Project LEVITATE Final Conference

Event: Final Conference 2022
Location: Brussels & Online
Date: 25/05/2022

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

Horizon 2020 Framework Programme

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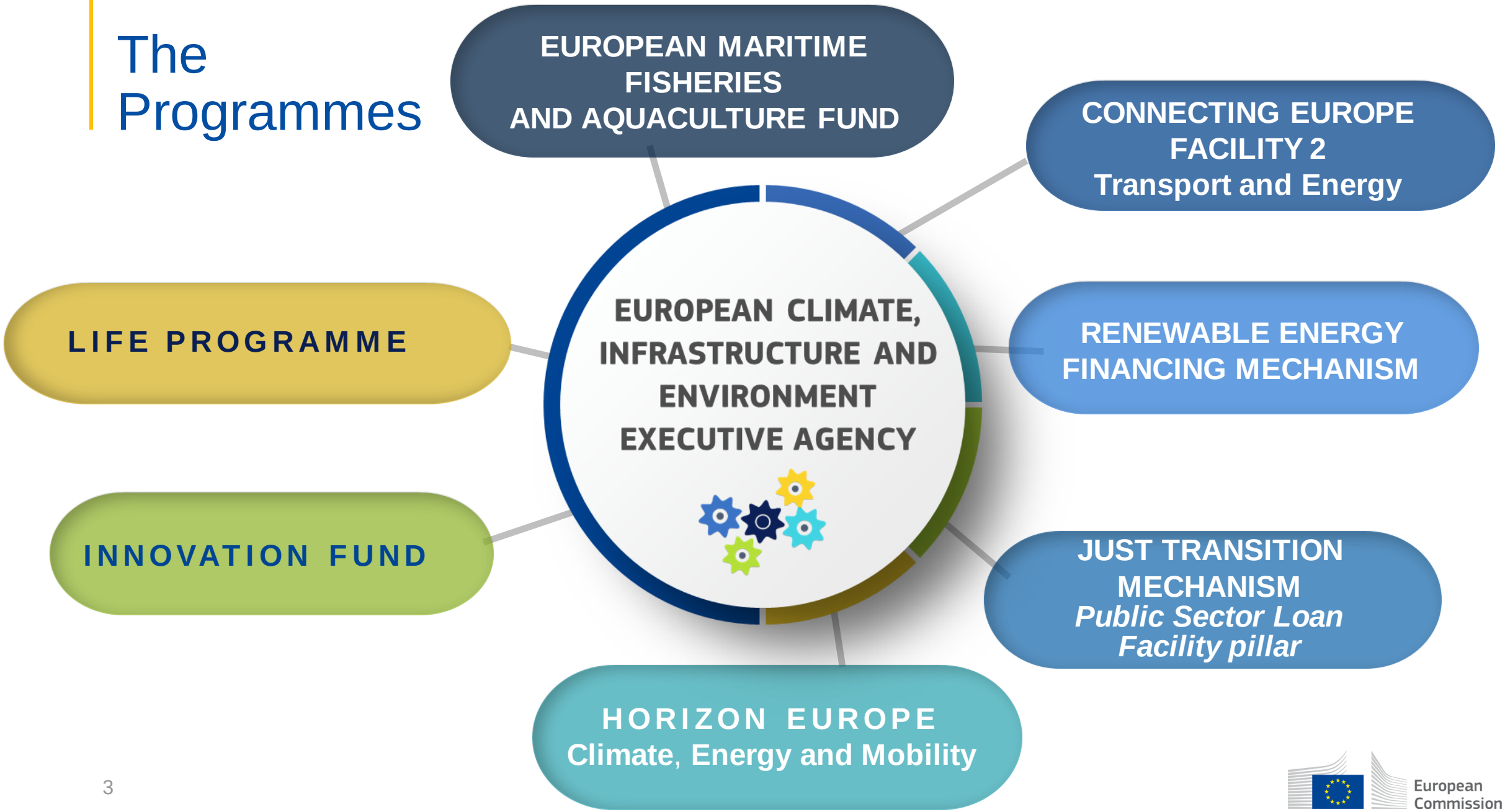
Final Conference, Brussels 25 May 2022

Georgios SARROS
Project Manager, Automated Transport Sector
European Climate, Infrastructure and Environment Executive Agency (CINEA)

European Commission

The Programmes



European Commission

CCAM

CONNECTED, COOPERATIVE & AUTOMATED MOBILITY

- Co-programmed European Partnership on CCAM
- Kicked-off in Horizon Europe
- Align all stakeholders
- Accelerate innovation in mobility in Europe by developing a shared R&I agenda
- Enable a more user-centred all-inclusive mobility
- Reduce congestion and contribute to protecting environment

*https://www.ccam.eu/

European Commission

HE Cluster 5 – First calls on CCAM 2021 & 2022

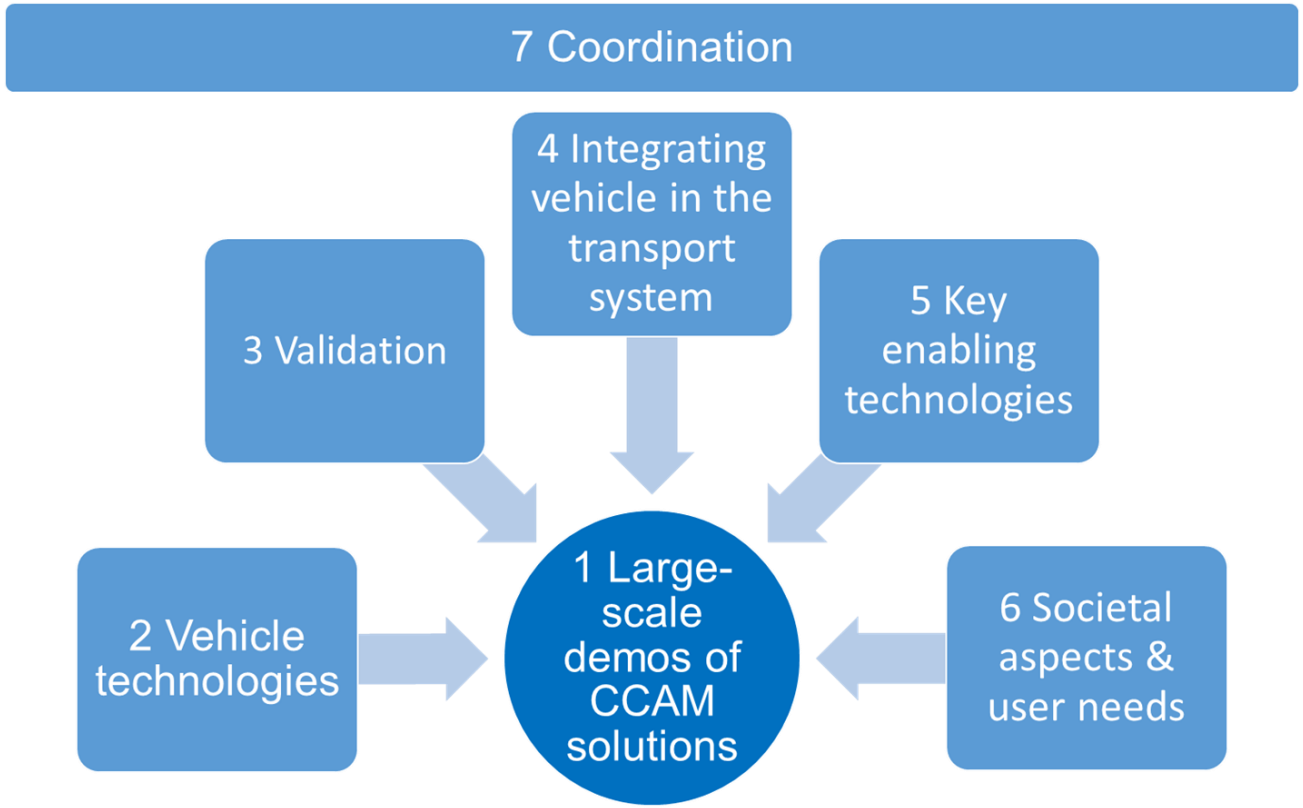
VEHICLE TECHNOLOGIES	• On-board perception and decision-making technologies, addressing complex environmental conditions **(2021)** • Reliable occupant protection technologies and HMI solutions to ensure the safety of highly automated vehicles **(2022)**
VALIDATION	• Common approaches for the safety validation of CCAM systems **(2021)** • Human behavioural model to assess the performance of CCAM solutions compared to human driven vehicles **(2022)**
INTEGRATING VEHICLE IN THE TRANSPORT SYSTEM	• Physical and Digital Infrastructure (PDI), connectivity and cooperation enabling and supporting CCAM **(2021)** • Integrate CCAM services in fleet and traffic management systems **(2022)**
KEY ENABLING TECHNOLOGIES	• Cyber secure and resilient CCAM **(2021)** • Artificial Intelligence (AI): Explainable and trustworthy concepts, techniques and models for CCAM **(2022)**
SOCIETAL ASPECTS AND USER NEEDS	• Analysis of socio-economic and environmental impacts and assessment of societal, citizen and user aspects for needs based CCAM solutions **(2021)**
COORDINATION	• Framework for better coordination of large-scale demonstration pilots in Europe and EU-wide knowledge base **(2021)**
LARGE-SCALE DEMONSTRATIONS	• European demonstrators for integrated shared automated mobility solutions for people and goods **(2022)**

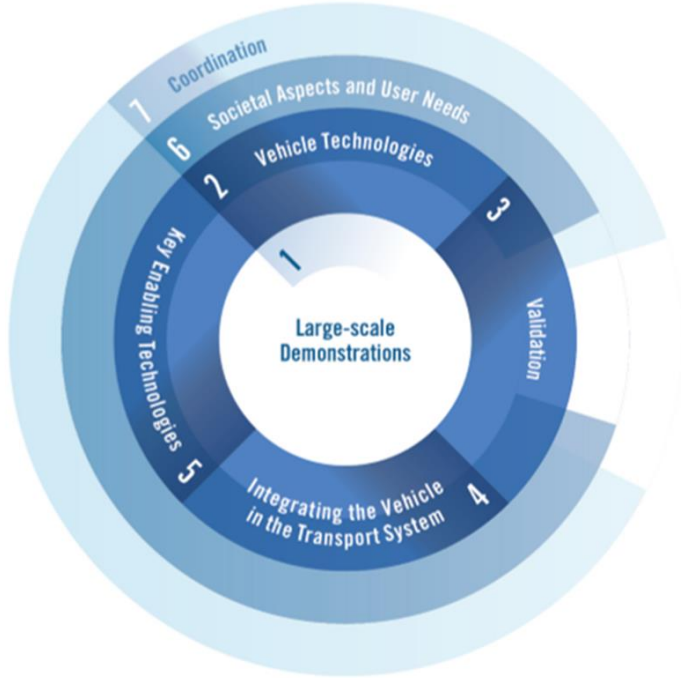
European Commission

European Partnership on CCAM – R&I Agenda

Multiannual roadmap, guiding the CCAM Partnership.

Describes the portfolio of activities, resources, and timeline for 7 main R&I areas.





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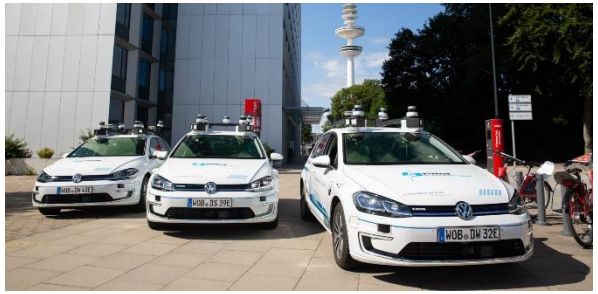
Flagship Automated Road Transport ‘Horizon 2020’ projects

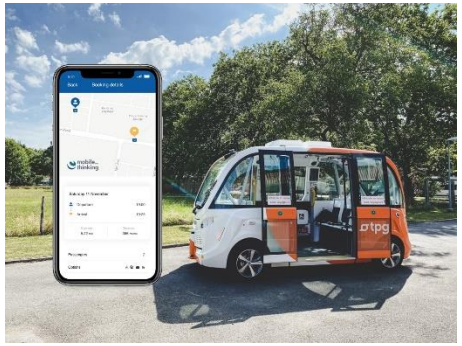
Projects’ Acronym



Large Scale Pilots of automated driving systems for passenger vehicles

L3Pilot Driving Automation

HI DRIVE



Fully automated urban road transport and shared AV fleets in urban areas

AVENUE

SHOW AUTOMATED URBAN MOBILITY

Multi-brand truck platooning and autonomous real logistics operations

ENSEMBLE

AWARD Scaling autonomous logistics

European Commission

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Look for CINEA!

https://cinea.ec.europa.eu/index_en

European Commission

Andrew Morris,
Loughborough University

Welcome Words

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Societal Level Impact of Connected and Automated Vehicles (CAVs)

HORIZON 2020 PROJECT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824361. The views expressed in this presentation are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

Project coordinator:	Loughborough University
Start date:	1st of December, 2018 – 3.5 years
Partners:	12 – from 10 countries
Total value	€6.5 m

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Project partners

Loughborough University

Institute of Transport Economics
Norwegian Centre for Transport Research

Tongji University

POLIS
CITIES AND REGIONS FOR TRANSPORT INNOVATION

National Technical University of Athens

Transport for Greater Manchester

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

SWOV
INSTITUTE FOR ROAD SAFETY RESEARCH

CARRS

aimsun.

UMTRI

City of Vienna

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Why LEVITATE?

- High expectations about CAVs in terms of safety, mobility, environment and prosperity
- Most previous research has focused on the technology and functionality of CAVs
- There is a gap in knowledge of the likely impacts of the vehicles and the services they enable, particularly during the transition phase
- The need to measure the impacts of existing systems as well as forecasting the impact of future systems represents a major challenge
- The dimensions for assessment are wide including safety, mobility and environment, with many sub-divisions adding to the complexity of future mobility forecasts

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

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Scope – connectivity and automation related services

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

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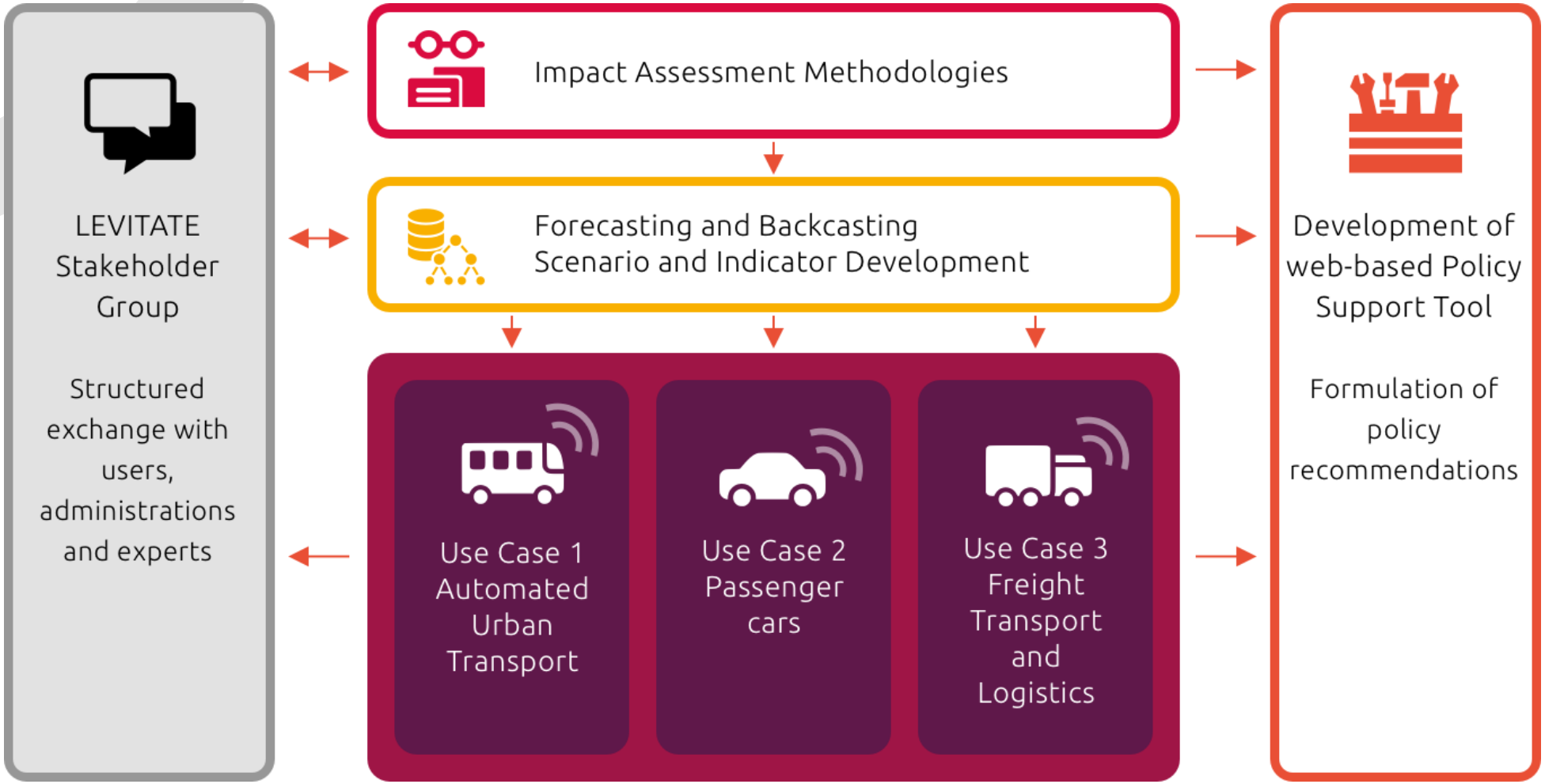
Work Plan Overview



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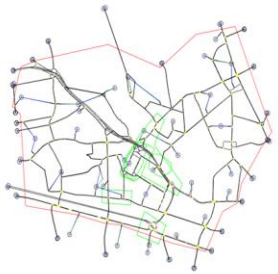
Methods within LEVITATE

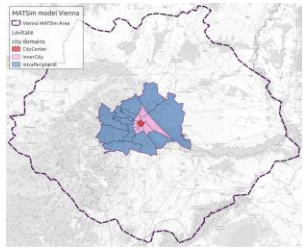
Microscopic Simulation

- Traffic,
- Safety, and
- Environment Impacts



Mesoscopic Simulation

- modal split
- road network loads
- vehicle utilisation rate



System Dynamics

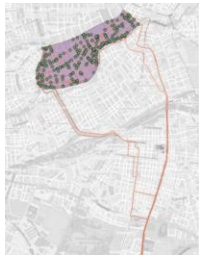
- Modelling the system by broken down sub-system components
- Algebraic relationships and sometimes differential equations.
- Linear or non-linear functions.
- Relationships can be continuous or discrete time events
- Feedback loops
- Simulation of the entire system level model

Delphi +Experts

- For items / relationships that cannot be predicted
- Group of experts and a collective opinion

Operations Research

- Freight Transport Use Case only
- Optimization algorithms for tour planning (fastest tour)



Driving Simulator

- Validation of some parts of simulation within this project

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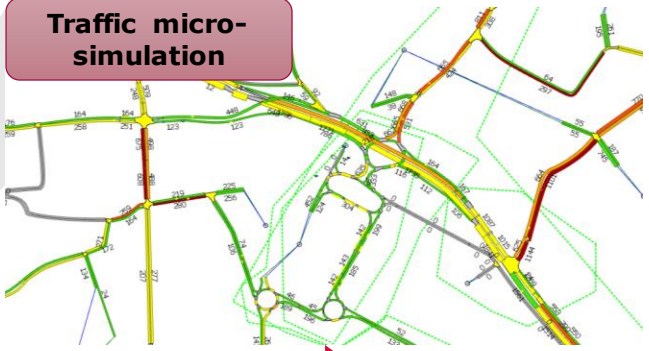
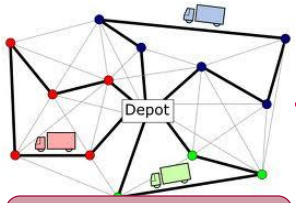
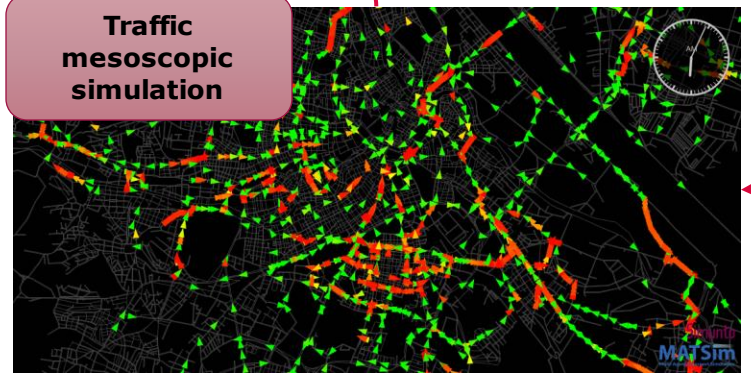
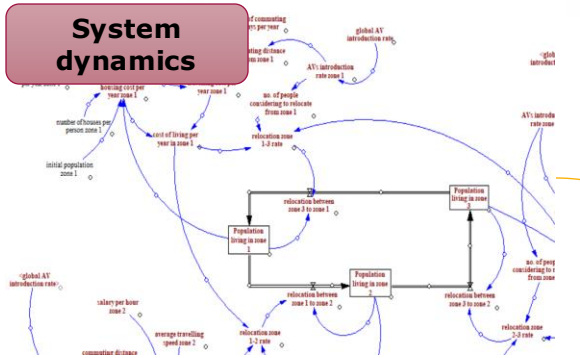
Progress and Main Findings









Travel time
Congestion
Conflicts
Emissions
Amount of travel

Traffic micro-simulation

Traffic mesoscopic simulation

Driving simulator

Changes in driving behaviour

Operations research

Fleet size
Total driven km
Vehicle operating costs

Safety (multiple methods)

No. of injury accidents
Changes in crashes and casualties

Sub-use Case

Delphi

Access to travel
Vehicle occupancy
Energy efficiency
Vehicle operating cost
Shared mobility rate
Vehicle utilisation rate
Inequality in transport

System dynamics

Public health
Demand for Parking space
Commuting distance
Modal split

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Policy Support Tool

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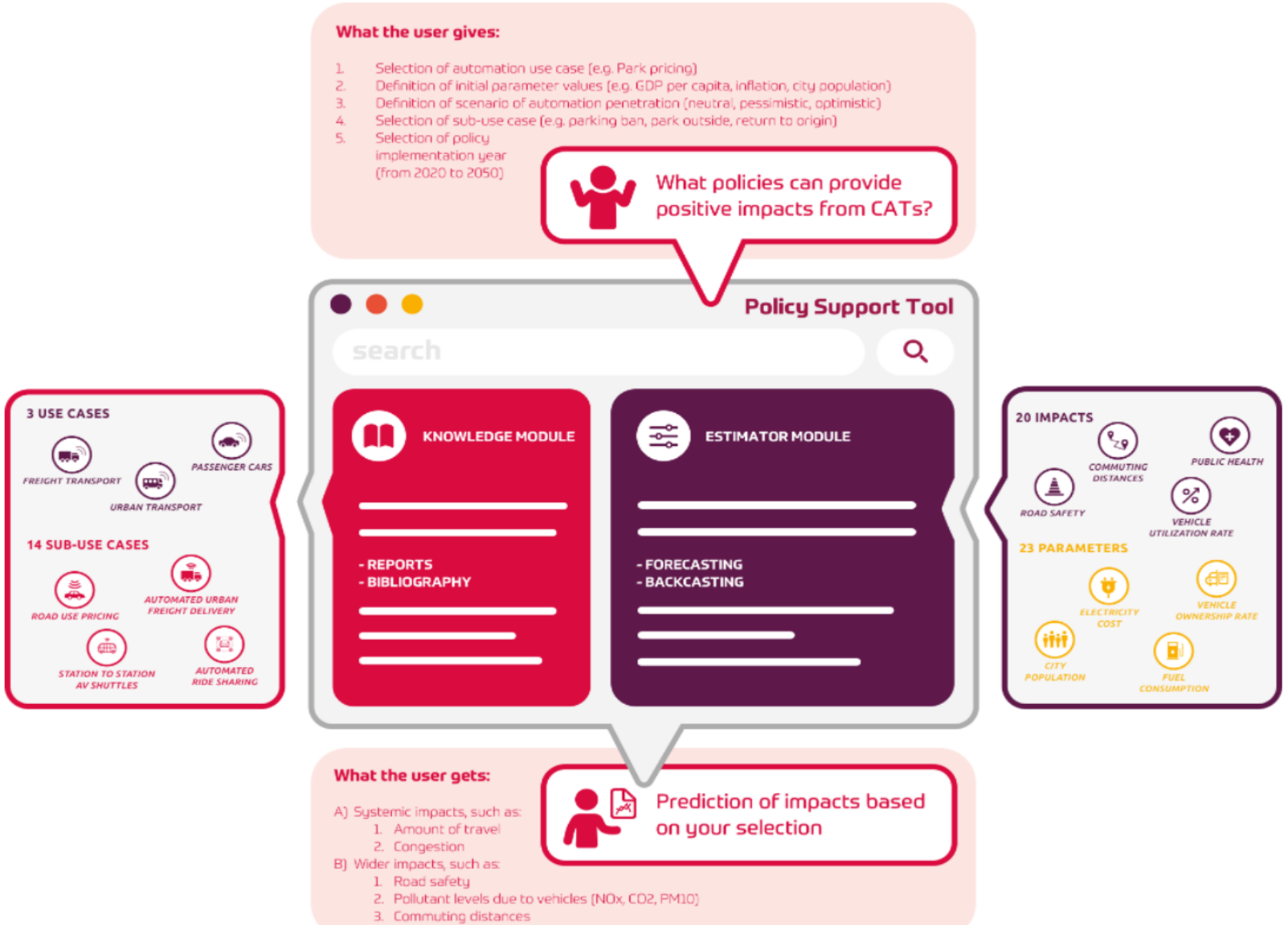
Concept



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Our Thoughts on Futre Requirements

- Need to **extend the Policy Support Tool** in terms of scope with new technologies in the pipeline
- Need to examine **Transferability** of the Methods and Results
- Need to consider support for cities who need **CCAM knowledge** for new policies
- Need to dig deeper to look at the potential **wider societal impacts** of CCAM

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LEVITATE Conference: Plan for Today

METHODS

10.30: The underlying methods and assumptions behind the LEVITATE impact assessment framework

11.15: Refreshments

KEY RESULTS

11.45: The short, medium and long-term impacts of CAVs, including the expected impacts of policy interventions:

12.15: Selected case studies

POLICY PERSPECTIVE

12.35: The role of LEVITATE in understanding the policy implications of CAVs

13.00-14.00: Lunch

14.00: LEVITATE Policy Support Tool

Hands-on trial of the PST CAV impacts prediction module, facilitated by LEVITATE partners

CLOSING SESSION

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Building Blocks of the LEVITATE impact assessment framework

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Rune Elvik, TOI

Determining the impacts of most relevance to cities

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Gaining an overview of societal impacts of connected and automated vehicles

- **This was one of the first activities in LEVITATE**
- **A taxonomy of impacts was developed**
- **Impacts were classified**
- **A causal diagram was developed**

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A total of 33 potential impacts were identified

- **Direct impacts**
  - **Noticed on each trip**
- **Systemic impacts**
  - **In the transport system**
- **Wider impacts**
  - **In society at large**

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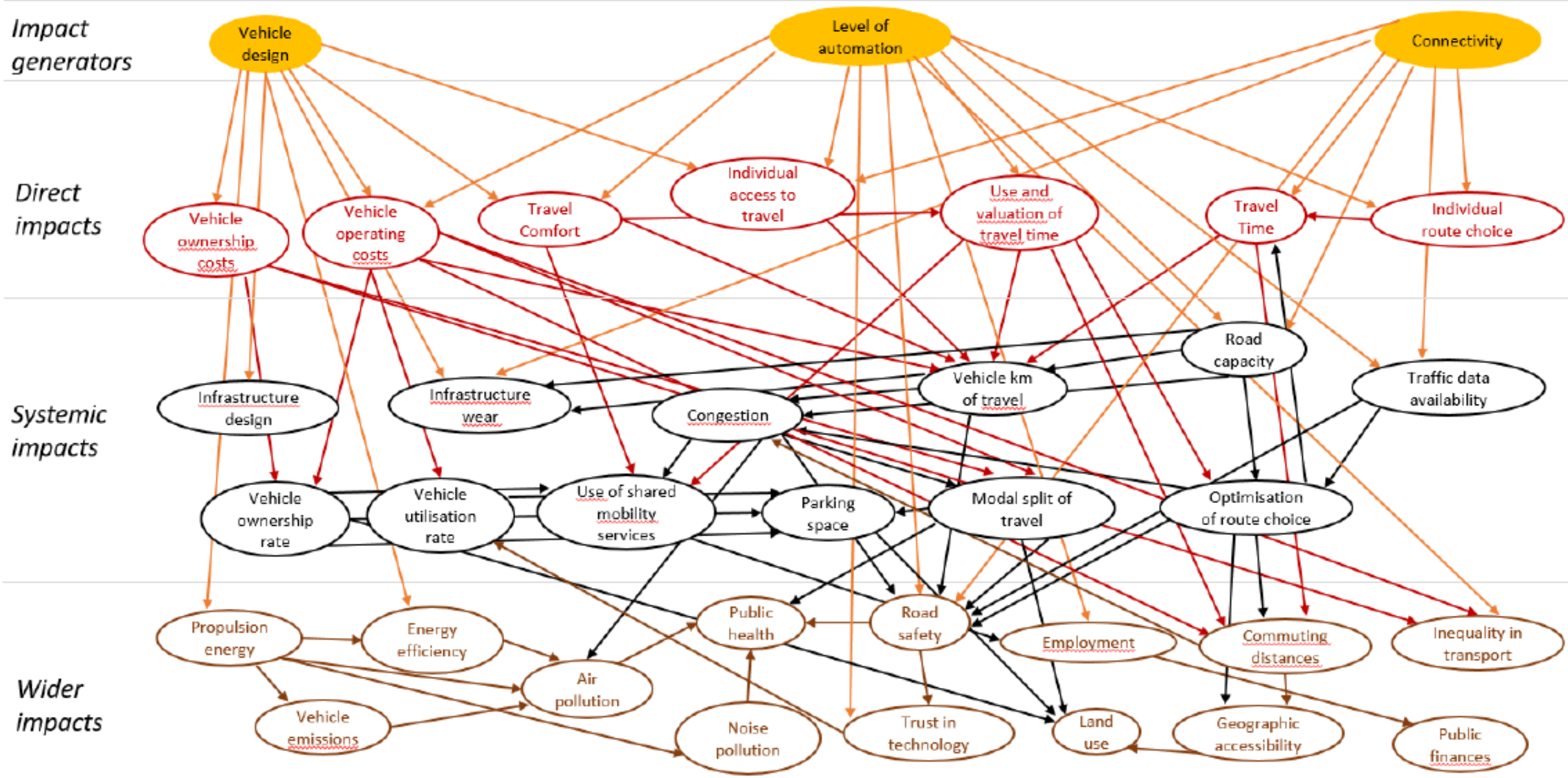
Primary impacts



Impacts of most relevance to cities

- **The systemic and wider impacts, in particular:**
  - **Use of shared mobility**
  - **Modal split of travel**
  - **Public health**
  - **Commuting distances**
  - **Etc**
- **Urban transport policy should aim for these impacts**

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Martin Zach, AIT

Developing backcasting: starting from desired visions

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What about the city *goals*?

Several approches on different geographical / organizational level, e.g.

- SDG: Sustainable Development Goals (United Nations)
- SUMI: Sustainable Urban Mobility Indicators
- City Strategies (examples: Vienna, Greater Manchester)

➔ *Goals / targets / indicators* have been classified along several dimensions:

Society - Environment - Economy - Safety

➔ Different *desirable visions* might be specified!

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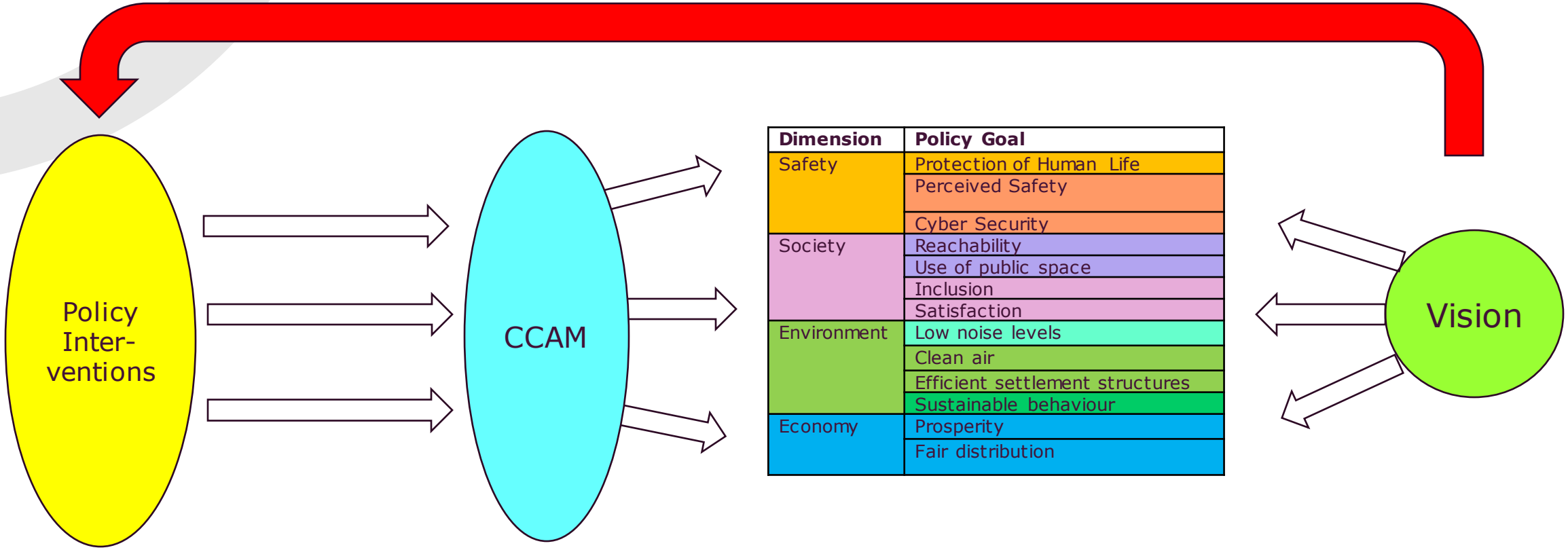
Backcasting in LEVITATE – the big picture



Dimension	Policy Goal
Safety	Protection of Human Life
	Perceived Safety
	Cyber Security
Society	Reachability
	Use of public space
	Inclusion
	Satisfaction
Environment	Low noise levels
	Clean air
	Efficient settlement structures
	Sustainable behaviour
Economy	Prosperity
	Fair distribution

Impact estimation

Indicator framework

Impact estimation

Strategy / targets

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Definition of quantified impacts

Policy Goals → Indicators → Calculated Impacts

Dimension	Policy Goal
Safety	Protection of Human Life
	Perceived Safety
	Cyber Security
Society	Reachability
	Use of public space
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Environment	Low noise levels
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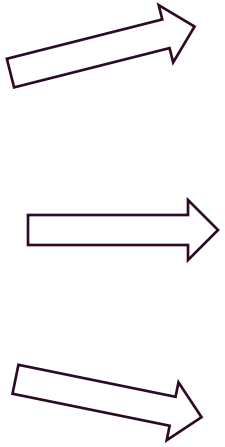
Economy	Prosperity
	Fair distribution



Impact	Description
Travel time	Average duration of a 5Km trip inside the city centre
Vehicle operating cost	Direct outlays for operating a vehicle per kilometre of travel
Freight Transport Cost	
Access to travel	The opportunity of taking a trip whenever and wherever wanted (10 points Likert scale)
Congestion	Average delays to traffic (seconds per vehicle-kilometre) as a result of high traffic volume
Amount of travel	Person kilometres of travel per year in an area
Modal split using public transport	% of trip distance made using public transportation
Modal split using active travel	% of trip distance made using active transportation (walking, cycling)
Shared mobility rate	% of trips made sharing a vehicle with others
Vehicle utilisation rate	% of time a vehicle is in motion (not parked)
Vehicle occupancy	average % of seats in use
Truck Platooning	
Road safety	Number of traffic conflicts per vehicle-kilometre driven (temp. until crash relation is defined).
Parking space	Required parking space in the city centre per person (m^2/person)
Energy efficiency	Average rate (over the vehicle fleet) at which propulsion energy is converted to movement
NO_x due to vehicles	Concentration of NOx pollutants as grams per vehicle-kilometre (due to road transport only)
CO_2 due to vehicles	Concentration of CO_2 pollutants as grams per vehicle-kilometre (due to road transport only)
PM10 due to vehicles	Concentration of PM10 pollutants as grams per vehicle-kilometre (due to road transport only)
Public health	Subjective rating of public health state, related to transport (10 points Likert scale)
Accessibility in transport	The degree to which transport services are used by socially disadvantaged and vulnerable groups including people with disabilities (10 points Likert scale)
Commuting distances	Average length of trips to and from work (added together)

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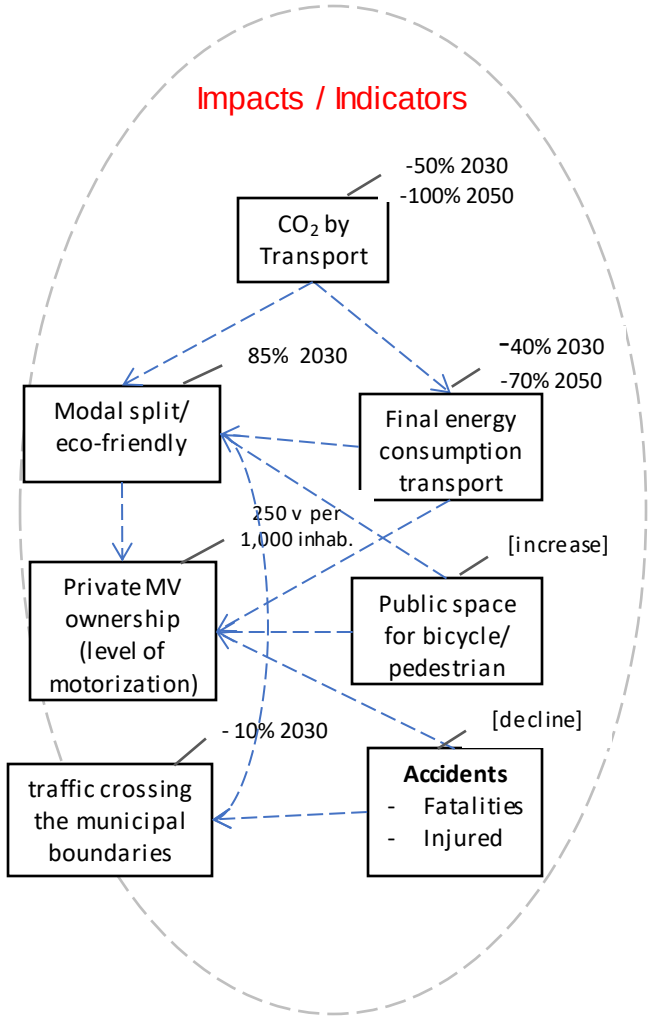
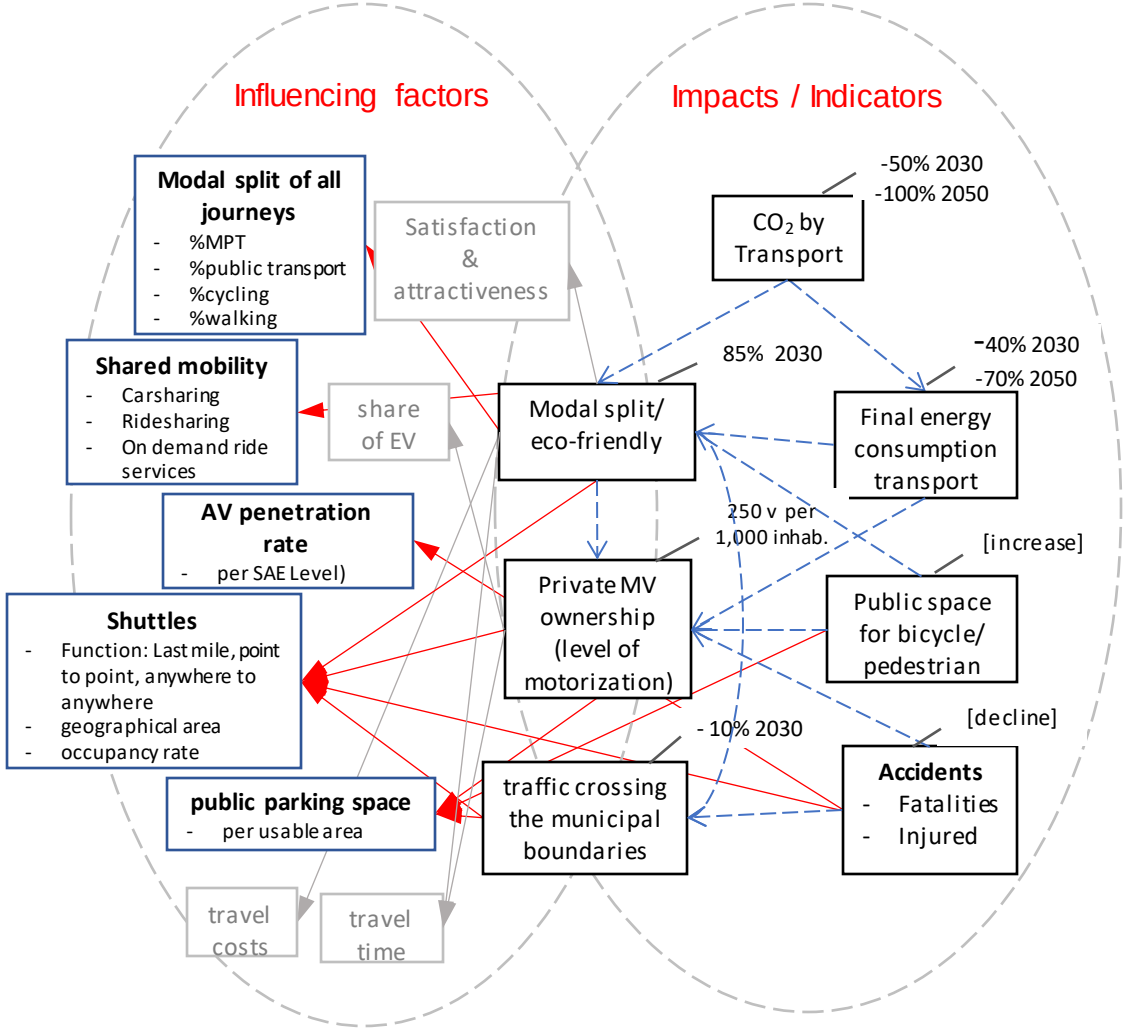
City Dialogue Vienna – specifying the vision

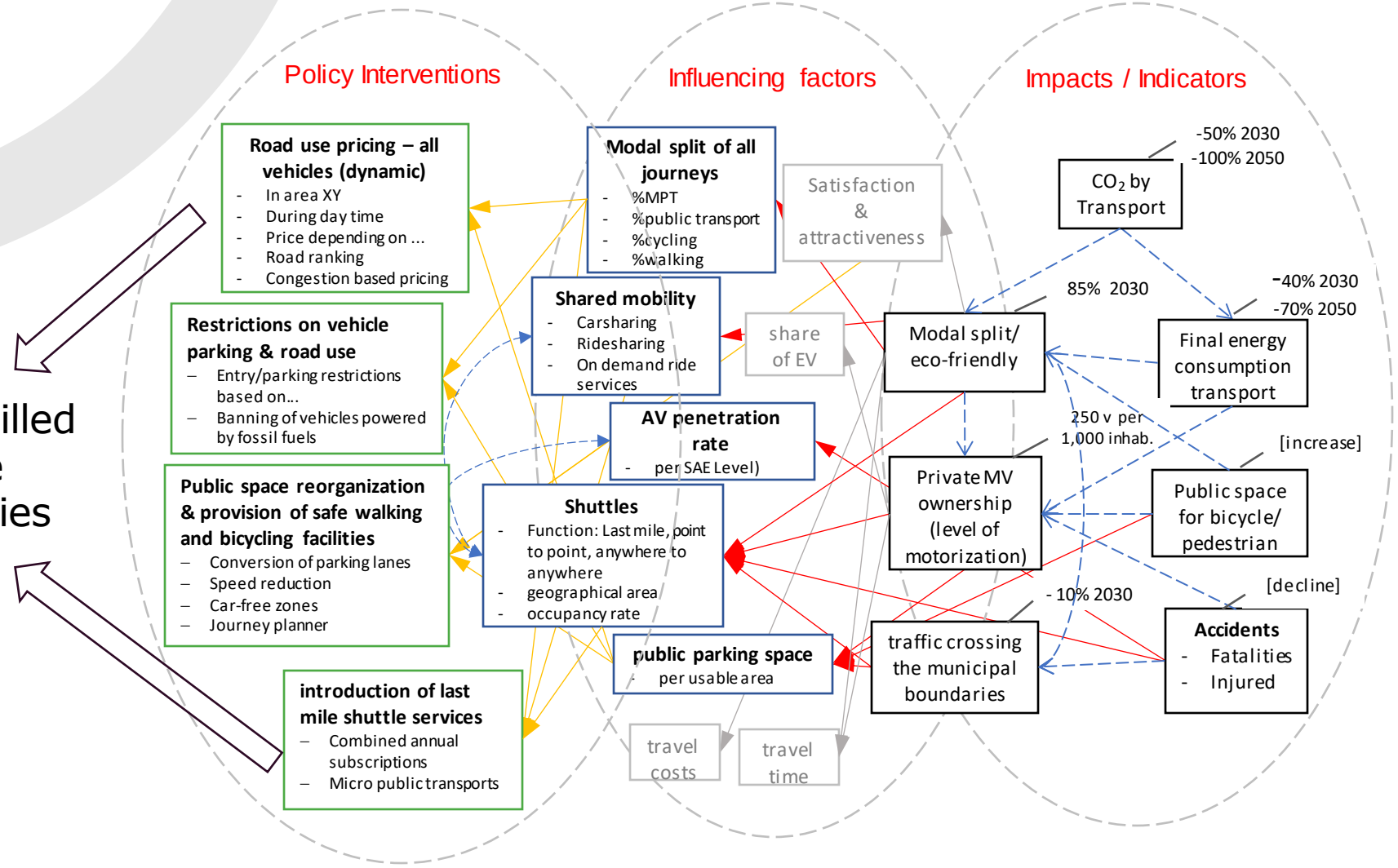


City Dialogue Vienna – influencing factors (related to CCAM)



City Dialogue Vienna – most promising areas of policy interventions

Detailled Case Studies



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Wolfgang Ponweiser, AIT

Defining the use cases and policy interventions

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LEVITATE Use Cases

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Passenger cars 

Urban transport 

Freight Transport 

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LEVITATE Use Cases

Passenger cars 
Dedicated lanes for AVs
Parking regulation • Parking price regulation • Removing half on-street parking spaces • Replace on-street parking with other facilities
Road use pricing • Static toll • Dynamic toll • Exemptions for residents
Green light optimised speed advisory (GLOSA)
Automated ride sharing

Urban transport 
Point to point automated shuttles • Automated shuttles connecting two modes • Automated shuttles in a large-scale network
On-demand automated shuttles
Last mile automated shuttles

Freight Transport 
Automated urban delivery • Semi-automated delivery • Fully-automated delivery
Automated consolidation • Consolidated delivery via white label city-hubs
Hub to hub automated transfer
Truck platooning • Effects of truck platooning on highway bridges

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Process for Identifying the List

1. Generation of an initial long list by the consortium
2. Definition and **categorization**:
    - Application
    - **Intervention**
3. **Selection criteria** for the final list of **sub-use cases**:
    - Consultation of stakeholders during a **workshop**
    - Amount of **existing literature** on the topic
    - Importance in the ERTRAC Connected Automated Driving **Roadmap**
4. Refinement and clustering
5. Identify / develop **suitable methods** for the sub-use cases and the impact dimensions

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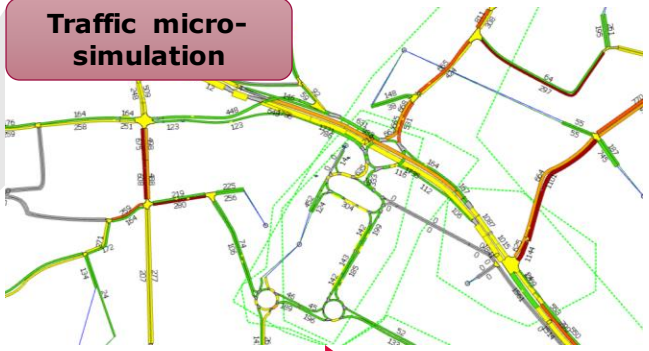
Multi-method framework

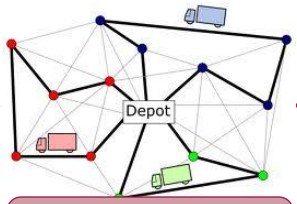
Travel time
Congestion
Conflicts
Emissions
Amount of travel

Traffic micro-simulation



Driving simulator

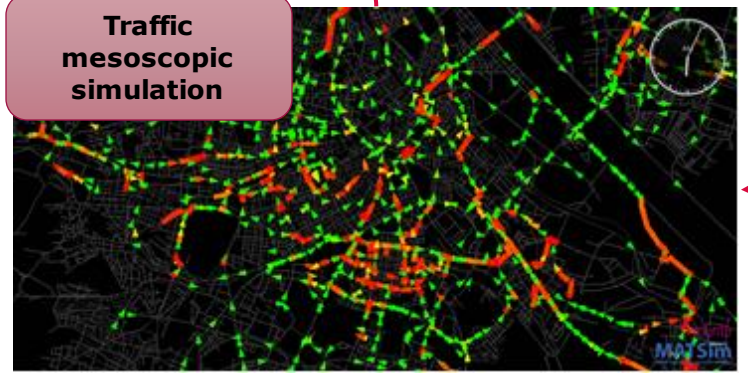
Changes in driving behaviour



Operations research

Fleet size
Total driven km
Vehicle operating costs

Traffic mesoscopic simulation



Sub-use Case

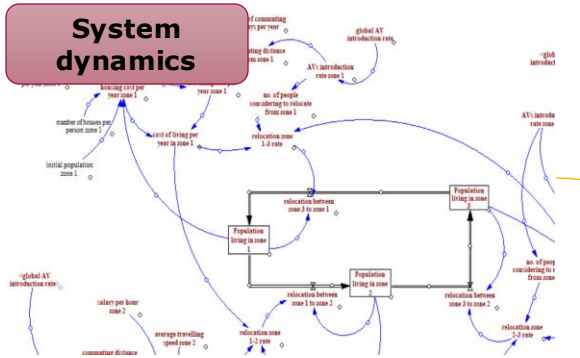
Safety (multiple methods)

No. of injury accidents
Changes in crashes and casualties

Delphi

Access to travel
Vehicle occupancy
Energy efficiency
Vehicle operating cost
Shared mobility rate
Vehicle utilisation rate
Inequality in transport

System dynamics



Public health
Demand for Parking space
Commuting distance
Modal split

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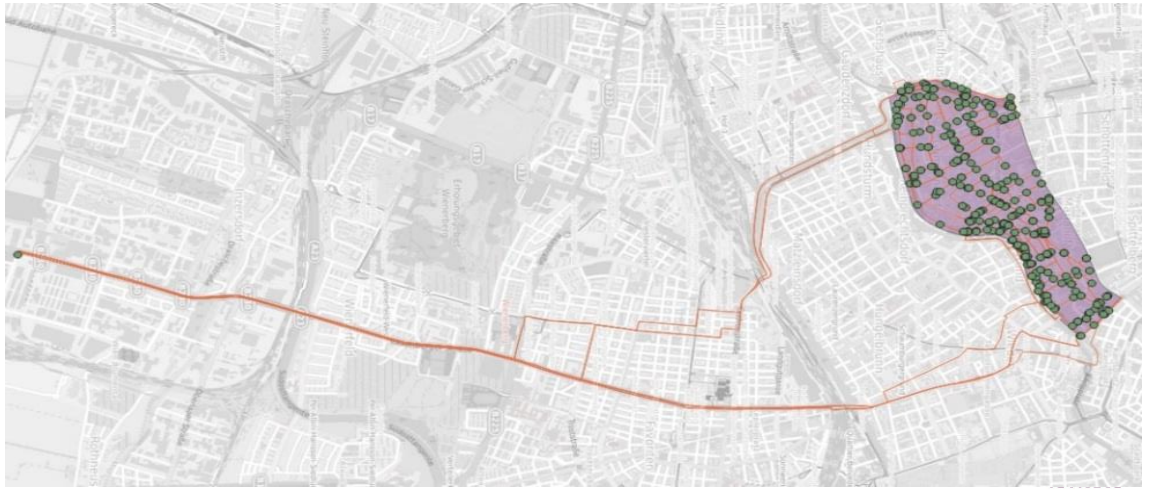
Example: Automated delivery

- **Automated delivery**:
  Robo-van + delivery robots

- **Automated consolidation**
  Consolidated delivery via city-hubs

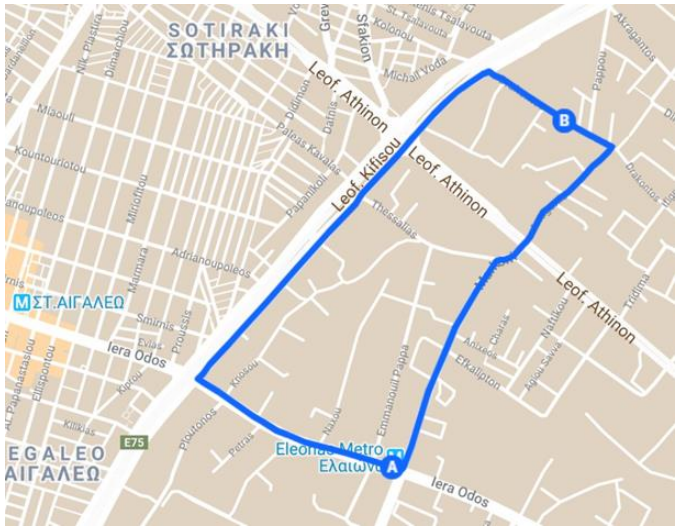
Automated van with delivery robots

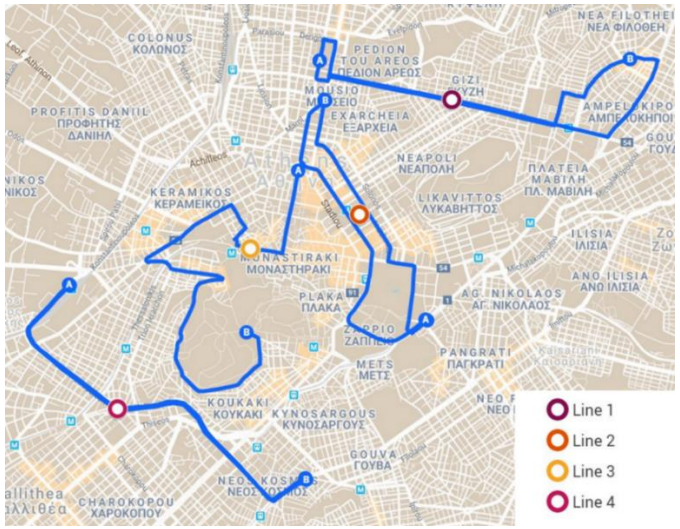
- Main method:
  Operations research
  - Define network
  - Generate addresses and POIs
  - Calculate delivery tours and evaluate results



Example: Automated shuttles

- **Automated shuttles connecting two modes**
- **Automated shuttles in a large-scale network**





- Main method: **Micro-simulation** (Aimsun Next)
  - Define network
  - Define vehicle parameters and CAV market penetration rates
  - Define services and operating scenarios
  - Run simulation and evaluate results

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Wendy Weijermars, SWOV

Predicting the impact of CAVs on road safety

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Road safety impacts within Levitate

Two-step approach:

1. In which ways is road safety impacted by CCAM?
2. Quantification of impacts

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Road safety impacts within Levitate

- Increasing penetration levels of CAVs (baseline scenario)
- Various SUCs

Passenger vehicles	Urban transport	Freight transport
Road use pricing	Point to point automated urban shuttle	Automated freight consolidation
Dedicated lanes	On demand automated urban shuttle	Automated urban freight delivery
Parking price policies		Hub to hub automated delivery
Parking space regulations		
GLOSA		
Automated ride sharing		

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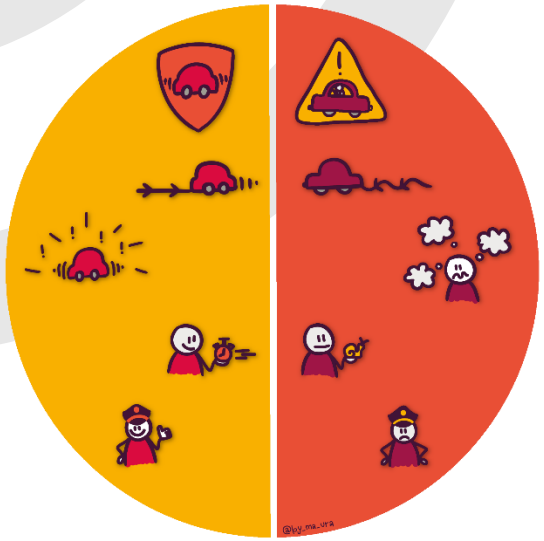
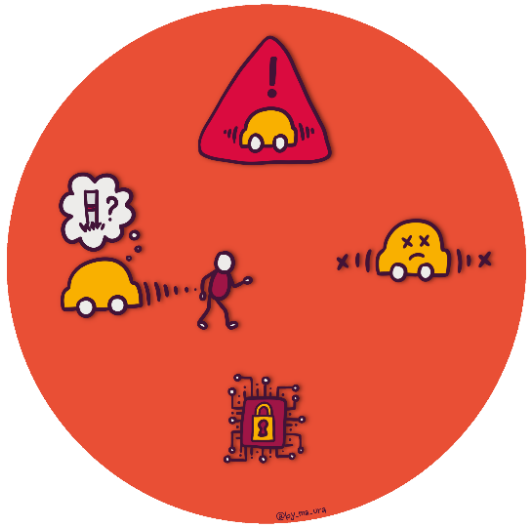
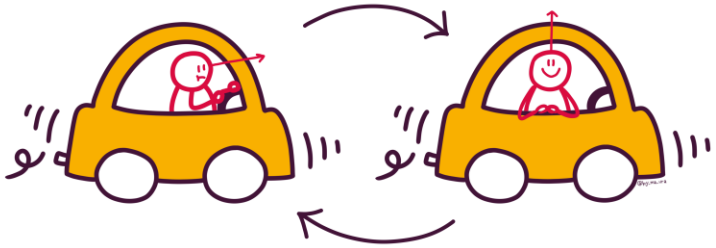
Ways in which road safety is impacted



Improved driver behaviour



New risks



Transition of control

Rebound effects

Drawings by Maura van Strijp

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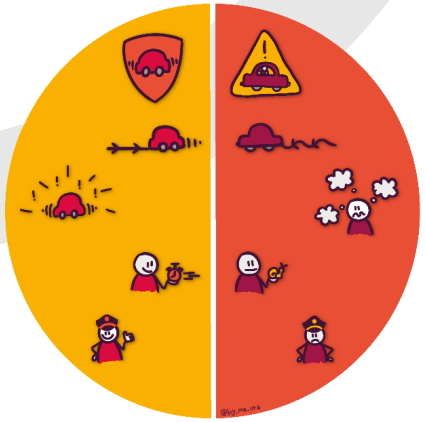
Quantification of impacts

- Not all impacts could be quantified!!



Improved driver behaviour

Microsimulation

VRUs: accident data and assumptions

→ Changes in crash rates

Changes in distance travelled per transport mode

→ Changes in crashes

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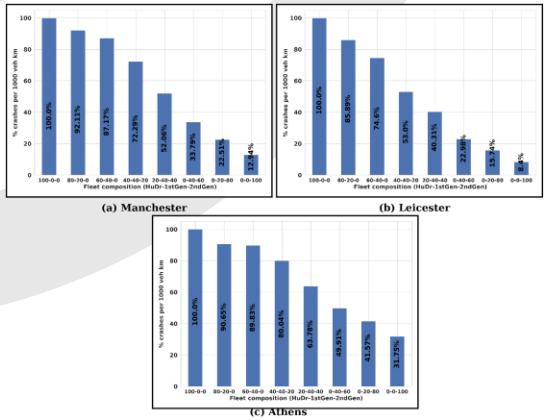
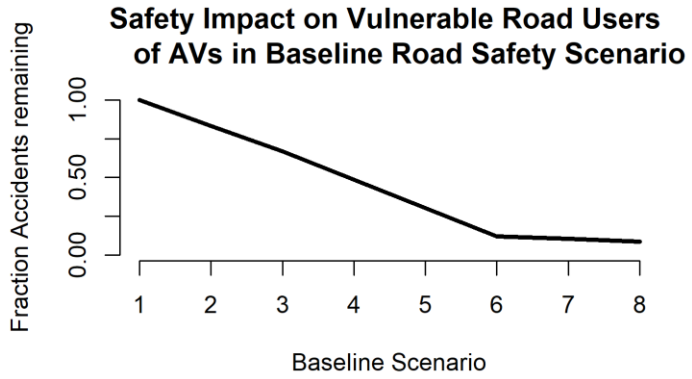
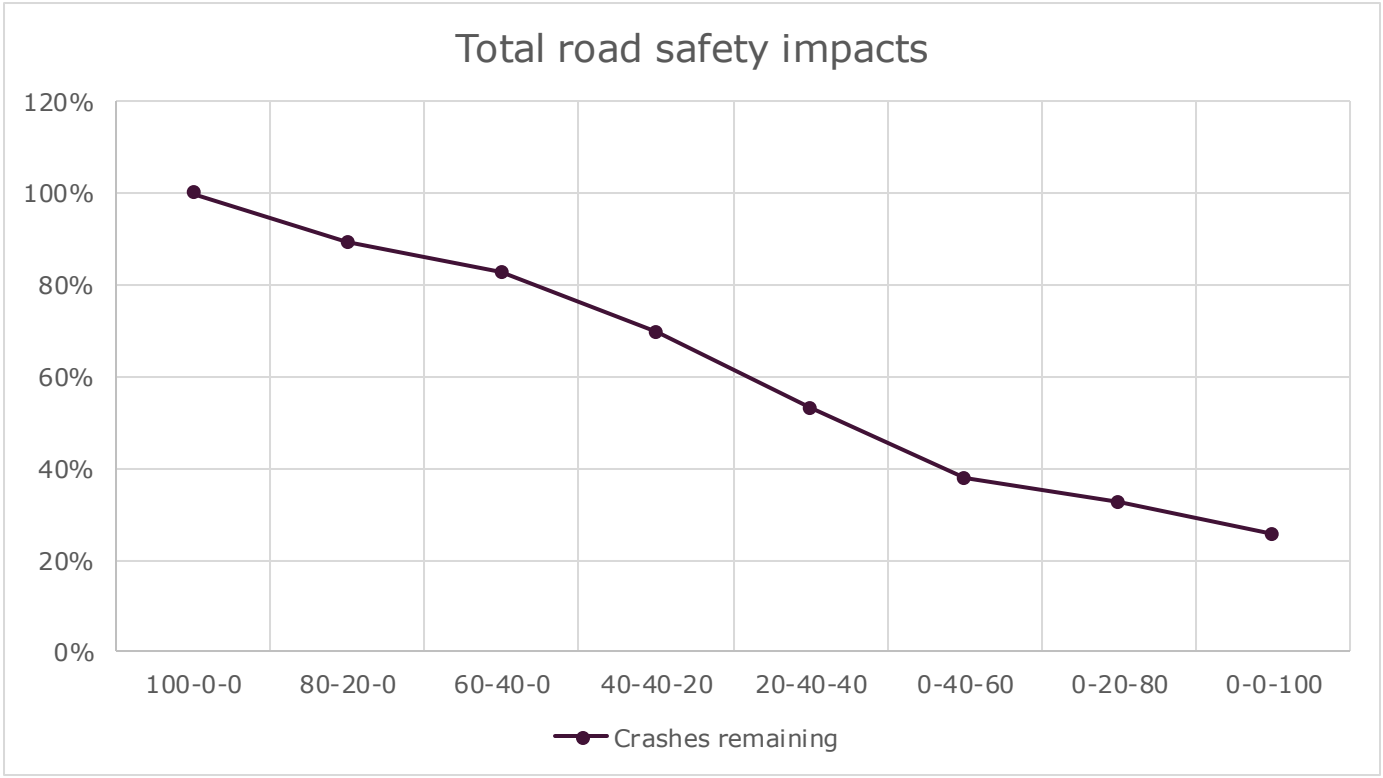
Quantified impacts (baseline)







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Knut J. L. Hartveit, TOI

Conducting a cost-benefit analysis

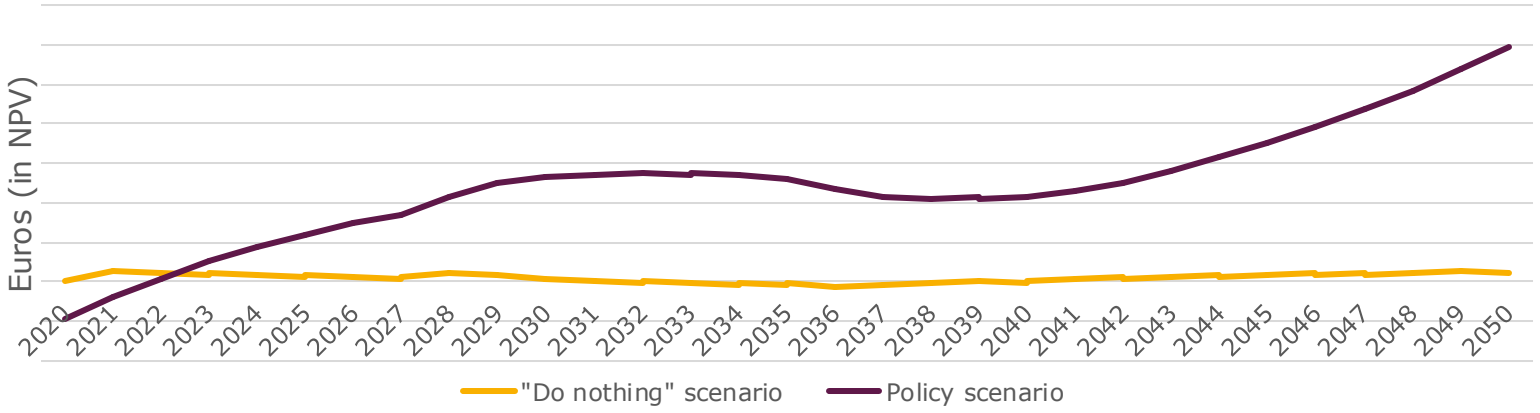
Based on Hartveit & Veisten, 2022

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

Concept of CBA

- Economic appraisal of different policy interventions
  - ➢ *How does a policy implementation scenario compare to a reference ("do nothing") scenario?*

- $NPV = -Investment + cash\ flow$ (effects over the time period)



Equivalently:
NPV = *-costs of intervention* (investment + maintenance & management) *+benefits* (monetised positive & negative impacts of intervention)

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CBA module within PST

Input for CBA

PST inputs/outputs

- x km driven
- x sec delay per km
- x crashes per mill. km
- x g emission per km
- Modal split
- Specific input for freight transport (and automated shuttles / ride sharing)
- Etc.

Extra CBA input

- Discount rate
- Project lifetime
- Costs of implementing policy (for policy entity)
- Etc.

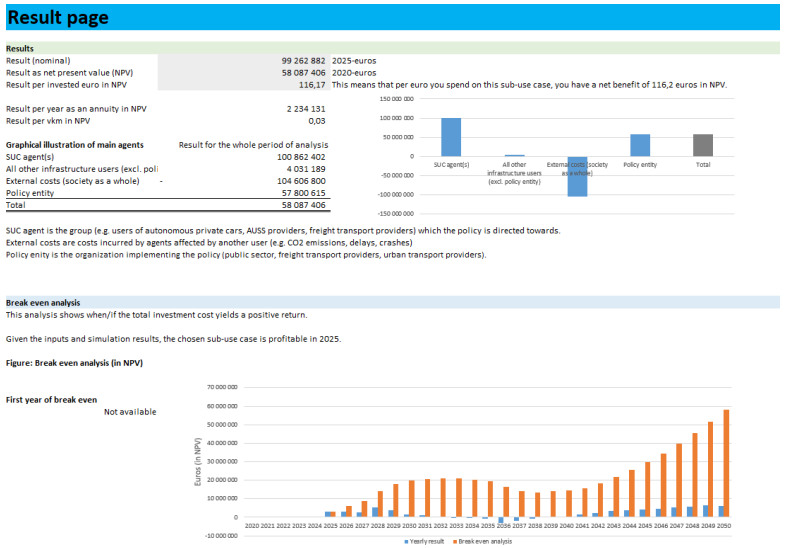
CBA functionalities

Valuations

- Value of travel time change
- Average value of crash risk change
- Value of emission change
- Vehicle operating and ownership
- Etc.

CBA – estimations

- Change in consumer & producer surpluses
- Change in monetized external effects
- Change in costs/income for policy entity
- Etc.



Result page

Results

Result (nominal)	99 262 882	2025-euros
Result as net present value (NPV)	58 087 406	2020-euros
Result per invested euro in NPV	116,17	This means that per euro you spend on this sub-use case, you have a net benefit of 116,2 euros in NPV.
Result per year as an annuity in NPV	2 234 131	
Result per vkm in NPV	0,03	

Graphical illustration of main agents

	Result for the whole period of analysis
SUC agent(s)	100 862 402
All other infrastructure users (excl. poli	4 031 189
External costs (society as a whole) -	104 606 800
Policy entity	57 800 615
Total	58 087 406

SUC agent is the group (e.g. users of autonomous private cars, AUSS providers, freight transport providers) which the policy is directed towards.
External costs are costs incurred by agents affected by another user (e.g. CO2 emissions, delays, crashes)
Policy enity is the organization implementing the policy (public sector, freight transport providers, urban transport providers).

Break even analysis

This analysis shows when/if the total investment cost yields a positive return.

Given the inputs and simulation results, the chosen sub-use case is profitable in 2025.

Figure: Break even analysis (in NPV)

First year of break even
Not available

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Main CBA categories and agents

Main CBA categories	Sub-categories of the CBA	Agents (modes) of impacts 
Monetised impacts for infrastructure users ($\Delta CS + \Delta PS$)	Consumer surplus changes for transport consumers	Passenger car users (manual & automated) Active transport users (cycle & walk) Public transport users (rail & bus) Users of automated shuttle bus (& automated ride-sharing cars)
	Producer surplus changes for transport service providers	Public transport providers (rail & bus) Automated shuttle bus (& automated ride-sharing car) providers Freight transport providers (manual & automated)
Monetised external impacts (ΔM)	Attributed monetised external effects (emissions, crashes, congestion) to transport modes	All transport modes «produce» some external effects
Monetised effects for policy entity (ΔPE)	Income (parking space, fees) Cost of implementation	Policy entity (public or private)

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Dedicated lanes, motorway only

- Default values of the PST variables
- 500.000 inhabitants
- €1 million in start-up costs and €10,000 in running costs (set arbitrarily, equals €557,377 and €5,574 with GDP/capita of €17,000)
- Project period: 2025-2050

Impact (for all agents)	Monetised impacts, €/year (in NPV)	Monetised impacts, € (in NPV)/vkm
Travel time & internal delay impact	-26,038,269	-0.034
Vehicle operating & ownership costs	19,630,518	0.025
Parking space (& fares, fees)	-2,876,609	-0.004
Internal crash risk impact	92,925	0.000
External crash risk impact	78,534	0.000
External delay impact	2,357,083	0.003
Emissions, NO_X & PM_{10}	750,398	0.001
Emissions, CO_2	5,133,985	0.007
Policy implementation	-43,844	-0.000
Overall result, NPV, EUR2020/year	**-915,278**	**-0.001**

Agent	Monetised impacts, €/year (in NPV)	Monetised impacts, € (in NPV)/vkm
Active transport users	49,647	0.001
Passenger cars, autonomous – user	-6,273,495	-0.030
Passenger cars, manual – user	-11,027,990	-0.026
Public transport – user	-	-
Public transport – provider	2,015,699	0.106
AUSS + ride-sharing users	-	-
AUSS + ride-sharing providers	-	-
SUC freight providers	-	-
Non-SUC freight providers	7,483,519	0.093
External costs	8,320,001	0.011
Policy entity	-1,482,659	-0.002
Overall result, NPV, EUR2020/year	**-915,278**	**-0.001**

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For more information:
www.levitate-project.eu

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