Rethinking transport
27–30 April 2020

TRA 2020 HELSINKI

Proceedings of 8th Transport Research Arena TRA 2020, April 27-30, 2020, Helsinki, Finland

Developing a Policy Support Tool for Connected and Automated Transport Systems

Anastasios Dragomanovits[a], George Yannis[a], Julia Roussou[a]*, Rune Elvik[b], Bin Hu[c], Alexandra Millonig[c], Ashleigh Filtness[d], Pete Thomas[d]

[a]*Department of Transportation Planning and Engineering – National Technical University of Athens, 5 Iroon Polytechniou Str., GR-15773 Athens, Greece*
[b]*Departement of Safety and Security – Institute of Transport Economics Norwegian Centre for Transport Research, Gaustadalléen 21, 0349 Oslo, Norway*
[c]*AIT Austrian Institute of Technology, Center for Mobility Systems, Giefinggasse 2, 1210 Vienna, Austria*
[d]*Loughborough University, Loughborough, LE11 3TU, United Kingdom*

Abstract

Connected and automated transport systems (CATS) 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 CATS 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 CATS, 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 CATS on urban areas. 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.

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

* Corresponding author. Tel.: +30-210-772-1265;
E-mail address: jroussou@mail.ntua.gr

1. Introduction

Connected and automated transport systems (CATS) are expected to be introduced in increasing numbers over the next decade based on the rapidly developing capability of modern technologies. Automated vehicles have attracted the public imagination and there are high expectations in terms of safety, mobility, environment and economic growth. By taking the human out of the loop it is theoretically possible that up to 90% of fatal crashes might be prevented (European Commission, 2017). Vehicles that are individually connected to urban traffic management systems are expected to operate more efficiently, reducing journey time and environmental impact. There will also be a more immediate impact, particularly in urban areas, with Mobility as a Service (MaaS) applications enhancing real-time traveler choice.

However, there are potential disbenefits from the introduction of CATS. 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 engineering jobs 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 Levitate H2020 research project is to prepare a new impact assessment framework to enable policymakers to manage the introduction of CATS, maximize the benefits and utilize the technologies to achieve societal objectives. As part of this objective, the project seeks to forecast societal level impacts of CATS and develop a Policy Support Tool, focusing 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. These authorities have a need for a new evidence-based approach to policy-making. With advanced mobility systems not yet in widespread use there is a lack of data and knowledge, some of the technologies may be disruptional so that future impacts cannot be determined from historic patterns. Furthermore, estimates of future impacts of automated and connected mobility systems may be based on forecasting approaches, yet there is no agreement over the methodologies or baselines to be used. The need to measure the impact of existing systems as well as forecasting the impact of future systems represents a major challenge. Finally, the dimensions for assessment are themselves very wide including safety, mobility and environment but with many sub-divisions adding to the complexity of future mobility forecasts.

The objective of this study 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. The study is structured as follows: in Chapter 2, the impact assessment methodology of the Levitate project is briefly presented. Chapter 3 focuses on the structure, operation and results expected from the Policy Support Tool. Finally, in Chapter 4, the conclusions of the research so far, the identified limitations and the next steps of the project are presented.

2. Multi-disciplinary impact assessment methodology

Levitate PST will include estimates of the impacts of CATS 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 to allow for confounding factors. Levitate aims to develop forecasts that are informed by knowledge about factors producing current trend and the likely future changes of those factors. The nature of the intervention and the indicators to measure impact determine the methods used to assess and forecast future outcomes so a broad range of methods is required. The dimensions to be evaluated cover mobility, safety and environmental effects as well as other societal level impacts. There are high public expectations for safety benefits, particularly from vehicle automation so this will be a key focus area. Within each dimension there will be a number of related indicators that together define a more complete set of measures of the overall impact of CATS.

2.1. Taxonomy of impacts

The first step to a successful impact assessment is the identification of potential impacts. While connected and automated transport systems are developing fast, they have still not been implemented to such an extent that one can evaluate their impacts by means of, for example, before-and-after studies. Therefore, all impacts in Levitate are potential impacts, and the ones that will actually materialize depend on the level of CATS implementation and on applied policy measures.

In order to provide a structure to assist in understanding how CATS impacts will emerge in the short, medium and long-term, a taxonomy of the potential impacts of CATS 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 CATS. Impacts were classified into three categories: direct impacts, systemic impacts and wider impacts (Figure 1). Direct impacts are changes that are noticed by each road user on each trip. These impacts are relatively short-term in nature and can be measured directly after the introduction of intervention or technology. Systemic impacts are system-wide impacts within the transport system. These are measured indirectly from direct impacts and are considered medium-term. Wider impacts are changes occurring outside the transport system, such as changes in land use and employment. These are inferred impacts measured at a larger scale and are result of direct and system wide impacts. They are considered to be long-term impacts. This draft taxonomy will be systematically evaluated and become more extensive throughout the duration of the project during structured workshops, where stakeholders are asked to prioritise impacts and indicate missing topics.

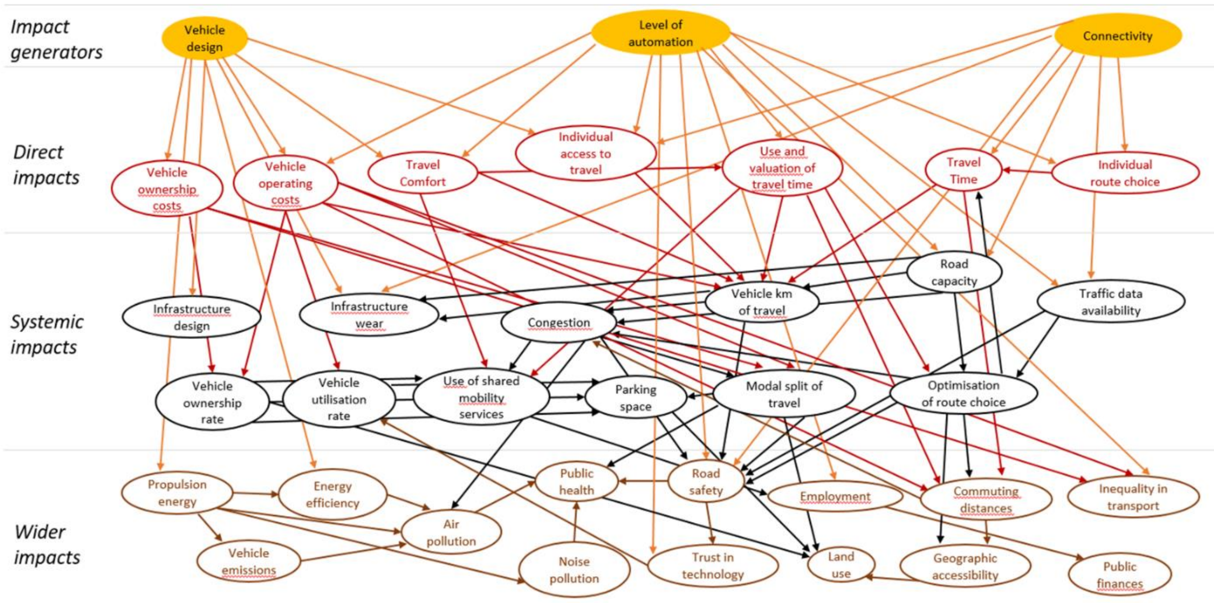


Fig. 1 Taxonomy and causal diagram for primary impacts of CATS (Elvik et al., 2019)

2.2. Estimation methodologies

In order to forecast impacts of CATS, the Levitate project utilizes several impact estimation methodologies:

- Literature reviews: It involves applying known mathematical relationships from the literature to predict the specific indicators of interest. In case of several studies regarding a single indicator, meta-analysis and statistical approaches are used to extract appropriate relationships. A targeted review of recent international literature on the future of CATS as well as deliverables of relevant EU projects (to promote cross-fertilisation) is under way.
- Traffic simulations: Extensive traffic micro-, meso- and macro-simulations are used to predict changes in traffic patterns, including travel time, traffic volume, air quality, etc., under several traffic simulation scenarios and thereby directly derive impact indicators. Microscopic traffic simulation provides information related to single vehicles, whereas macroscopic models refer to flow streams.

- Delphi-panel surveys: For complex impacts and impacts of more qualitative nature, the consensus opinion of a panel of experts is sought, through the application of Delphi method (either in a dedicated workshop or through rounds of online questionnaires).
- Operations research: Mostly used for impacts related to CATs in freight transport, it involves a combination of methods to identify causal relationships.

2.3. Case studies

Impact assessment focuses on three primary use cases of CATS: urban transport with shuttle buses, passenger vehicles and freight transport. Within each of these use cases there are many specific scenarios relating to the deployment of automation, connected systems or Mobility as a Service applications, which may be vehicle or infrastructure based. Several cities and road authorities support the Levitate project and participate in the Stakeholders Reference Group (SRG) and some, including Transport for Greater Manchester and the City of Vienna, are providing simulation models and data. These are used to analyze the use cases and all the related applications, policy interventions and technologies (named as sub-use cases), in order to demonstrate the operation of the Levitate methodology and to validate aspects of performance against real-world results.

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 CATS technologies will be identified.

3. Policy Support Tool

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 objective is to bridge the gap between technology and policy objectives assisting cities with CATS implementation avoiding the unwanted and unforeseen consequences and rebound effects. The PST comprises two main modules: the Knowledge module (static component) and the Estimator module (dynamic component), as presented in Figure 2.

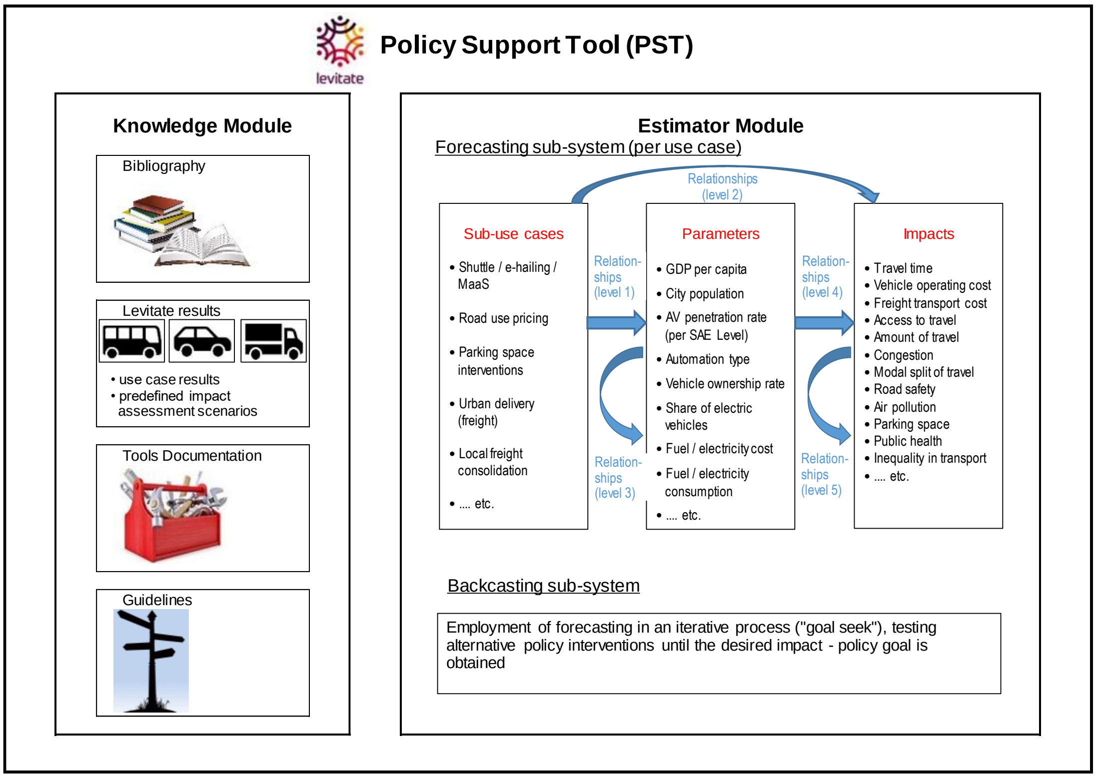


Fig. 2 Structure of the Levitate Policy Support Tool.

3.1. Knowledge module

The knowledge module will consist of a static repository, searchable through a fully detailed, flexible and documented way. The user will be 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. More precisely, the Knowledge module will include namely:

- the bibliography of all relevant literature concerning impact assessments of CATS,
- the project results, including the case studies on the participating cities (scenarios and baseline conditions, results) and the predefined impact assessments,
- the documentation about the toolbox of methods developed in LEVITATE, to enable cities to explore the expected impacts of CATS in the users circumstances (including underlying models, data and impact assessment methods),
- excerpts from CATS guidelines.

3.2. Estimator module

The estimator module will provide estimates for different types of impacts and allow comparative analyses. It includes two parts, the forecasting and the backcasting sub-system.

In the forecasting sub-system, the user will be able to select a CATS application or policy intervention (or group of interventions), 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 impact assessment results will also include:

- an assessment of uncertainty in the estimates (e.g. confidence intervals or qualitative assessment);
- references on the methodology applied for the impact assessment (i.e. how were the respective relationships estimated: literature review, questionnaire survey, simulation study, etc.).

Predefined values for each parameter not influenced by the intervention will be available; however the user will be able to change these values if needed. Also, indications on the evolution of the estimated impacts over time - short (5 years), medium (10 years) and long term (25+ years) impacts - will be included.

In the backcasting sub-system, the user will be able to select a policy objective, i.e. a targeted impact, and the PST will provide relevant interventions that are expected to result in this impact. Similarly to the forecasting sub-system, predefined values for parameters will be available, with the option to be modified by the user.

In order to provide useful estimations, the following components of the Estimator Module have been defined and investigated, used in both of the aforementioned sub-systems.

- Sub-use cases (policy interventions, CATS applications, etc.);
- Parameters;
- Impacts;
- Relationships between sub-use cases, parameters and impacts.

3.2.1. Sub-use cases

Sub-use cases refer to policy interventions (i.e. actions undertaken by a policy-maker to achieve a desired objective) or CATS applications (i.e. automated ride-sharing). Interventions may include educational programs, new or stronger regulations, technology improvements, a promotion campaign, road pricing regulations, etc. 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 and their descriptions clarified, as presented in Table 1.

Table 1. PST sub-use cases.

Sub-use cases	Description	Related use case
Category: Shuttle / e-hailing / MaaS		
Introduction of station to station AV shuttles	Automated urban shuttles travelling between fixed station.	urban shuttles
Introduction of anywhere to anywhere AV shuttles	Automated urban shuttles travelling between different, not fixed locations.	urban shuttles
Introduction of last-mile AV shuttles	Automated urban shuttles providing convenient first/ last mile solutions, complementing public transport.	urban shuttles
Introduction of automated ride sharing	Automated passenger cars booked by multiple passengers (using a smartphone app) to travel between convenient points. Passengers' final destinations could be near each other, but not necessarily the same.	passenger cars
Category: Road use pricing		
Introduction of a dynamic city toll for all empty vehicles	A dynamic fee is applied to every empty vehicle inside the city center (depending on area, traffic load and time of day).	passenger cars, freight transport
Introduction of a static city toll for non-automated vehicles	A fixed fee is applied to all non-automated vehicles entering the city center.	passenger cars, freight transport
Introduction of a static city toll for all vehicles	A fixed fee is applied to all vehicles entering the city center.	passenger cars, freight transport
Introduction of a dynamic city toll for non-automated vehicles	A dynamic fee is applied to all non-automated vehicles inside the city center (depending on area, traffic load and time of day).	passenger cars, freight transport
Introduction of a dynamic city toll for all vehicles	A dynamic fee is applied to all vehicles inside the city center (depending on area, traffic load and time of day).	passenger cars, freight transport
Category: Parking space interventions		
Replace long term parking space with space for public use	On-street long term parking inside city center is reduced by the designated rate, and the space previously used for parking is transformed to sidewalks, planted areas, etc. (**definition of long-term is pending**)	urban shuttles, passenger cars, freight transport
Replace long term parking space with driving lanes	On-street long term parking inside city center is reduced by the designated rate, and the space previously used for parking is transformed to additional driving lanes (**definition of long-term is pending**)	urban shuttles, passenger cars, freight transport
Replace long term parking space with short term parking space	On-street long term parking inside city center is reduced by the designated rate, and transformed to short term parking space (**definitions of long-term and short-term are pending**)	urban shuttles, passenger cars, freight transport
Category: Freight specific sub-use cases		
Automated urban freight delivery	Delivery of parcels and goods in urban area is automated.	freight transport
Local freight consolidation	Automated freight consolidation using hubs and terminals with the goal to increase transport efficiency, especially in dense urban areas.	freight transport

3.2.2. 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 (according to the views of the participating stakeholders). In Table 2, a preliminary list of CATS related parameters considered in the Levitate PST is presented.

Table 2. PST Parameters.

Parameters	Unit of Measurement	Related use case
GDP per capita	€	all
Annual GDP per capita change	%	all
Inflation rate	%	all
City Population	million persons	all
Annual City Population change	%	all
Vehicle ownership rate	no. of vehicles/person	passenger car
Urban shuttle fleet size	no. of vehicles	urban shuttles
Freight vehicles fleet size	no. of vehicles	freight transport
Average load per freight vehicle	tones	freight transport
Average annual freight transport demand	million tones	freight transport
Annual freight transport demand change	%	freight transport
AV fleet share: Levels 0-2	%	passenger car
AV fleet share: Level 3	%	passenger car
AV fleet share: Level 4	%	passenger car
AV fleet share: Level 5	%	passenger car
Connected AVs (of Levels 4 & 5)	%	passenger car
Freight CAV fleet share	%	freight transport
Urban shuttle CAV fleet share	%	urban shuttles
Electromobility ratio in non-AV vehicles	%	passenger car
Fuel cost	€ / lt	all
Electricity cost	€ / KWh	all
Fuel consumption	lt / 100Km	all
Electricity consumption	KWh / 100Km	all

3.2.3. Impacts

Based on the impacts identified by Elvik et al. (2019) and several consultation rounds with project partners and city stakeholders, the impacts with highest importance from a decision-making point of view, selected to be included in the PST, are presented in the following table.

Table 3. PST Impacts

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

Parameters	Description	Unit of Measurement	Type
Vehicle occupancy	average % of seats in use	%	Systemic
Parking space	Required parking space in the city centre per person	m2/person	Wider
Road safety	Number of injury accidents in an area	accidents/year	Wider
Energy efficiency	Average rate (over the vehicle fleet) at which propulsion energy is converted to movement	%	Wider
NOX due to vehicles	Concentration of NOx pollutants per cubic metre of air (due to road transport only)	μg/m3	Wider
CO2 due to vehicles	Concentration of CO2 pollutants per cubic metre of air (due to road transport only)	μg/m3	Wider
PM10 due to vehicles	Concentration of PM10 pollutants per cubic metre of air (due to road transport only)	μg/m3	Wider
Public health	Subjective rating of public health state, related to transport (10 points Likert scale)	-	Wider
Inequality in transport	To which degree are transport services used by socially disadvantaged and vulnerable groups, including people with disabilities (10 points Likert scale)	-	Wider
Commuting distances	Average length of trips to and from work (added together)	Km	Wider

3.2.4. Relationships

In order to effectively develop the Levitate PST Estimator module, the relationships between policy interventions and CATS parameters and impacts need to be quantitatively defined. More precisely, in the PST there are five levels of relationships (see also Figure 2 above):

1. Relationships Level 1 – Sub-use cases to Parameters
2. Relationships Level 2 – Sub-use cases to Impacts
3. Relationships Level 3 – Parameters to Parameters
4. Relationships Level 4 – Parameters to Impacts
5. Relationships Level 5 – Impacts to Impacts

The definition process of the aforementioned relationships will be based on the estimation methodologies presented in paragraph 2.2 of the paper (literature reviews, traffic simulations, Delphi surveys, operations research).

3.2.5. Demonstration of the forecasting sub-system operation

The steps to be followed by the user to obtain an impact assessment for a specific policy intervention are as follows:

1. Selection of use case: The user is asked to select amongst urban shuttles transport, passenger vehicles and freight transport use case.
2. Definition of initial values: The user reviews default initial values for parameters and impact indicators, and changes any initial value that is not appropriate for the specific urban environment under consideration. For the participating cities of Vienna and Manchester, a database of initial values will be available, which can potentially be expanded for additional cities.
3. Definition of base scenario: The user chooses between four predefined scenarios regarding penetration rates of: autonomous vehicles (AVs), connected AVs and electro mobility. These scenarios are: "no automation", "pessimistic", "neutral" and "optimistic". Alternatively, he/ she will be allowed to define a custom scenario. The base scenario, without considering any interventions, will be used as the reference business-as-usual scenario for the impact assessments.
4. Selection of one or more policy interventions (sub-use cases): The user will be provided with a list of policy interventions (sub-use cases) and will be able to choose one or more for consideration by the PST forecasting estimator. Most policy interventions will be considered on a binary (yes/no) basis; some

however require more details, e.g. when considering city tolls, the amount of money per entrance in the city center (static toll) or per Km inside the city center zone (dynamic toll).

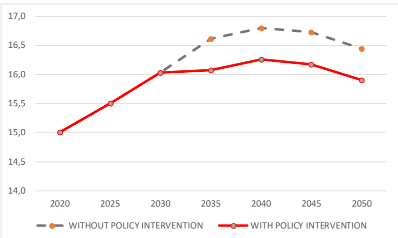
5. Definition of implementation year: The user defines on which year the policy intervention(s) under consideration will be implemented.
6. Analysis for reference scenario: The PST forecasting estimator, using the relationships at various levels, provides an estimation for the values of all impact indicators and for every year of the analysis. No sub-use cases / policy interventions are considered in this analysis.
7. Analysis for scenario with policy intervention(s): The PST forecasting estimator, using the relationships between policy interventions, parameters and impacts, will provide an estimation for the values of all impact indicators and for every year of the analysis, taking into consideration the intervention(s) selected by the user cumulatively, from the defined implementation year onwards.
8. Impact estimation: The difference between the reference estimations of step 6 and the intervention estimations of step 7 is the estimated impact of the selected intervention(s).
9. Presentation of results: Results in terms of forecast of the expected future in the reference scenario, the scenario with intervention(s) and the impact of the intervention(s) will be presented both quantitatively and graphically as presented in Figure 3.

Step 3: Definition of base scenario — SCENARIO 3 - NEUTRAL

Step 4: Selection of policy intervention — Introduction of a static city toll for non-automated passenger cars
€ per entrance in city centre — 0,80 € (0€ - 10€)
Implementation year — 2030 (2020 - 2045)

RESULTS

Show graph for Impact no: 1



			WITHOUT POLICY INTERVENTION							WITH POLICY INTERVENTION						
no.	Impact	Unit of Measurement	2020	2025	2030	2035	2040	2045	2050	2020	2025	2030	2035	2040	2045	2050
Direct impacts																
1	Travel time	min	15,0	15,5	16,0	16,6	16,8	16,7	16,4	15,0	15,5	16,0	16,1	16,3	16,2	15,9
2	Travel comfort	-	5	5	5	6	6	6	6	5	5	5	6	6	6	6
3	Value of travel time	€	1,00	1,07	1,15	1,12	1,15	1,27	1,32	1,00	1,07	1,15	1,13	1,17	1,30	1,35
4	Vehicle operating cost	€/Km	0,250	0,251	0,253	0,258	0,260	0,283	0,286	0,250	0,251	0,253	0,253	0,255	0,278	0,282
5	Access to travel	-	5	5	5	5	6	6	7	5	5	5	5	6	6	7
Systemic impacts																
6	Amount of travel	Km	6.000	6.030	6.060	6.180	6.300	6.375	6.450	6.000	6.030	6.060	6.180	6.301	6.376	6.451
7	Road capacity	veh/hr.lane	1.500	1.504	1.508	1.523	1.556	1.594	1.641	1.500	1.504	1.508	1.523	1.556	1.595	1.641
8	Congestion	min	10,0	10,3	10,7	11,1	11,2	11,1	11,0	10,0	10,3	10,7	10,5	10,7	10,6	10,4
9	Modal split of travel 1	%	40,0%	40,4%	40,9%	41,0%	40,9%	40,9%	41,0%	40,0%	40,4%	40,9%	42,0%	41,9%	41,9%	42,0%
10	Modal split of travel 2	%	3,0%	3,0%	3,0%	2,9%	2,8%	2,8%	2,7%	3,0%	3,0%	3,0%	2,9%	2,8%	2,8%	2,7%
11	Vehicle ownership rate	veh	1,20	1,20	1,21	1,19	1,18	1,18	1,18	1,20	1,20	1,21	1,19	1,18	1,18	1,18
12	Shared mobility rate	%	4,0%	4,0%	4,3%	5,4%	8,3%	12,1%	15,4%	4,0%	4,0%	4,3%	5,4%	8,3%	12,1%	15,4%
13	Vehicle utilisation rate 1	%	8,0%	8,1%	8,6%	11,5%	18,6%	27,6%	35,8%	8,0%	8,1%	8,6%	11,3%	18,6%	27,6%	36,0%
14	Vehicle utilisation rate 2	%	35,0%	35,1%	35,2%	34,7%	32,7%	30,0%	26,4%	35,0%	35,1%	35,2%	34,7%	32,7%	30,0%	26,4%
Wider impacts																
15	Road safety	accidents/year	2.000	2.018	1.984	1.999	1.708	1.336	1.020	2.000	2.018	1.984	2.003	1.713	1.340	1.024
16	Air pollution	μg/m3	20,0	18,5	18,3	20,2	23,4	26,6	28,6	20,0	18,6	18,4	17,2	19,6	22,0	23,4
17	Noise pollution	%	5,0%	4,6%	4,6%	5,0%	5,9%	6,6%	7,1%	5,0%	4,6%	4,6%	4,4%	5,2%	6,0%	6,5%
18	Commuting distances	Km	20,0	20,2	20,3	20,8	21,2	21,5	21,8	20,0	20,2	20,3	20,8	21,2	21,5	21,8

Fig. 3 PST results visualization

3.2.6. Backcasting Estimator Principles

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. This perspective is clearly relevant, for example, in the case of a city with policy objectives of preventing a growth in travel performed by fossil fuel vehicles, increasing walking and cycling, and, at the same time, reducing the number of traffic injuries. Realizing all objectives at the same time is clearly challenging and requires great ingenuity in the development of policy options or instruments. One may, however, interpret backcasting in a different sense, as a form of historical reconstruction of factors that have contributed to past changes. Such a reconstruction may have value in providing a basis for assessing whether the factors contributing to past changes are likely to exert similar effects in the future.

As an example, a Norwegian study (Høye, A et al. 2014) identified factors that contributed to the decline in the number of killed or seriously injured road users in Norway from 2000 to 2012. The factors whose influence could be quantified accounted for 48% of the observed decline; for the remaining 52%, no specific contributing factors could be identified. By assessing whether the factors that were quantified can be expected to exert a similar influence in the future, a basis is obtained for making informed forecasts that are not just projections of past trends.

The operation of the backcasting estimator is visualized in Figure 4. More specifically, the user defines the desired policy vision described in terms of changes in the 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.

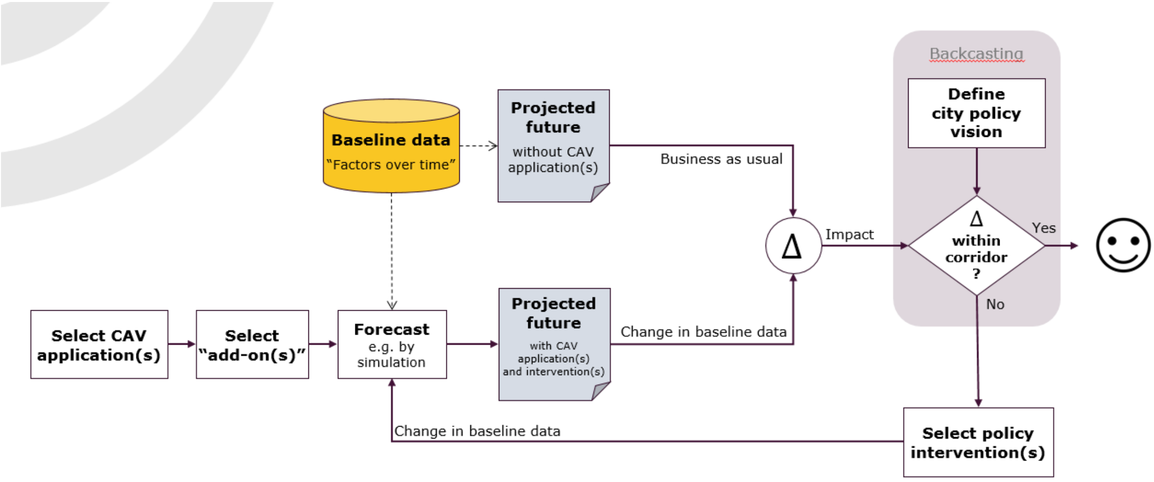


Fig. 4 PST backcasting function

4. 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 CATS 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 decision support tool will integrate both pillars of analysis; forecasting, on the basis of the quantitative and qualitative estimated impacts for different horizons and backcasting, on the basis of the relevant policy targets for each impact area.

The core component of the PST is naturally the forecasting estimator, and especially the framework of relationships, at various levels, linking policy interventions and CATS applications with parameters and impacts. The effective integration of these relationships, derived from the application of different methodological approaches (statistical analyses of literature results, traffic simulations, Delphi surveys, etc.) is a challenge that will be addressed during the next stages of the Levitate project.

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 CATS, 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 CATS. 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.

Acknowledgements

The present research was carried out within the research project "LEVITATE - Societal Level Impacts of Connected and Automated Vehicles", which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824361.

References

Corey D. Harper, Chris T. Hendrickson, Sonia Mangones, Constantine Samaras, Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions, 2016. Transportation Research Part C: Emerging Technologies, Volume 72, Pages 1-9, ISSN 0968-090X, https://doi.org/10.1016/j.trc.2016.09.003

Elvik, R., Quddus, M., Papadoulis, A., Cleij, D., Weijermars, W., Millonig, A., Vorwagner, A., Hu, B., Nitsche, P., 2019. A taxonomy of potential impacts of connected and automated vehicles at different levels of implementation. Deliverable D3.1 of the H2020 project LEVITATE.

European Commission, 2017. Connected and Automated Transport. Studies and reports. Directorate-General for Research and Innovation, Smart, Green and Integrated Transport, Brussels.

Høye, A., Bjørnskau, T., Elvik, R. 2014. Hva forklarer nedgangen i antall drepte og hardt skadde i trafikken fra 2000 til 2012? Transportøkonomisk institutt, Rapport 1299, Oslo.

Milakis, D., van Arem, B, van Wee, B. 2017. Policy and society related implications of automated driving: A review of literature and directions for future research. Journal of Intelligent Transportation Systems, 21, 324-348.