Forecasting and backcasting of Connected-Automated Vehicle impacts using multiple methodological inputs

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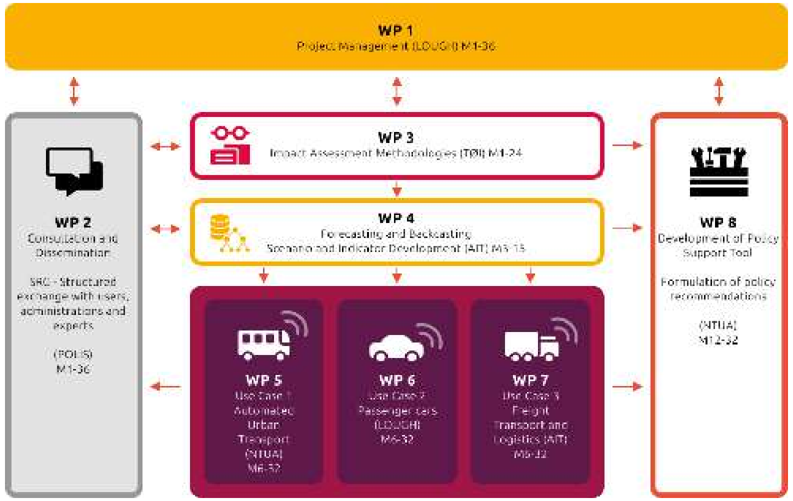
The LEVITATE Project



LEVITATE focuses on the development of a new impact assessment framework, in order to enable policymakers to manage the introduction of connected and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives

- **Project partners:**
  LOUGH (UK), AIT (AT), AIMSUN (ES), NTUA (EL), POLIS (BE), SWOV (NL), TOI (NO), TfGM (UK), City of Vienna (AT), QUT (AU), TJU (CN), UMTRI (US)

- **Duration of the project:**
  36 months (December 2018 – December 2021)

- **Framework Program:**
  Horizon 2020 - The EU Union Framework Programme for Research and Innovation – Mobility for Growth

Introduction

- Rapid technological advances leave limited margins for the preparation of cities in order to receive Connected and Automated Transport Systems (CATS).
- Automation technologies are expected to roll out in a rapid pace in all transport domains, including land transport modes such as passenger cars, urban public transport and freight transport.
- The LEVITATE project endeavors to develop an open access web-based Policy Support Tool (PST) targeting Decision makers at all levels: Municipalities, Regional Authorities & National Governments.

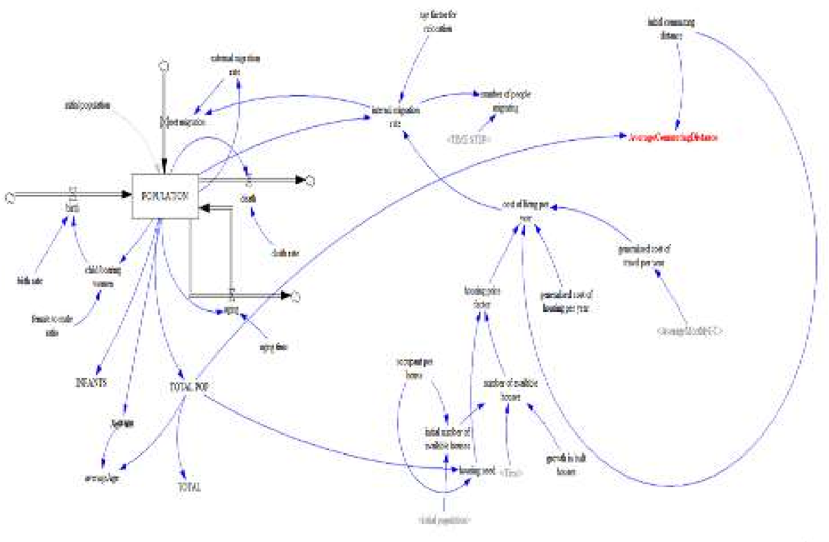
PST Scope

- To consolidate the outputs of different methods into an overall framework for the assessment of impacts, benefits and costs of CATS, for different automation and penetration levels and on different time horizons;
- To analyze user needs for a decision support tool aiming to assist in the analysis of urban policy scenarios and targets;
- To develop and implement a toolkit and a decision support tool, allowing the testing of various policy scenarios on the basis of the needs of relevant stakeholders, incorporating both forecasting and backcasting approach;
- To provide the respective policy recommendations.

PST Components

- Three automation use cases are considered:
  - Passenger cars
  - Urban transport
  - Freight transport
- Twenty examined impacts are considered, classified into three distinct categories:
  - Direct impacts,
  - Systemic impacts and
  - Wider impacts
- Four scenarios of automation penetration are established:
  - No automation base scenario
  - Pessimistic base scenario
  - Neutral base scenario
  - Optimistic base scenario
- Three different methods used to provide inputs:
  - Microsimulation
  - Systems dynamics
  - Delphi method

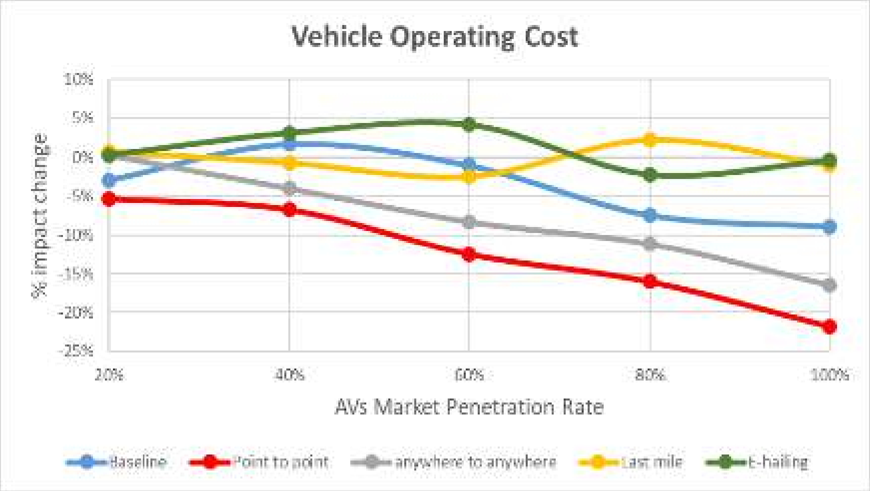
PST Methodologies (1/2)

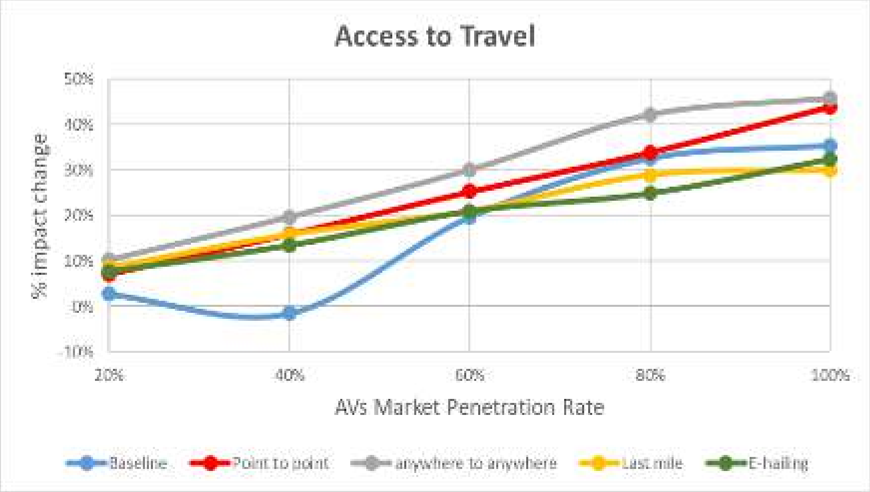


- **Microscopic simulation:**
  - Impacts of CATS on traffic: travel times, flows, traffic emissions and road safety under several simulation scenarios
  - Influence of different CAV penetration rates on a microscopic level
  - AIMSUN software is used within LEVITATE, with inputs including road geometry and design, traffic volume, modal split, O-D matrices etc.

- **System Dynamics:**
  - Transportation systems that are undergoing transformation are considered
  - Assess impacts of policy interventions (e.g., road use pricing/last-mile shuttles) during a transition period of increasing AV percentage
  - Impacts are typically commuting distances, modal split and others as a function of time (or MPR per scenario)

PST Methodologies (2/2)





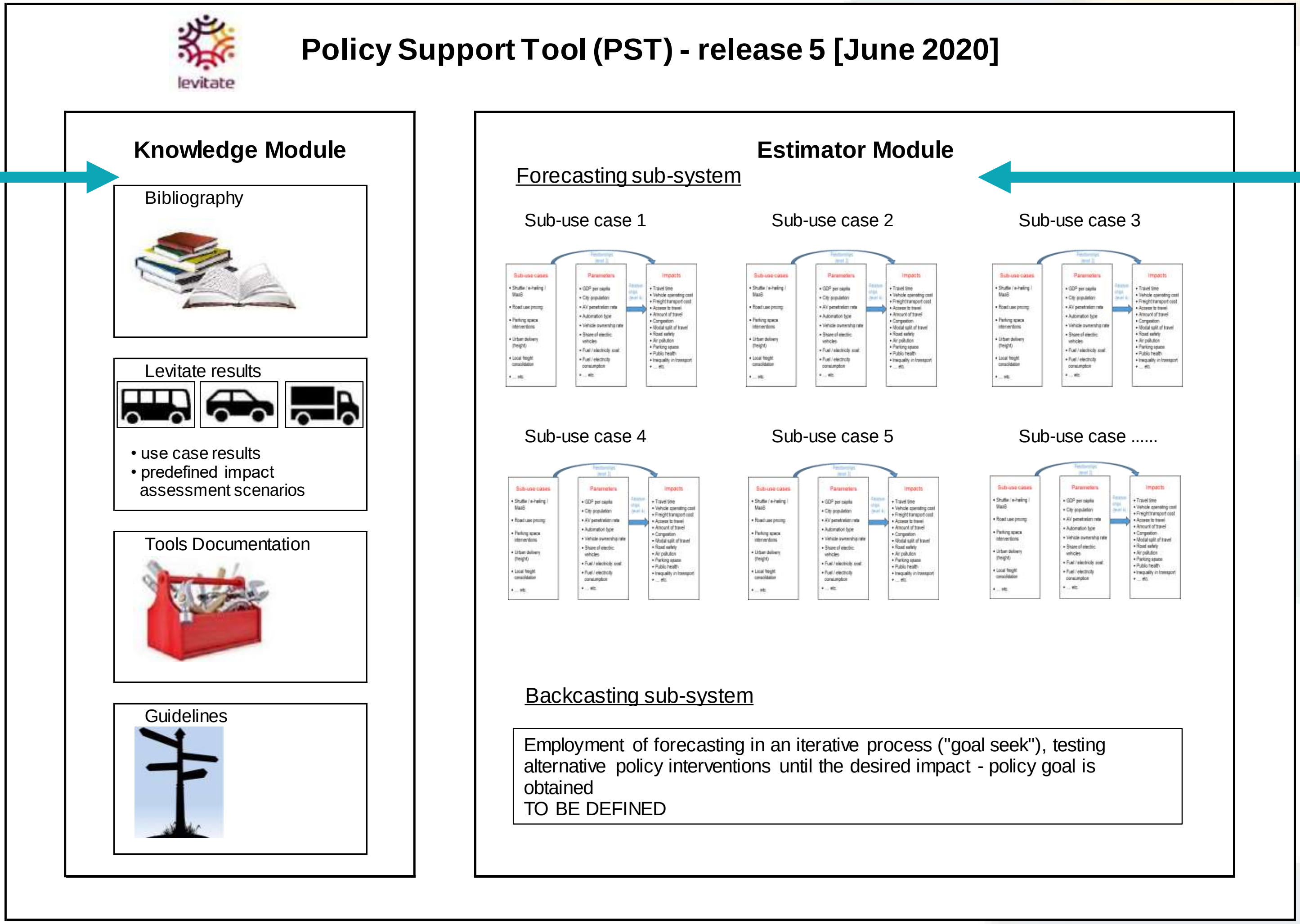
- **Delphi Panel:**
  - A process used to arrive at a collective, aggregate group opinion through an expert panel
  - Used to obtain impacts that cannot be calculated by other quantitative methods
  - Two-round 45-min questionnaires, regarding 2 to 4 automation interventions based on expertise
  - Answers were aggregated as percentage change coefficients

- **Mesoscopic simulation and operations research** are implemented auxiliary for certain impacts (modal split using public transport/active travel) and freight-related impacts

- All results are standardized, converted to percentage rates and are harmonized based on CATS market penetration rates

PST Structure

- Static
- Searchable
- Components:
  - Bibliography
  - Results
  - Tools
  - Guidelines and policy recommendations



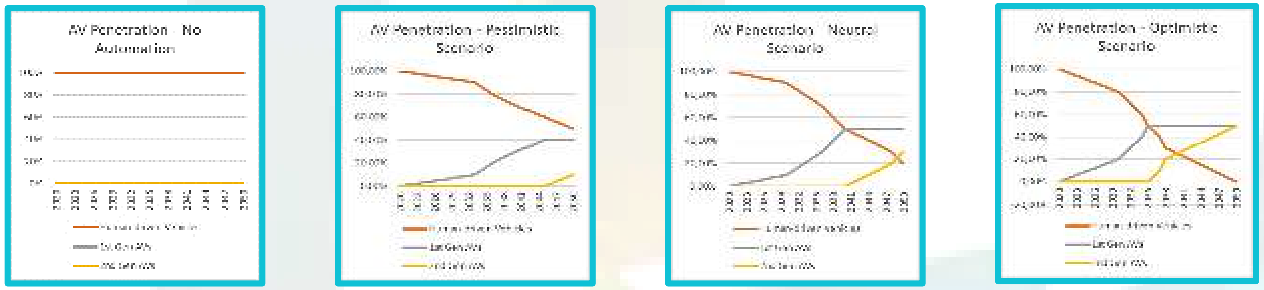
- Dynamic
- Interactive
- Javascript Design
- Sub-systems:
  - Forecasting
  - Backcasting
  - CBA module
  - Case studies

Knowledge Module: Overview

1. Bibliography: Relevant literature
    - Systematic literature review
    - The documentation of each sub-use case
    - Short synopsis
2. Project results: Case studies, impact assessments
    - Information regarding the scenarios conditions
    - Assumptions and limitations
    - Showcasing of case study results
3. Documentation of tools: Toolbox of Levitate methods
    - Information regarding the methodological background
    - Assumptions and limitations relevant to each methodology
4. Guideline excerpts: Guidelines & policy recommendations
    - Explanations and tutorials on the use of the PST overall recommendations to cities
    - Additional recommendations from literature

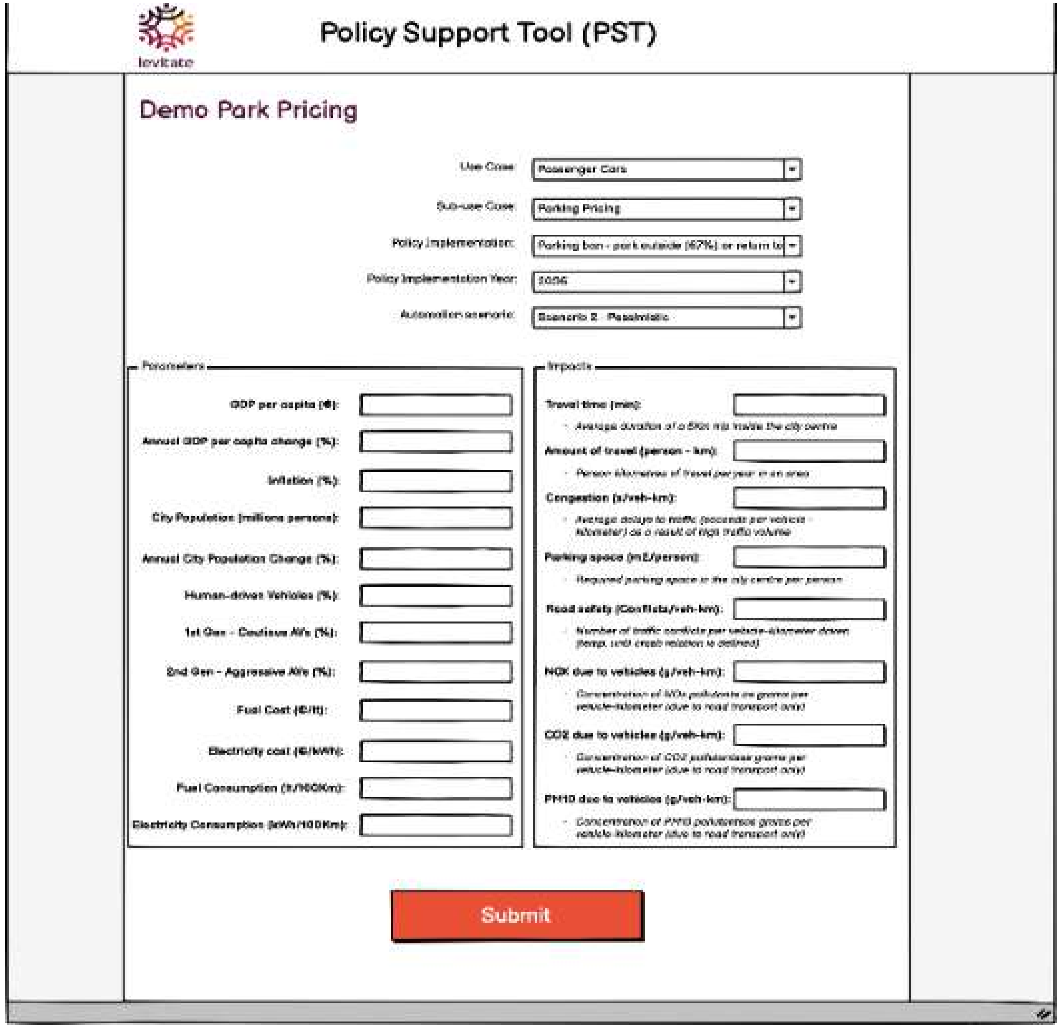
Forecasting Estimator

- Step 1: Selection of Use Case and Sub-Use Case (SUC):



- Step 2: Definition of initial values
- Step 3: Definition of base scenario:
- Step 4: Details of sub use-case implementation
- Step 5: Estimation of forecasted impact indicator values for reference scenario
- Step 6: Estimation of forecasted impact indicator values for intervention scenario
- Step 7: SUC impact estimation – presentation of results

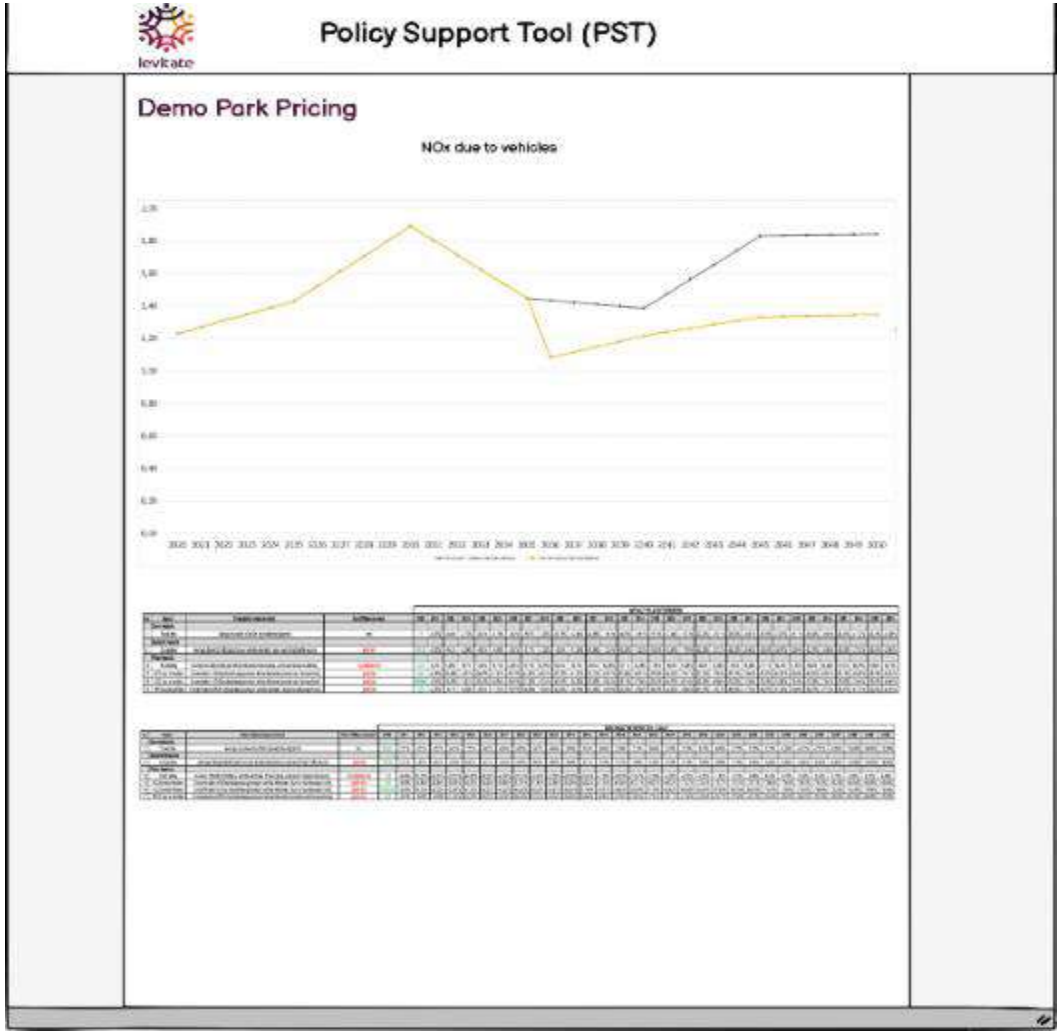
Forecasting Estimator Example (1/2)



User Input

- Selection of Passenger Cars use case, Parking pricing sub-use case and 67% park outside policy implementation,
- Selection of 2036 as implementation year and pessimistic automation scenario,
- Selection of initial values and details of sub-use case implementation.

Forecasting Estimator Example (2/2)



Results

- Estimation of forecasted NOx due to vehicles impact indicator values for reference scenario (without SUC),
- Estimation of forecasted NOx due to vehicles impact indicator values for intervention scenario (with SUC),
- SUC NOx due to vehicles impact estimation – presentation of results.

Backcasting Estimator

- Functionality: The backcasting process is envisioned to be the inverse of forecasting, ie.:
  Set a vision, investigate how it can be reached.

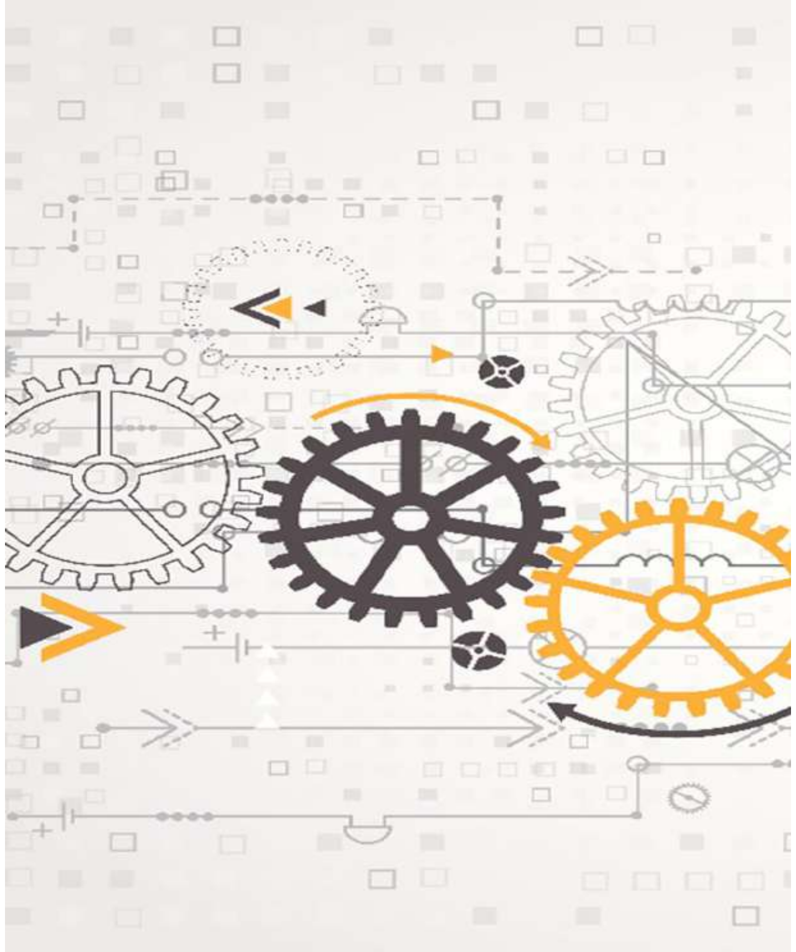
- Projection: Are the selected measures enough or not?

- If not, define best possible attainable outcome.

- Measure combination: Using combined Impact Modification Factors (IMFs).

- Measure change: Option to substitute a measure for another midway once in the PST
  (e.g. Measure 1 performs better in low MPR, and Measure 2 performs better in high MPR).

Policy Intervention Combination



- Adopting and expanding the CMF Approach:
  The creation of Impact Modification Factors (IMFs) and their combinations in pairs drawing from the US FHWA HSM philosophy for CMFs

  - Additive method:
    $IMF_c = 1-[(1-IMF_1) + (1-IMF_2)]$
  - Multiplicative method:
    $IMF_c = IMF_1 * IMF_2$
  - Dominant effect method:
    $IMF_c = min(IMF_1, IMF_2)$
  - Dominant common residuals method:
    $IMF_c = (IMF_1 * IMF_2)^{min(IMF_1, IMF_2)}$
  - Amplificatory method (not existing in FWHA):
    $IMF_c = [IMF_1 * IMF_2]^2$

Combination Example

- The case of two SUCs:
  - SUC_1: Parking pricing→ Parking toll-balanced behavior
  - SUC_2: Provision of dedicated lanes→ Motorway (outermost)
- The CO_2 impacts on the year 2035 for the pessimistic scenario
- The year of policy implementation is 2025
- User input is a baseline of 2000 g/veh-km

$\left\{\begin{array}{l} \text{CO2, Base}(SUC_1)\text{, 2035=1043.49 g/veh-km} \\ \text{CO2, }SUC_1\text{, 2035=910.02 g/veh-km} \end{array}\right.$ ➡ IMF_1=1–(910.02-1043.49)/1043.49=**0.8721**

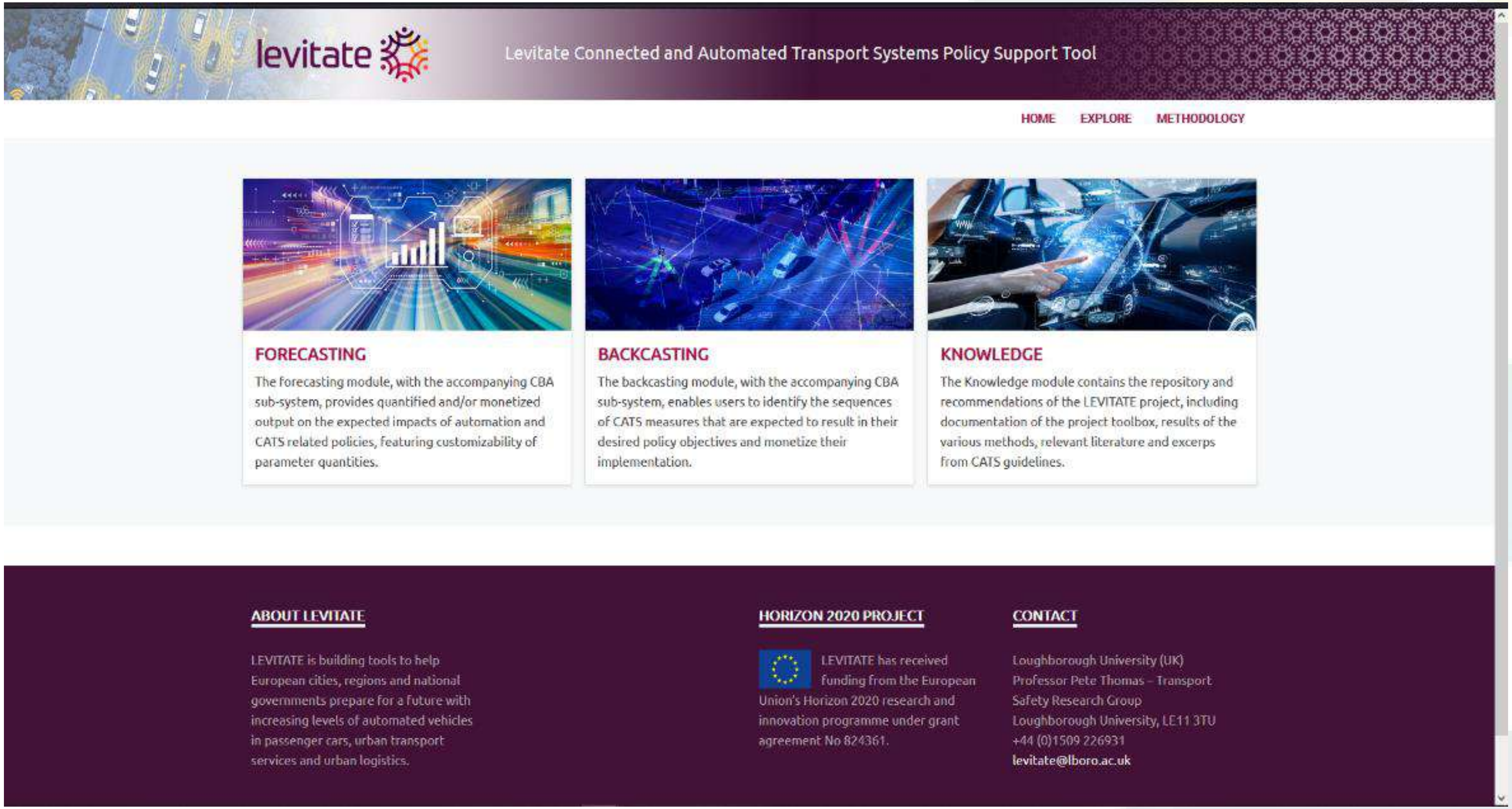
$\left\{\begin{array}{l} \text{CO2, Base(SUC2), 2035 = 1857.58 g/veh-km} \\ \text{CO2, }SUC_2\text{, 2035 = 1841.98 g/veh-km} \end{array}\right.$ ➡ **IMF_2** = 1–(1841.98-1857.58)/1857.58=**0.9916**

Additive method:

IMF_c = 1-[(1-IMF_1) + (1-IMF_2)] = 1 – [(1 – 0.8721) + (1 – 0.9916)] = 0.8637

⟶ $CO_{2,\ comb,\ 2035}$ = 2000 g/veh-km * 0.8637 = 1727.39 g/veh-km

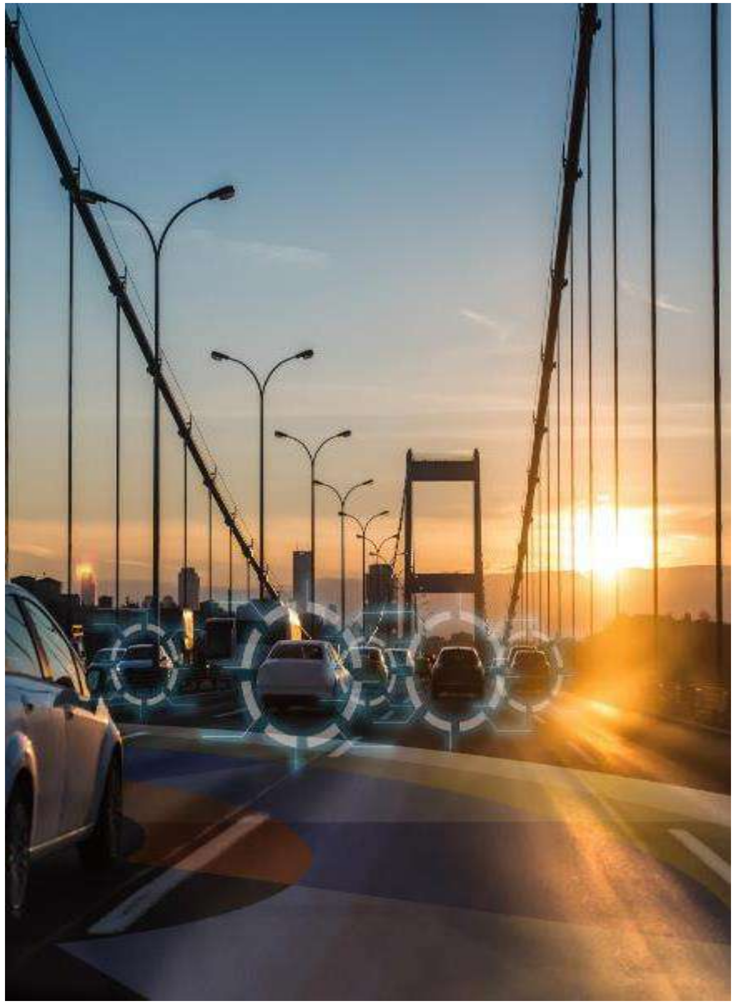
Online PST pre-alpha version



Future Developments

- As the LEVITATE project moves forward, additional results and functionalities will be available for the PST user.
- Work conducted within the Road Safety Working Group of LEVITATE will allow for the addition of three crash categories (total crashes, fatal and VRU crashes).
- CBA capabilities are already being examined as an extension of the forecasting module database in order to monetize costs and benefits induced from the overall transformation of the transport networks.
- Overall, the Levitate PST aspires to become the go-to, one-stop-shop tool for the calculation of societal impacts of automation by experts, authorities, stakeholders and any other interested party.

CCAM Challenges & lessons learned



- The integration of the expectations of different users (City/road management authorities, researchers, industrial practitioners) in a functional Policy Support Tool remains an uphill battle.
- Backcasting capabilities for impact assessment provide a powerful means to complement forecasting and to define visions & goals to be reached.
- Large degrees of uncertainty remain for the CCAM landscape regarding the scope, form & feasibility of automation-based policy interventions.
- The combination of multiple methodologies for CCAM impact assessment brings considerable advantages (increased parameter coverage) but is hard to integrate (different variable dependencies) and requires high-level coordination.

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