) as a result of high traffic volume
Modal split using urban 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
	Long-term / wider impacts
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 NO_x pollutants as grams per vehicle-kilometer (due to road transport only)
CO_2 due to vehicles	Concentration of CO_2 pollutantsas grams per vehicle-kilometer (due to road transport only)
PM_{10} due to vehicles	Concentration of PM_{10} pollutantsas grams per vehicle-kilometer (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)
Unmotorized VRU crash rates	Injury crashes with unmotorized VRUs per vehicle-kilometer driven
Road safety motorized	Number of crashes per vehicle-kilometer driven
Road safety total effect	Road safety effects when accounting for VRU and modal split

2.4 Methods

The aforementioned impacts have been estimated and forecasted using appropriate assessment methods. The methods used are the microscopic simulation, mesoscopic simulation, system dynamics, operations research and the delphi method. For the sake of simplicity and transferability 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.

2.4.1 Microscopic simulation
In the LEVITATE project, the microscopic simulation method was selected to examine several impacts of CAVs mainly on traffic, environment and energy efficiency. More specifically, the main purpose of this methodology is to identify the impacts of the adoption of CCAM on traffic, including travel times, flows, traffic emissions and road safety under several simulation scenarios and to evaluate the influence of different CAV penetration rates on a microscopic level. Microscopic simulation provides information related to individual vehicles by modelling traffic flows at a high level of detail (Ehlert & Rothkrantz, 2001). The simulation inputs concern data from various sources such as the network geometry, traffic volume and modal split. The data exported by the microsimulation can provide an initial, descriptive estimation of several impacts. Each vehicle is tracked as it interacts with surrounding traffic as well as with the environment.

2.4.2 Mesoscopic simulation
Mesoscopic simulation method combines the elements from both microscopic and macroscopic simulations. Through mesoscopic simulation models, individual vehicles are simulated, while their interactions are based on aggregate and macroscopic relationships. The simulated traffic flows are based on estimation of the macroscopic indices on a microscopic level. In addition, mesoscopic models present traffic entities at a high level of detail while provide significant reductions in simulation time and modeling efforts, in case of a large area network analysis, without compromising the accuracy of their results (Burghout et al., 2005). Therefore, mesoscopic models are considered ideal for forecasting cases that require detailed modelling of route choice and other driver choices, while the driver interaction with the road network and other drivers is not needed. Within the LEVITATE project, the mesoscopic simulation method was selected in order to identify additional impacts of CAVs regarding modal split of travel using public transport or active travel as well as the amount of travel. Through this methodology, the impacts of the adoption of CCAM were investigated under several simulation scenarios and for different CAV penetration rates.

2.4.3 System dynamics
As Boghani & Zach (2020) note, system dynamics is a modelling technique where a system is modelled at an abstract level by modelling the sub-systems at component level and aggregating the combined output. This breaking down and individual examination of components enables the use of feedback/feed forward mechanisms from one component to another within the system, which unfolds when the output is viewed against time. In the context of LEVITATE, system dynamics is mainly used to evaluate the impact of policy interventions (for example, road use pricing or the introduction of last-mile shuttles) during a transition period of increasing CAV percentage. The impact indicators will be typically commuting distances, modal split and others as a function of time so that the evolution of impacts over the long-term duration can be compared against various scenarios.

2.4.4 Operations research
Operations Research methods are widely used in freight transport (Lagorio et al, 2016) and calculates results for freight transport costs, fleet operation costs, and vehicle mileage. 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. Within the LEVITATE project operations research method was used to identify the impacts of all the freight transport related sub-use cases.

2.4.5 Delphi method
The Delphi method is a process used to arrive at a collective, aggregate group opinion or decision by surveying a panel of experts. The Delphi methodology is based on a repetitive interview process in which the respondent can review his or her initial answers and thus change the overall information on each topic (Hsu & Sandford, 2007). The Delphi method guarantees the anonymity of experts which assures free expression of opinions provided by the experts. At any point, experts can change their opinions or judgments without fear of being exposed to public criticism, providing controlled feedback as experts are informed about views of other experts who participate in the study (Profilidis & Botzoris, 2018). Within LEVITATE, the Delphi method is used to determine all impacts that cannot be defined by the other quantitative methods. The Delphi process consists of two rounds of e-mails. During the first round experts received a questionnaire (30-45min duration) regarding a few (2-4) automation interventions related to automated urban transport, automated passenger cars or automated freight transport, as per their specific expertise. They were asked to evaluate the percentage influence of the proposed interventions on the different impact areas for various AVs market penetration rates. Their answers were then analyzed in order to create anonymized summaries for the different CCAM related interventions, which were sent during the second

round of the Delphi, giving the experts the opportunity to change their answer or retain the original. The outcome of the Delphi that will be introduced in the PST is a coefficient representing the percentage of change that each sub-use case will have on each impact.

3. Analysis and Results

The Policy Support Tool will be an open access, web-based system that will provide future users with access to Levitate methodologies and results. The PST comprises two main modules as presented in Figure 1: the Knowledge module (static component) and the Estimator module (dynamic component).

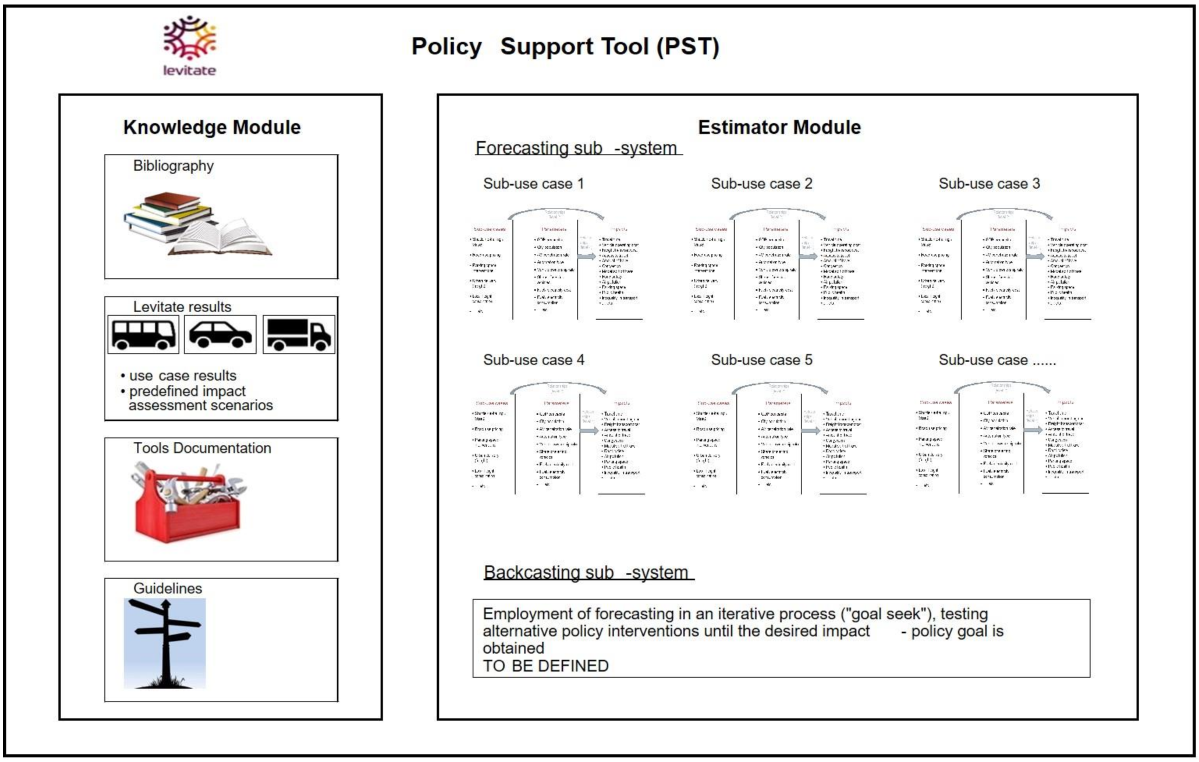

Figure 1: Structure of the LEVITATE Policy Support Tool

3.1 Knowledge module

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 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. More precisely, the Knowledge module will include namely:

- the bibliography containing a systematic literature review that has been conducted within the project.,
- the project results, a material introductory of the case studies is provided on project level, describing their objectives, common reasoning, issues and limitations.,
- 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),
- excerpts from CCAM guidelines, consisting of overall recommendations for the cities from project results for each use case and also additional recommendations from the literature.

3.2 Estimator module

The estimator module is a dynamic, flexible and interactive tool, that 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.

3.2.1 Forecasting sub-system

In the forecasting sub-system, the user will be able to select a CCAM sub-use case (or combine 2 sub-use cases), define the required parameters (or accept pre-defined values) and the module will provide quantified and/or monetized output (depending on the impact) on the expected impacts. The system will give the user the opportunity to choose between predefined base scenarios concerning the temporal distribution of the market penetration rates (MPRs) of connected and autonomous vehicles referring only to the advent of CAVs in the traffic of the network regardless of any policy interventions that are or are not adopted by authorities, throughout the study period, which is from 2020 to 2050.

Within the LEVITATE project, two main driving profiles of connected autonomous vehicles are considered and are the following:

- 1st Generation (Cautious): limited sensing and cognitive ability, long gaps, early anticipation of lane changes and longer time in give way situations.
- 2nd Generation (Aggressive): advanced sensing and cognitive ability, data fusion usage, confident in making decisions, small gaps, early anticipation of lane changes and less time in give way situations.

In order to enable the impact assessments, predefined base scenarios are established, 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 the following:

1. No automation base scenario: All vehicles will be conventional (i.e. human-driven) vehicles up to 2050.
2. Pessimistic base scenario: Vehicles will be 50% conventional vehicles, 40% autonomous vehicles of first generation and 10% autonomous vehicles of second generation in 2050. The first generation of autonomous vehicles will appear in 2021 and will rise from 10% in 2028 to 40% in 2045 and will remain stable till 2050. The second generation will appear in 2046 and will rise to 10% in 2050.
3. Neutral base scenario: Vehicles will be 20% conventional vehicles, 40% autonomous vehicles of first generation and 40% autonomous vehicles of second generation in 2050. The first generation of autonomous vehicles will appear in 2021 and will be rise from 10% in 2024 to 40% in 2036 and will remain stable till 2050. The second generation will appear in 2037 and will rise to 40% in 2050.
4. Optimistic base scenario: All vehicles will be autonomous up to 2042. More specifically, vehicles will be 0% autonomous vehicles of first generation and 100% autonomous vehicles of second generation in 2050. The first generation of autonomous vehicles will appear in 2021 and will be rise from 10% in 2023 to 40% in 2030, will remain stable till 2042 and will be drop to 0% in 2050. The second generation will appear in 2031 and will rise to 100% in 2050.

The results included in the forecasting sub-system originate from the aforementioned methods. Given the fact that these methods are very different, in order to include the results in the PST there was the need to establish a common ground. The selected approached involves attaching all results to specific MPR percentages as those mentioned in the predefined base scenarios. The temporal compression or expansion of the distribution of the MPR percentages lead to one of the four scenarios. Therefore, initial results are spread differently across the timespan examined by the project. For intermediate years, simple linear interpolation is conducted to obtain the respective values, as follows:

Let x_1, x_2 be the examined impact values at two different years t_1, t_2 with milestone MPRs, for which results are available from the three methods. The impact at intermediate year t_i, x_i is calculated as:

$$x_i = x_1 + (x_2 - x_1) * \frac{t_i - t_1}{t_2 - t_1} \qquad (1)$$

The functionalities that the forecasting sub-system will provide to the users are the following:

- Select the time within the study period (i.e. 2020-2050) at which a policy intervention (sub-use case) is introduced in the considered network.
- Define the policy intensity: a percentage which refers to what lies within the control of the authorities, such as route frequency for shuttle buses.

- Define the policy effectiveness: a percentage 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, more importantly, the behavior of the network users.
- Combine two sub-use cases: The impacts are combined with a methodological basis drawn from the Crash Modification Factor (CMF) approach highlighted in the Highway Safety Manual (HSM) and the respective CMF clearinghouse repository of the US Federal Highway Administration (FHWA) (CMF Clearinghouse, 2013).

3.2.2 Backcasting sub-system

As applied in policy analyses, the term backcasting usually refers to an analysis designed to answer the following question: What measures need to be taken in order to realize a specific (quantified) objective set for a specific year? The task of the analyst is then to estimate the contributions various programmes or measures can be made towards realizing the target, thus putting together a package of actions policymakers can take to ensure that the objective is realized. The specification of "desirable visions" is important to disclose conflicting goals and to allow a city to become aware about which goals should be prioritised in this respect, e.g. should economic goals be prioritised over societal goals. This enables cities to develop a clearer definition of its desired future and a more realistic assessment of the feasibility of reaching multiple goals. Such a vision can then form the starting point for a backcasting exercise marking out a transformation pathway including appropriate policy interventions steering the development.

The user will define the desired policy vision described in terms of changes in the impacts (2-5 impacts). The PST then will control which interventions lead to this expected impact by running the forecasting estimator for all interventions. If the impact lies within the targeted corridor towards the desirable policy vision, the solution is retained. Otherwise, a new set of baseline data and interventions is assumed and the analysis runs again. The combination of the interventions will be made with a methodological basis drawn from the Crash Modification Factor (CMF) approach highlighted in the Highway Safety Manual (HSM) and the respective CMF clearinghouse repository of the US Federal Highway Administration (FHWA). CMFs are coefficients which influence crash numbers when a road safety countermeasure or treatment is applied. A positive CMF denotes a beneficial intervention leading to crash reductions, while a negative CMF denotes a detrimental intervention leading to crash increases. More detailed introduction to CMFs can be found online (CMF Clearinghouse, 2013). Apart from the previous, the HSM predicts CMFs when multiple treatments are applied to a single location. In other words, a single CMF that represents the combined treatments is calculated and applied to represent the cumulative crash change. Therefore, in a parallel reasoning with the HSM, Impact Modification Factors (IMFs) are calculated within the Levitate project. IMFs are coefficients with which baseline impacts are multiplied, in order to reach a forecasting or backcasting estimate.

3.2.3 Cost-benefit analysis

CBA provides a comparison of the impacts that a policy measure is estimated to yield, in money terms, against the cost of carrying-out the policy measure (Broadman et al., 2018; Mishan & Quah, 2020). An economic or social CBA, is carried-out from a societal perspective, as opposed to financial analysis (e.g., for a firm). CBA is based on an aggregation of individual preferences, whether these are revealed in markets or in other ways. E.g., the proposals for common transport-impact valuations in the EU have comprised survey-based valuations of travel time savings, emissions, and the prevention of transport fatalities/injuries (Bickel et al., 2006).

The CBA module builds primarily on the inputs/outputs already established within the PST but adds monetization of impacts. The PST user can also adjust some of the particular inputs to the CBA module. The CBA comprises particular functionalities and types of calculations and provides the following results:

- The final result: monetized effects of the intervention are showed in net present value (NPV). NPV shows today's (or a certain year's) value of the present and future cash flow and takes into the investment's alternative use. As people are impatient, money is worth more now than later, and the NPV illustrates this.
- Sensitivity analysis: Due to the apparent uncertainties in predicting and simulating the future, the CBA functionality will also provide a sensitivity analysis of central impacts that are calculated in LEVITATE. Sensitivity analyses are good for illustrating the uncertainties in these sorts of calculations. They illustrate how the result changes if the value of a chosen variable is 150% of what the PST estimates.
- Residual value: if the user chooses a long project lifetime or late implementation year, the sub-use case will have effects after 2050 (which is the final year of calculated effects). That means that we are likely to under- or overestimate the effects of the use-case as all the likely effects of the initiative is not included. To handle this, the project's residual value is calculated.

- Break even analysis: this analysis shows all the yearly effects, the sum of all the yearly effects prior to each year and hence, also when/if the sub-use case turns out positive or negative.

3.2.4 Case studies

Case studies will be used to demonstrate the operation of the LEVITATE methodology. Several cities and road authorities supporting LEVITATE, including Transport for Greater Manchester and the city of Vienna have shared simulation models and data (Table 4). There will be one case study for each use case in each city. Assessments will be made of the impact of infrastructure and vehicle-based connectivity and automation technologies on the selected city environments. Traffic and mobility simulation models of the cities will be used to assess the changes in vehicle movements resulting from specific technologies. From this data the impact assessment indicators will be derived, and the practical and economic benefits of the CCAM technologies will be identified. The outcomes of the case studies will be directly applicable to the cities and will demonstrate the expected outcomes of CCAM technologies used in each location. The results will be directly applicable to local policy decisions and will support the application of wider evidence-based approaches. They will be publicly accessible through in the Policy Support Tool so that other cities can learn from the results.

Table 4: Case studies

Case study	Use Case	City
Last-mile shuttles	Automated Urban Transport	Vienna, Austria
Automated ride-sharing	Automated Passenger Cars	Leicester, UK
GLOSA	Automated Passenger Cars	Leicester, UK
Road use pricing	Automated Passenger Cars	Vienna, Austria
Platooning on urban highway bridges	Automated Freight Transport	Vienna, Austria
Automated urban delivery and consolidation	Automated Freight Transport	Vienna, Austria and Manchester, UK

4. Discussion

Naturally, the present 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. More precisely, each quantitative method has different parameters and is applied in a different city model, partly due to the resources in which the LEVITATE partners had access to, for example the mesoscopic simulation is using the MATSim model for Vienna, the microscopic simulation considers the AIMSUN model for Athens, and on the other hand the Delphi method is a qualitative method, based on the experts' opinions and not on a specific city model. Regarding the Delphi method, limitations are posed by the number of experts, the specificity of the scenarios and the accuracy of their estimations. Thus, the Delphi results will be used to fill in the PST when no other method can. Approaches such as Delphi can be updated when CCAM reach increased maturity and revisited for future efforts either in projects such as LEVITATE or in broader research. 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. 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.

5. Conclusions

The Policy Support Tool will integrate the methodologies and findings of the LEVITATE project, in order to develop an overall framework for the assessment of impacts, benefits and costs of CCAM for different automation and penetration levels and on different time horizons, as well as a public toolkit and a decision support system allowing the testing of various policy scenarios on the basis of the needs of relevant stakeholders. The PST objective is to bridge the gap between technology and policy objectives assisting cities with CCAM implementation to harness positive impacts and make informed decisions. The PST will include a knowledge module; a static repository, searchable through a fully detailed, flexible and documented way; and an estimator module, which provides estimates for different types of impacts and allow comparative analyses. The estimator module is based on 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.

Furthermore, although the PST is expected to provide cities and regions with an accurate estimation of possible policy-pathways for reaching their target goals by implementing CCAM, it is important to take into account that the transferability of results needs to be tackled. Additionally, the PST will provide results for a restricted number of policy interventions without taking into consideration the different regulations and political decisions that could also influence the societal impacts of CCAM. Nevertheless, upon its completion, the Levitate PST will provide the first openly available web-tool to effectively support decision making for connected and automated transport systems in a holistic way, with guidance on both forecasting impacts of policy measures as well as identifying those measures that are appropriate for achieving specific policy goals.

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