Feasible paths of interventions

Deliverable D4.3 – WP4 – PU

Feasible paths of interventions

Work package 4, Deliverable D4.3

Please refer to this report as follows:
Zach, M., Sawas, M., Boghani, H.C., de Zwart, R. (2019). Feasible paths of interventions. Deliverable D4.3 of the H2020 project LEVITATE.

Project details:	
Project start date: **Duration:** **Project name:**	01/12/2018 36 months LEVITATE – Societal Level Impacts of Connected and Automated Vehicles
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	The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824361.

Deliverable details:	
Version: **Dissemination level:** **Due date:** **Submission date:**	Final PU (Public) 31/01/2020 31/01/2020

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Revision history

Date	Version	Reviewer	Description
09/01/2020	Draft 1	Don Guikink (Guick, External Reviewer) Mohammed Quddus (Loughborough University	Main Review
30/01/2020	Final draft	Don Guikink (Guick, External Reviewer)	Quick Checks
31/01/2020	Final report	Camellia Hayes (Loughborough University, English language reviewer)	Sanity check before submitting
31/01/2020	Final deliverable	Pete Thomas – Loughborough University ➔ EC	

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Executive Summary

The main goal of this deliverable (Feasible paths of interventions) is to provide preliminary answers to one of the central questions of the LEVITATE project: Given a certain vision, a set of quantified policy goals for a city or a region, how can this be connected to recommended policy interventions, supporting to achieve that vision?

The policy support tool (PST) developed in LEVITATE will be the main project output, linking policy interventions to the final impacts of Connected and Automated Transport Systems (CATS) and corresponding indicators. This link should work in both directions:

1. Forecasting: Predicting the impacts and the development of indicators for certain scenarios and bundles of policy interventions.
2. Backcasting: Starting from a given vision of the future, defined by vision characteristics and come up with recommended sequence of policy interventions that facilitates a path (development) towards that vision.

This deliverable is setting the basis for the second direction, the backcasting approaches (dynamic and static) in LEVITATE: The results are relevant to integrate the backcasting process into the final version of the PST (dynamic backcasting), but also – in the form of case studies – for further city specific evaluation in WP 5-7 (static backcasting).

Recently, backcasting approaches have been applied in several domains, as discussed in a focussed survey of relevant literature, using various qualitative and quantitative methods. Of particular relevance for LEVITATE is the application of backcasting in the domain of automated driving. A recently completed research project titled "System Scenarios Automated Driving in Personal Mobility" (SAFIP), gives insight how policy interventions can be selected and fine-tuned in order to reach given targets.

Defining a desirable vision in a quantitative way is the essential starting point for the backcasting process. From that vision the idea is to work backwards, via influencing factors (that are impacting the goals and indicators of the vision), to policy interventions which address these factors and thereby contribute towards the vision. Generating this series of logical links represents the central aim of this deliverable, as it highlights feasible paths of intervention, steering into the desired direction.

Previous work in LEVITATE in several work packages has already provided the basic ingredients for this approach. In particular, methods for defining quantitative visions related to CATS have been proposed in WP4, considering a wider range of indicators across four dimensions (safety, society, environment and economy), impact relationships have been analysed in WP3, and relevant use cases, parameters and policy interventions have been collected in WP 5-7, where following main use cases are considered:

- Use case 1 – Automated urban transport (WP5)
- Use case 2 – Passenger cars (WP6)
- Use case 3 – Freight transport and logistics (WP7)

After summarising the background and related work that sets the context for backcasting in LEVITATE, the actual backcasting process is explained in more detail. Its main inputs are the existing documentation of city strategies which are relevant to mobility and the LEVITATE indicator framework. Based on that, the following main steps are performed by means of a dialogue with city representatives:

1. Define Vision
2. Propose and prioritise Influencing Factors
3. Propose and prioritise Policy Interventions

For defining the vision of a city and possible transformation corridors in a quantitative way, data-driven methods previously applied in WP4 can be used to support the city dialogues. This results in a relatively small set of target indicators, along with target values and a target timescale.

The most challenging part in the backcasting process might be the second step – to determine the most promising influencing factors – as the impact relationships between these and the target indicators can only be estimated qualitatively, at this stage in the project. Therefore, it will be important to verify the assumed relationships afterwards by means of quantitative methods in WP 5 - 7.

Finally, promising policy interventions are discussed and prioritised with the cities, derived from the selected influencing factors. These policy interventions in principle are taken from the candidates that have already been analysed in the early phase of LEVITATE, but are adapted to specific city requirements and strategies.

The core part of this deliverable presents the detailed results of the backcasting city dialogues for three cities (or regions, respectively)

1. City of Vienna
2. Greater Manchester
3. City of Amsterdam

This will be the base for developing case studies further in LEVITATE. The results of these dialogues show a high degree of congruence (for example, regarding environmental goals), but also exhibit different prioritisation of key targets and influencing factors. One striking difference that was observed is that for the Greater Manchester (GM) area, the economic goals (e.g. increase in employment) and related factors (e.g. housing and road capacities between cities) are seen as a high-priority agenda and is driving force for the activities in GM but not for Vienna and Amsterdam.

The qualitative results presented and discussed in this deliverable can be considered as the first step in describing feasible paths of interventions for cities related to CATS. They will be used for further investigations in task T4.4, where use cases and policy interventions will be combined and, their timewise implementation will be analysed further. Task T4.4 will also provide a brief description of modelling and simulation techniques that will be applied for detailed verification within WP5-7.

1 Introduction

1.1 LEVITATE

Societal Level Impacts of Connected and Automated Vehicles (LEVITATE) is a European Commission supported Horizon 2020 project with the objective to prepare a new impact assessment framework to enable policymakers to manage the introduction of connected and automated transport systems, maximise the benefits and utilise the technologies to achieve societal objectives.

Specifically, LEVITATE has four key objectives:

1. To incorporate the methods within a new web-based policy support tool to enable city and other authorities to forecast impacts of connected and automated transport systems (CATS) on urban areas. The methods developed within LEVITATE will be available within a toolbox allowing the impact of measures to be assessed individually. A Decision Support System will enable users to apply backcasting methods to identify the sequences of CATS measures that will result in their desired policy objectives.
2. To develop a range of forecasting and backcasting scenarios and baseline conditions relating to the deployment of one or more mobility technologies that will be used as the basis of impact assessments and forecasts. These will cover three primary use cases – automated urban shuttle, passenger cars and freight services.
3. To establish a multi-disciplinary methodology to assess the short, medium and long-term impacts of CATS on mobility, safety, environment, society and other impact areas. Several quantitative indicators will be identified for each impact type.
4. To apply the methods and forecast the impact of CATS over the short, medium and long-term for a range of use cases, operational design domains and environments and an extensive range of mobility, environmental, safety, economic and societal indicators. A series of case studies will be conducted to validate the methodologies and to demonstrate the system.

1.2 Work package 4 and Deliverable 4.3 within LEVITATE

The objective of work package 4 is to develop target scenarios (visions) and feasible paths to reach them with interventions concerning automated vehicles, contributing mainly to the second LEVITATE objective. The main steps are:

- Research of national/European policy goals in the impact dimensions
- Definition and description of goals and visions1 of cities and other stakeholders for short, medium and long-term.
- Applying the resulting impacts from WP3 and data available from the cities to define targets.
- Using backcasting methodologies to define feasible paths to reach the stakeholders' goals with special consideration to automated vehicles.

[1] The term "visions" is used here instead of the term "scenarios" that has been used in the project proposal. Refer also to relevant part of terminology agreed in the project, given in the Appendix (Used Terminology).

- Definition of forecasting scenarios and desired outputs for the consolidation of the different use-cases.

The main goal of Deliverable 4.3 is the close analysis of specific city goals and visions (based on previous work in the project) and the preliminary proposal of feasible paths towards these visions, based on an interactive backcasting dialogue with the stakeholders. This process is performed for three City case studies: Vienna, Greater Manchester and Amsterdam. Further analysis to verify the proposed paths of interventions will be conducted in WP5, 6 and 7, also with respect to sequence and timing of the policy interventions.

1.3 Organisation of the deliverable

This deliverable is organised as follows:

Chapter 2 briefly describes related work and approaches that can be considered as basis for further investigations documented in this deliverable, both within LEVITATE – work performed so far – and from a focused literature survey. This starts with analysing possible applications of backcasting approaches, specifically in the domains relevant for LEVITATE. The building blocks of the backcasting process that will be used in this deliverable are discussed in the following subsections:

- Defining feasible visions (and corresponding indicators)
- Influencing factors (specific for CATS) and impact relationships connecting them to the vision
- Policy Interventions that might be promising in terms of supporting the paths to the vision

Based on that, Chapter 3 defines and documents the actual process that has been selected to elaborate on the backcasting in LEVITATE: The proposed steps are explained, conveying the big picture. In the following, each of these steps is discussed in more detail, and the used methods are presented:

- Describe a simplified vision based on several indicators
- Describe a feasible transformation corridor
- Identify & prioritise CATS influencing factors
- Consolidation of "scenarios"
- Identify feasible policy interventions / packages

The chapter closes with documenting the general structure of the City dialogues that represent the main activity documented in this deliverable.

In chapters 4 – 6, each of the three backcasting case studies is described – for the three Cities (regions) Vienna, Greater Manchester and Amsterdam. The multi-step backcasting was followed in this sequence: 1) the indicators and targets most relevant for LEVITATE were extracted from city strategies (main inputs), 2) identifying the most relevant influencing factors and 3) proposing relevant policy interventions.

In chapter 7, a conclusion on the three case studies, with common findings and identified discrepancies, is given and the further processing of these preliminary results in LEVITATE is outlined.

2 Background and related work

The purpose of this chapter is to collect relevant input from the literature search and summarise previous work in LEVITATE, as basic input for the backcasting process and for the specification of policy interventions that can be used in LEVITATE.

2.1 Backcasting approaches

The term "Backcasting" was coined by (Robinson, 1990) and is a method to define future scenarios and to investigate their effects. Backcasting means defining future goals without current restrictions in order to be able to answer the following questions: "What shall we do today to get there, and what measures may lead into blind alleys and should be avoided?" (Bibri, 2018). The key assumptions of Robinson's backcasting approach are oriented to the goal, policy, design and system.

A paper by Höjer (2000) demonstrates four backcasting steps as follows:

1. Setting of a few long-term targets
2. Evaluation of each target against the current situation, prevailing trends, and expected developments
3. Generation of images of the future that fulfill the targets
4. Analysis of images of the future in terms of feasibility, potential, and path toward images of the future (Akerman, 2006)

The applications of bacasting in the areas of CATs is particularly relevant to LEVITATE. The research project tilted Systems Scenarios Automated Driving in Passenger Mobility (SAFIP) presented three different scenarios and used a backcasting method. The future goals and indicators relevant to the project relate on the mission 2030 strategy (Austrian "BMVIT"). Using the developed scenarios with the help of the MARS (Metropolitan Activity Relocation Simulator) model, the traffic-relevant impact spectra (for example traffic, environmental effects, travel time, number of roads, modal split) could be estimated. This model is suitable for the consideration of long-time horizons and complex correlations (TU, 2019).

The three scenarios developed in the SAFIP project for the diverse future of automated driving in Austria are:

1) Market-driven AV euphoria - focus on competitiveness and the economy
2) Policy-driven AV control - focus on environmental sustainability and social inclusion
3) Individualised mobility and slow AV development - focus on competitiveness and the economy

Staricco (2019) demonstrates three visions for the Italian city of Turin. These visions are referred to as fully autonomous vehicles (SAE Level 5), i.e. vehicles that can travel on public roads regardless of the origin and destination of the journey or intervening road. Their research is intended as a vision exercise and is considered the first step in the development of a backcasting process. It shows how the different forms of AV traffic regulation and parking may impact the quality of life within the city. Automated driving could drastically reduce the amount of road space required for traffic and parking the vehicle as it could reduce the distance between vehicles being picked up / dropped door-to-door to reach a parking space. Roadside parking could be removed and transferred to parking garages. These facilities could be located outside the city, where land is cheaper, freeing up space in the denser parts. This is based on the assumptions that AVs are like elevators, not privately owned. The assumption that AV's are completely shared may be exaggerated. Now most people own a car, with the electrification more and more people start to lease a car, but it is still a big step towards sharing a car. Socio-economic research is still lacking convincing arguments that this will happen when vehicles are automated.

An article by Gonzáleza (2019) is based on the think-tank model and a backcasting approach that is path-oriented, with focus on the development of policy interventions. "Planning for long term development (i.e. more than ten years) such as the implementation of AVs, requires strategic planning or visioning studies (i.e. forecasting and backcasting) based on the consideration of future scenarios." As mentioned here, a large uptake of urban AV is a long-term action that is difficult to quantify in a backcasting technique, the uncertainties simply are too big to be significantly correct. Qualitative pathways may be more promising and useful at this stage. Therefore, their approach is divided into three steps - these are as follows:

1. Step 1: based on literature research, defining core values[2] and visions of the city's future without traffic.
2. Step 2: analysing potential effects of AV introduction on opportunities and threats for each core value.
3. Step 3: identification of the key city planning and political goals to achieve the desired driverless city.

The most important part for the backcasting approach in LEVITATE is the linking of these steps to the (already specified) visions of cities and regions – as these visions represent the starting points for backcasting.

Investigating related work in which quantitative backcasting approaches have been applied, several methodologies can be found to envision a desirable future. For example, in one approach, a discrete choice experiment was conducted to elicit future ecosystem services demand (Brunner, 2016).

Backcasting related methodologies have been developed quite some time ago. The following paragraphs give a description and examples of some backcasting models like normative models, system dynamic and scenario technology.

Normative models were used in the Sustainable Economic Development Study (Verbruggen, 1996), in which a special retroactive model was developed in order to optimise the added value of the Dutch economic sectors so that the environmental goals are achieved. Normative models describe how a system of certain (target) sentences can be achieved in order to find the "optimal" situation.

The most well-known example of system dynamic modeling is the modeling work as described in (Donella H-Meadows, 1972). System dynamic models are based on a theory

[2] examples of the core values for a city of tomorrow are environmentally sustainable (land use, green public spaces, etc.), safe (Citizen's safety) and accessible & with a sustainable mobility (accessibility, connectivity, public transportation and active mobility).

of the causal structure and its relationship to dynamic behavior. These models enable feedback between the system components. In particular, the "open" structure and the dynamic character of the models have several advantages in studies on retroactive effects.

A study by the "Baden-Württemberg Stiftung" (Ruth Blanck, 2017) has the aim of showing the sustainable development paths of mobility, traffic and the Baden-Württemberg mobility economy by 2050. The study used the scenario technology as a methodical approach. Discussions with stakeholders on the one hand selected the relevant key factors for passenger transport, and on the other hand the framework conditions, measures and political instruments were defined. The expert assessments are essential for the development of a successful mobility strategy and can take complex relationships into account. "With the support of scenario technology, hypothetical qualitative and quantitative developments in the form of individual sub-developments can be analysed and described and then put together to form a future state" (Ruth Blanck, 2017).

In an article for presenting the backcasting study the Environmentally Friendly Transport (EST) in the Netherlands, the authors describe the backcasting approach to policy making and its application to this case study (Wee, 2004). "[…] the EST project is based on a 'backcasting' approach, in contrast to traditional sustainable transport studies, that focuses on doing what is necessary to achieve a desired future rather than avoiding an unwanted future."

"The backcasting analysis is based on the business-as-usual scenario to describe the expected developments between 1990-2030, and selected measures to calculate the necessary effects of measures which meet the targets in a 'trial-and-error' scenario-building process, using expert judgement, and existing literature and model simulations. Brainstorm sessions were held with Dutch experts, and expert judgements from the experts involved in the other EST country studies and OECD were also included." As part of the EST project, a system dynamics model was developed to analyse the specific effects of EST on Germany.

2.2 Defining feasible visions

As discussed in the previous section, defining a desirable vision in a quantitative way – based on a certain set of targets for a specific point in time and underlying indicators – is the essential starting point for the backcasting process.

The set of objectives for a specific year in the future is referred to as "Vision" in this Deliverable. The precise definition as agreed in the LEVITATE Terminology Guide (refer also to Appendix) is: "Description of a future situation defined by a bundle of vision characteristics and dedicated at a specific point in time." It should be noted that the term "Vision" is used (as already in previous deliverables of WP4) instead of the term "desired future scenario" that was used in the project proposal, in order to avoid any confusions with simulation scenarios in LEVITATE context.

In the context of the LEVITATE project, the definition of feasible visions has been extended beyond the simple approach of specifying only certain targets, by also considering a wider range of indicators across four dimensions (safety, society, environment and economy). An overview of proposed goals and indicators is given in

Table 1. The list is organised along the four chosen dimensions, which provide a high-level structure (even if certain goals might be assigned to more than one dimension).

Table 1: Consolidated proposed goals and indicators for LEVITATE

Dimension	**Policy Goal**	**Indicator**
Safety	Protection of Human Life	Number of injured per million inhabitants (per year)
		Number of fatalities per million inhabitants (per year)
	Perceived Safety	Standardised survey: subjective rating of (overall) safety
	Cyber Security	Number of successful attacks per million trips completed
		Number of vulnerabilities found (fixed) (per year)
Society	Reachability	Average travel time per day (dispersion; goal: equal distribution)
		Number of opportunities per 30 minutes per mode of transport
	Use of Public Space	Lane space per person
		Pedestrian/cycling space per person
	Inclusion	Distance to nearest publicly accessible transport stop (including MaaS)
		Affordability/discounts
		Barrier free accessibility
		Quality of access restrictions/scoring
	Satisfaction	Satisfaction with active transport infrastructure in neighbourhood (walking and/or cycling)
		Satisfaction public transport in neighbourhood
Environment	Low Noise Levels	Standardised survey: subjective rating of main sources of disturbing noise
	Clean Air	Emissions directly measurable: SO_2, PM2,5, PM10, NO_2, NO, NO_x, CO, O_3

	Efficient Settlement Structures	Building volume per square kilometre (total and per built-up area)
		Population density (Eurostat)
	Sustainable Behaviour	Rate of energy consumption per person (total)
		Rate of energy consumption per person (transport related)
Economy	Prosperity	Taxable income in relation to purchasing power
	Fair Distribution	GINI index

This was followed by analysing correlations and possible conflicts between goals (Zach, Rudloff, & Sawas, 2019). The statistical analysis was based on open data (WDI, Eurostat) from years 1960 – 2018, mainly for Europe but also including other regions. Further, a Stakeholder Reference Group workshop has been performed in order to collect input on important indicators, goals and possible conflicts between them.

By exploiting these correlations and dependencies between indicators, a vision could be defined in a more comprehensive way, including forecasts of all other indicators considered in LEVITATE context, even if they have not been used to define a quantitative target. The selected approach also allowed to analyse and compare indicators and geo-entities (countries, regions or cities), by mapping them to the same abstract space (using principal component analysis (PCA) and collaborative filtering techniques):

- Similarities between indicators (i.e. strong correlation, but also anti-correlation) could be clearly identified.
- Clustering of geo-entities was found to be quite strong – geo-entities of same region (and for similar times) are “close to each other” in the abstract embedding space.

Two slightly different methodologies have been applied to elaborate and visualise a vision (on the examples of Vienna – with specific targets for 2030 and 2050 – and Greater Manchester). In both approaches a region for such a desirable region can be formally defined in the abstract space, and a path towards this vision, i.e. a “direction”. This direction (in abstract space) can be mapped back to a *change* in LEVITATE indicator values – i.e. indicating how all these indicators should change over time in order to reach the desired vision. In principle this information can then be connected to influencing factors, and finally to a sequence of policy interventions. These relationships and related preliminary LEVITATE project results will be discussed in the following sections, they also provide the base for the backcasting approach described in chapter 3.

Table 2 summarises the mapping of LEVITATE goals and indicators to key quantitative targets that can be used to identify a vision in LEVITATE context, for the two examples of Vienna and Greater Manchester, after analysing corresponding material on the city strategies. Note that for this mapping, only the most obvious indicators (out of those listed in Table 1) have been considered – which does not mean that other indicators are irrelevant.

Defining a quantified vision by a (prioritised) set of goals and targets in a formal way as discussed here seems to be straightforward. It is clear, however, that in reality this might be a quite lengthy and complex process. With the approaches followed in Zach, Rudloff & Sawas (2019), it has been demonstrated that it is possible to identify "regions" in indicator space that are close to such an idealised vision and consistent in terms of correlations between various target indicators – despite the limitations which are due to the high sparsity in the available data set.

Table 2: Mapping of LEVITATE goals and indicators to quantitative targets defining a vision

<table>
<tr><th>Dimension</th><th>Policy Goal</th><th>Indicator</th><th>Target Vienna</th><th>Target Greater Manchester</th></tr>
<tr><td rowspan="2">Safety</td><td rowspan="2">Protection of Human Life</td><td>Number of injured per million inhabitants (per year)</td><td>(decline)</td><td>as close as possible to zero (2040)</td></tr>
<tr><td>Number of fatalities per million inhabitants (per year)</td><td>(decline)</td><td>as close as possible to zero (2040)</td></tr>
<tr><td rowspan="2">Society</td><td rowspan="2">Use of public space</td><td>Lane space per person</td><td></td><td></td></tr>
<tr><td>Pedestrian/cycling space per person</td><td>(increase)</td><td></td></tr>
<tr><td rowspan="3">Environment</td><td>Clean air</td><td>Emissions directly measurable: SO2, PM2,5, PM10, NO2, NO, NOx, CO, O3</td><td>Greenhouse gas emissions -50% (2030), -85% (2050)</td><td>Robust low carbon pathway to 2050 at which Greater Manchester can become carbon neutral.</td></tr>
<tr><td rowspan="2">Sustain-able behaviour</td><td>Rate of energy consumption per person (total)</td><td>-30% (2030), -50% (2050)</td><td></td></tr>
<tr><td>Rate of energy consumption per person (transport related)</td><td>-40% (2030), -70% (2050)</td><td>Sustainable modes (walking, cycling or public transport) will increase from 39% in 2019 to 50% in 2040</td></tr>
<tr><td rowspan="2">Economy</td><td>Prosperity</td><td>Taxable income in relation to purchasing power</td><td>(increase)</td><td>(economic goals identified, but no clear mapping possible)</td></tr>
<tr><td>Fair distribution</td><td>GINI index</td><td>(decline)</td><td></td></tr>
</table>

2.3 Influencing factors and impact relationships

WP3 of LEVITATE (and in particular deliverable D3.1 (Elvik, 2019)) analyses how potential effects of connected and automated vehicles can be categorised and quantified. Impacts can be considered to reside on different levels, from direct to systemic and finally wider impacts (where systemic impacts are caused by direct impacts) and wider impacts are caused by systemic impacts. In addition, there are further (expected) causal relationships also between impacts belonging to the same level. Such a causal diagram for primary impacts considered in LEVITATE is shown in Figure 1. Comparing this classification of expected impacts to the policy goals listed in Table 1 and Table 2, it can be observed that the policy goals correspond primarily to the wider impacts shown at the bottom part of the figure.

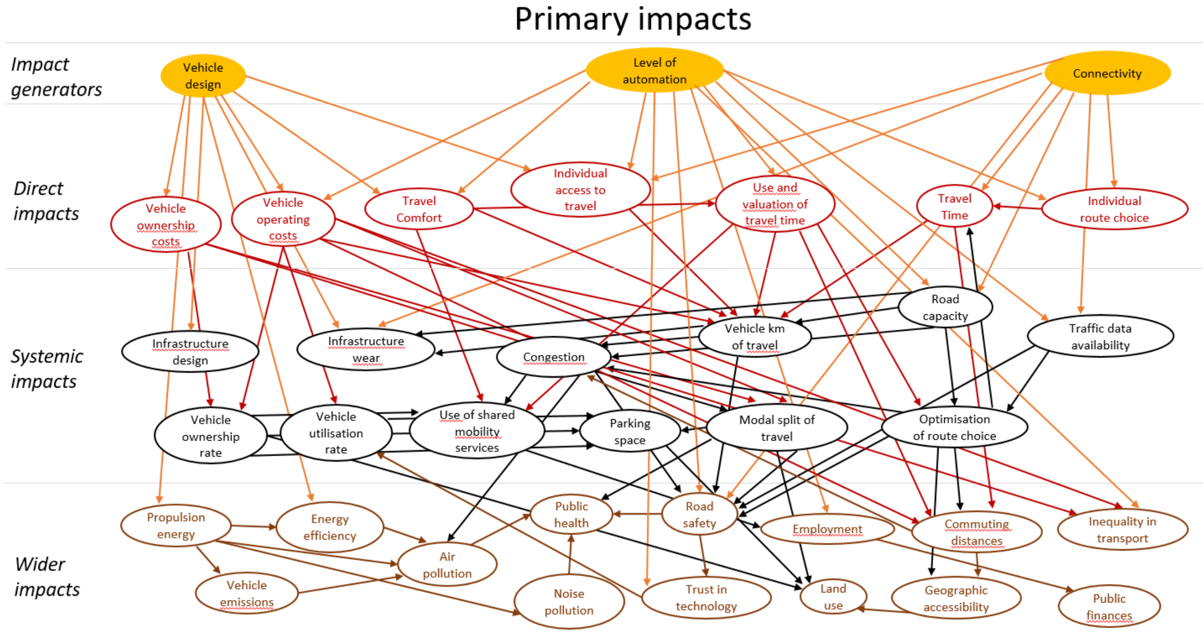

Figure 1 Causal diagram for primary impacts of vehicle automation

In a simplified first consideration, impacts are quantified as dose-response curves using the market penetration of automation technology as the dose and the size of an impact as the response. Such dose-response curves have been estimated on the basis of studies identified in a literature review. Furthermore, it is discussed how the dose-response curves can be used to predict impacts of connected and automated vehicles.

The market penetration of automation technology can be considered as one of the most relevant parameters that are used to describe a concrete implementation of CATS. These parameters are also referred to as influencing factors within this deliverable. One might think of many additional influencing factors, most of them specific to certain CATS technologies, applications or use cases. Examples are the shuttle fleet size or passenger number for last-mile shuttles in a city, the level of shared mobility (e.g. rate of shared drives), or the share of pedestrians / cyclists (for travels with specified characteristics).

Conceptually, if influencing factors are compared to the indicators and targets used to identify a vision, the main difference is the direction of causality: In order to improve the value of a certain indicator, several influencing factors (or more precisely – changes in these factors) might contribute to achieve that. As an example, an increased SAE Level 5 market penetration (under certain preconditions) is expected to contribute to a reduction in number of fatalities.

In general, influencing factors considered in this deliverable are not regarded as goals themselves, they are just instruments contributing towards a (higher) goal. For example, a level 5 market penetration rate is not considered as a goal by itself. However, it is clear that in reality, such a distinction between influencing factors and goals (or indicators) that define a vision, is not always possible in a strict way as certain overlaps exist between them. For example, a higher share of active transport modes is seen as important goal in many city strategies, but also contributes towards to the higher goals of lower emissions and increased health of citizens.

2.4 Policy interventions

Policy interventions are measures employed by the city to shape the framework condition and to actively steer the development of connected and automated transport systems. This section shows what is already known about expected impacts of AVs in urban environments and give a few examples of policy interventions in the literature.

The MARS simulations which were carried out in the SAFIP project (see Chapter 2.1), show that automated mobility with suitable transport measures - "including, for example, mobility pricing, parking management etc." has the potential to lead to a significant decrease in the volume of individual traffic. This results in positive traffic shift effects towards on public transport, pedestrian traffic and bicycle traffic. "Without linking the AV with post-fossil propulsion systems, increases in pollutant emissions are also expected. In contrast, the simulation results of increased public transport-based AV show positive effects for supporting more sustainable mobility" (TU, 2019).

In order to achieve the targets of the mission 2030 strategy in the SAFIP project, measures or combinations of interventions for scenarios 1 (market driven AV euphoria), 2 (policy driven AV control) and 3 (individualised mobility & slow AV development), are necessary. These interventions are necessary to avoid AV's taking a too large share. It is e.g. assumed that public transport will be reduced when AV's are penetrating urban environments in a too successful way. It depends on the question why walking to a bus stop when you can call for a vehicle?

These policy interventions are:
1. Introduction of distance-based road pricing
2. Increase the frequency of public transport and
3. Redistribution of street space in favor of active mobility.

The article "Automated vehicles and the city of tomorrow: A backcasting approach" by Gonzáleza claimed, that the large-scale implementation of private AVs could lead to an increase in circulating vehicles, aggravating congestion in large cities. Therefore, two main goals in their article were proposed:

- Promotion of a high quality multimodal public transport system.
- Promotion of shared mobility of privately-owned vehicles.

Through the implementation of AVs, public transport could be negatively impacted. Arguments are that the investment needed to develop new infrastructures could lead to a reduction in public transport finance. The attractiveness of public transport can be affected by well-being and speed.

Other authors argue that the use of public transport in certain political contexts could be exacerbated as it largely depends on decisions affecting the market share of shared AVs (SAVs).

Policies to achieve the city targets should focus on preventing the use of private AVs and prioritising the development of SAVs through market incentives to ensure that the SAVs complement each other with public transport services. In terms of active forms of mobility, greater use of AVs could potentially reduce walking and cycling for some or all journeys. To promote active mobility, the policy measures proposed in the article are limiting motorised access to specific areas and inactive mobility.

Another paper by (ASTRA, 2016) analyses the future of AVs in Switzerland and which new mobility offers will be developed. This concerns in particular three interventions:

- Flexibility / individualisation of public transport: in the near future an App will make it possible to drive in certain areas without a specific timetable and without a predefined network of routes. Therefore, users can determine the time and route of the ordered trip. These new technologies should enable the "first and last mile".
- Car sharing and car-pooling: with regard to sharing offers using driverless vehicles, users will not drive the car themselves and will be exempt from picking up and returning of the vehicle to its starting point. They have the option to use or share the vehicle alone. Sharing mobility offer an alternative to poorly utilised regional trains and are complementary to public transport.
- Mobility as a service (MaaS): each user has a personal mobility assistant. The users indicate the desired destination, the desired time of arrival and then select an offer, that suit them best. Whereby the mobility provider suggests the optimal door-to-door route chain.

The Smart City Framework Strategy (Wien S. , 2015) represent policy measures, which were taken to counter energy consumption in the transport sector, anchoring it at regional level through urban-rural mobility partnerships and transnational mobility management. These measures are necessary in order to use the idea of multimodality and the establishment of hubs (mobility hubs) in the future. An example of this is e-mobility on demand. In the future, public transport will be sensibly supplemented by electromobility, e-car sharing and will be used as a measure. Until now, electric cars have been used to replace fossil-fueled journeys in commercial traffic and to guarantee mobility when walking, cycling and public transport are not possible.

Table 3 demonstrates some of the AV-specific interventions linked to diverse target fields like economic, traffic system, settlement structure, traffic safety, etc. Nevertheless, some of these interventions serve multiple targets fields. The AV specific measures that can contribute to the achievement of objectives and can be taken up in the context of the implementation of AV political-planning. These interventions are related on various sources found in the literature.

Table 3: general interventions and AV-specific interventions (TU, 2019)

Target field	**AV-specific interventions**
Economic	• weight-based / weight-based vehicle taxes for AV with conventional drive or a tax on design

Traffic System	• introduce differentiated road charges depending on time, location, occupancy rate, etc. • introduce Mobility as a service (MaaS) • introduce assessments on empty trips of AV vehicles • expand digital infrastructure • implement integrated mobility platform with AV • introduction of distance-based road pricing
Settlement structure	• optimise transfer points with AV • promote last-mile solutions with AV • car-free zones to equalize entry and exit distances to the entry and exit point between the means of transport
Natural resources	• redistribute the parking areas in favor of active mobility. • define AV breakpoints at the beginning
Emission reduction	• introduce differentiated road charges depending on time, location, occupancy rate, etc. • introduce shared mobility • introduce prohibitions or charges for empty trips
Diverse mobility needs	• prioritisation of target groups • promote certain social groups in AV • promote AV offerings in specific rooms
Traffic safety	• adapt speed reduction for all vehicles depending on the complexity of the road situation and environmental conditions (ODD) • Linking with digital infrastructure and networking V2X as well as structural adaptation

For a further, more detailed discussion of CATS specific policy interventions for Vienna, Greater Manchester and Amsterdam refer to Chapter 4 to 6.

2.5 Summary of LEVITATE use cases, applications and interventions

Finally, the results of initial analysis and discussion in LEVITATE WP 5, 6 and 7 regarding the (sub) use cases, applications, technologies and interventions are summarised in this section. These WPs correspond to the three main use cases that are considered in LEVITATE.

- Use case 1 – Automated urban transport (WP5)
- Use case 2 – Passenger cars (WP6)
- Use case 3 – Freight transport and logistics (WP7)

Furthermore, the three categories that have been used for the classification are:

- Interventions: they can be seen as city / government driven policy interventions with the goal of actively regulating the use of CATS.
- Applications: they cover the actual usage of CATS. Compared to interventions, applications are market / business driven.
- Technology: these are (sub) systems for certain CATS functionalities and therefore enable other technologies or applications

The backcasting approach to be developed within LEVITATE will support policy makers by allowing consideration of the potential impacts of policy interventions relevant to each of the key use cases (freight transport, passenger cars and urban transport). Within the use cases on urban transport, passenger cars and freight transport, a set of sub-use cases and interventions will be developed to inform the predicted impacts of CATS.

In the following, a list of sub-use cases is presented that has been agreed in LEVITATE during the first phase of the project. These have also been influenced by the existing literature and recent research projects which were discussed in the last sections. Note that this set of sub-use cases will then be further refined and prioritised in a decision-making process; considering the relevance for CATS, as well as the feasibility of the methods that will be applied to predict the impacts. This will be described in deliverable D4.4.

Table 4 to Table 7 (Roussou, 2019) show the sub-use cases which are seen as general, i.e., relevant for all three use cases and those which are specific for urban transport, passenger cars and freight transport.

Table 4: General sub-use cases that are applicable for all Use Cases.

Use Case	**Description**	**Category**
Geo-fencing based powertrain use	Different powertrains on hybrid vehicles are used according to defined zones (e.g. low-emission zone in the city center)	Application
C-ITS day 1 services	Hazardous location notifications (slow or stationary vehicle, road works warning, emergency brake light, …) Signage applications (in-vehicle signage, in-vehicle speed limits, signal violation / intersection safety, …)	Application
C-ITS day 1.5 services	Charging stations info, vulnerable road user protection, on street parking management, off street parking info, park & ride info, connected & cooperative navigation, traffic info & smart routing	Application
Road use pricing	Prices are applied on certain road (segments) with the goal to incentive load-balancing. Can be dynamic depending on area, traffic load, and time.	Intervention
Centralised traffic management	Routing / navigation of vehicles is managed by a centralised system with access to traffic loads. The goal is to balance the traffic load across the road network.	Intervention
Segregated pathway operations	A policy measure where automated vehicles operate on separate roads/ lanes, for example a dedicated CATS lane or an automated urban transport lane	Intervention

Table 5: Urban transport use cases - Descriptions and categorisations

Use Case	**Description**	**Category**
Point to point shuttle	Automated urban shuttles travelling between fixed stations. Passengers will be able to take any passing shuttle from the fixed stations and choose any other station as a destination.	Application
Anywhere to anywhere shuttle	Automated urban shuttles travelling between different, not fixed locations	Application

Last-mile shuttle	Automated urban shuttles provide convenient first/last mile solutions supporting public transport. They are not competing with main lines of public transport.	Application
Street design implications	Road infrastructure should assist the operation of automated urban transport and be influenced by automated urban transport, e.g. lane size, intersections design	Intervention
Multi-modal integrated payments	Apply an integrated price depending on the use of multiple modes of urban transport (shuttle-to-shuttle, shuttle to underground, etc) Can be dynamic depending on area, traffic load, and time.	Application
e-hailing	Passengers will book rides from anywhere to anywhere with automated vehicles through a smartphone app with a transportation network company	Application
Automated ride sharing	Automated passenger cars will be booked by multiple passengers (using a smartphone app) to travel between convenient points. Passengers' final destinations could be near to each other, but not necessarily the same.	Application

Table 6: Passenger cars use cases - Descriptions and categorisations

Passenger Cars Use Cases	**Description**	**Category**
SAE L2/3/4 automation	Different levels of vehicle automation according to SAE International. The main difference across levels is the degree of human involvement in the driving task.	Technology
SAE L5 automation	Level 5 vehicle automation (and also level 5 penetration rate) poses a significant difference to levels 2,3,4 since level 5 means full automation (all functions under all conditions).	Technology
Highway pilot	A highly intelligent system consisting of assistance and connectivity sub-systems which enable the autonomous driving on the highway	Technology
Autopark	An autonomous car-manoeuvring system that moves the vehicle from a traffic lane into a parking spot to perform parallel, perpendicular or angle parking	Application
(Cooperative) Adaptive Cruise Control	A cruise control system for road vehicles that automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.	Technology
Traffic jam pilot	A currently existing cruise control system that takes over the driving task in traffic jams and slow-moving traffic up to 60 km/h	Application

Table 7: Freight transport use cases - Descriptions and categorisations

Freight Transport Use Cases	**Description**	**Category**
Highway platooning	Trucks dynamically join and leave platoons on highways where vehicles move with shorter headways.	Application

Urban platooning	Vehicles dynamically join and leave platoons in the city. In contrast to highway platooning, the goal is less on saving energy but more on increasing the throughput.	Application
Intelligent access control for infrastructure/bridge	Bridges and other critical infrastructure need to coordinate vehicle platoons accessing them to prevent overloading.	Intervention
Automated urban delivery	Delivery of parcels and goods in urban area is automated. Appropriate infrastructure for handover is required.	Application
Hub-to-hub automated transport	Transfer of goods between two hubs (e.g. production, warehouse, consolidation center) which are mainly connected via highways / motorways.	Application
Automated intermodal transport	Automated freight transport across multiple modes (e.g., truck and train) and handling at transfer sites.	Application
Local freight consolidation	Automated freight consolidation using hubs and terminals with the goal to increase transport efficiency, especially in dense urban areas.	Application
Multi-purpose vehicles	The use of automated MPVs for passenger and freight transportation. An application could be the to use MPVs for passengers during peak hours and freight and delivery during off-peak hours.	Application

Based on the above lists the preliminary policy interventions which have been proposed and prioritised in LEVITATE so far are listed below (note that the full process of this selection will be documented in D4.4) :

Urban transport and shuttles

- Introduce automated shuttles
    1. Point to point shuttles
    2. Anywhere to anywhere shuttles
    3. Last mile shuttles
- Introduce shared or non-shared Mobility as service (MaaS)offers (several models)
- Automated ride sharing

Economic incentives

- Road use pricing
    1. Empty km pricing
    2. Static toll on non-automated vehicles
    3. Static toll on all vehicles
    4. Dynamic toll on non-automated vehicles
    5. Dynamic toll on all vehicles

Access and space allocation

- Reduce long-term parking (>15min)
    1. Replace with public space
    2. Replace with driving lanes
    3. Replace with short-term parking
- Provision of dedicated lanes for AVs on urban highways
- Street design optimised for urban AV shuttles

Freight consolidation (city hubs)

3 Description of LEVITATE backcasting steps

Whereas the previous chapter tried to summarise the background and main inputs for task T4.4, this chapter describes the actual backcasting process in detail.

3.1 Overview on proposed steps

The flow chart in Figure 2 gives an overview on the proposed steps in the process, the used inputs and the expected outputs.

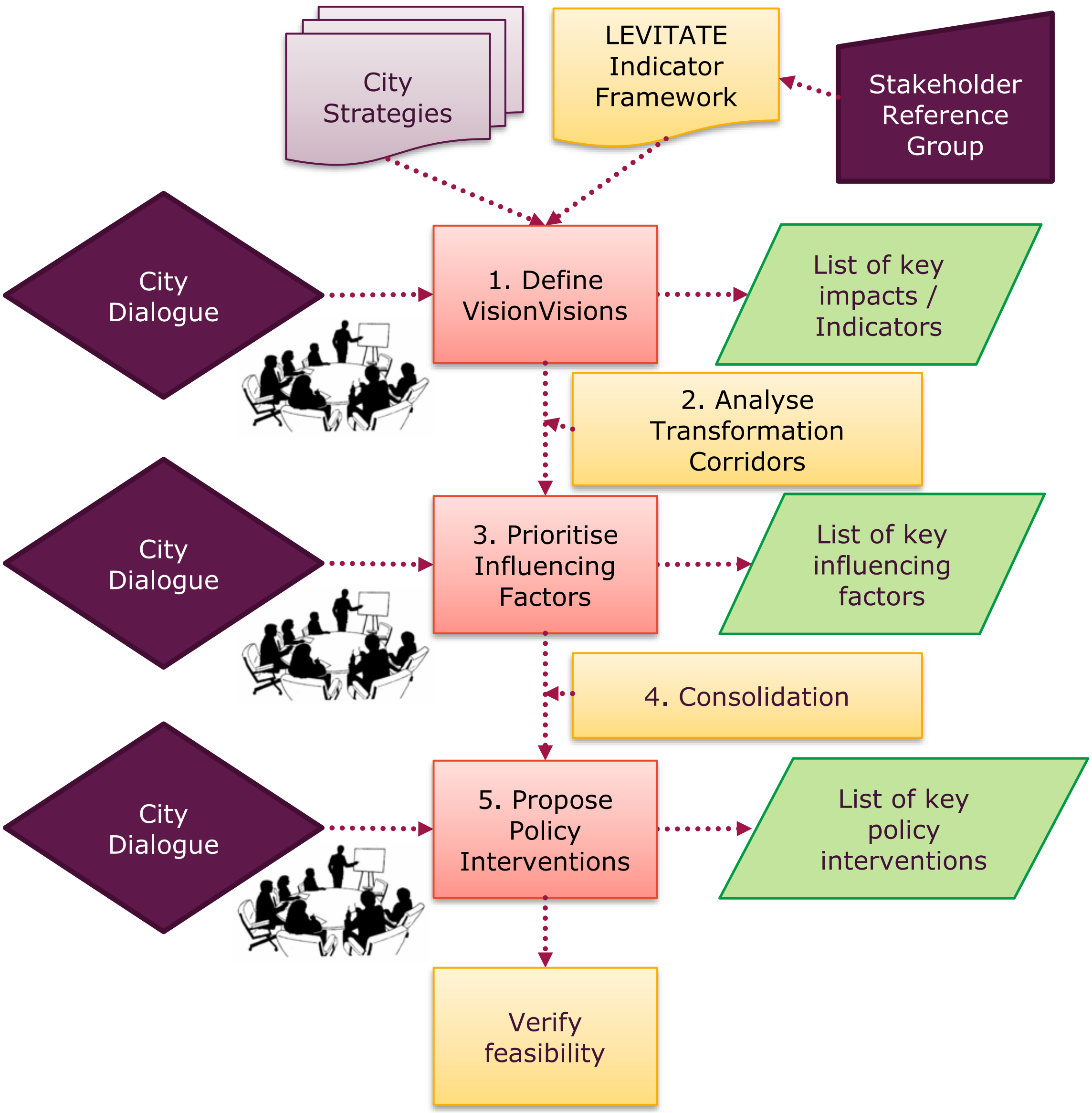

Figure 2: Flow chart for the steps of backcasting process in LEVITATE

In step 1, the city strategies for future mobility are studied and relevant visions are extracted according to the impact indicators identified in LEVITATE. This is carried out through a dialogue with representatives from city authorities. Transformation corridors are analysed using the historical data available and projecting them to the future. (forecasting approaches?) In the next step, influencing factors that have positive or negative impact on impact indicators (i.e. visions) are identified. Again, this is done through dialogues with city authority representatives. Once consolidated, with the help of city authority representative, possible interventions are identified and listed. In the last step covered in this deliverable, the feasibility of interventions to achieve city visions is verified through various modelling techniques for impact assessments. The final step of verification is not performed in this deliverable as it is ongoing work within the project and will be carried out through work in WP 5, 6 and 7. The overall backcasting process mentioned above will produce output shown in the following.

From the perspective of relationship between vision, influencing factors and policy interventions, the following diagram in Figure 3 further illustrates the steps.

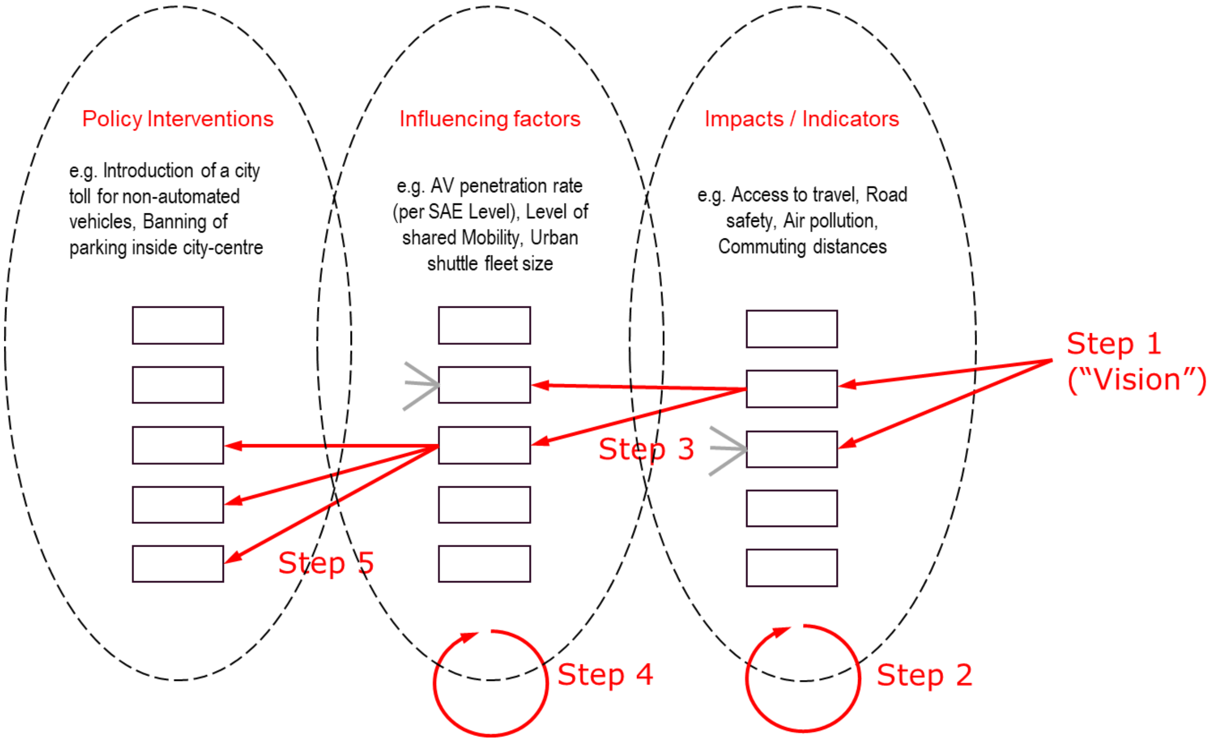

Figure 3: LEVITATE backcasting steps – three pillars view

The main outputs of this process are shown as the three pillars, where the direction of arrows indicates the backwards propagation:

1. A set of (simplified and focused) visions are specified by selecting and prioritising a subset of LEVITATE indicators. For these indicators, specific target values and target dates should be assigned, and historic data up to present time should be available.

2. These visions can be consolidated and cross-checked for consistency, based on previous data modelling work in WP4 Constraints for feasible transformation corridors can be indicated, based on the time-based development in the past and the "direction" (in indicator space) towards the desired vision.
3. Influencing factors are selected and prioritised. They are related to indicators via *expected* impact relationships: For each indicator, one or several factors are derived as indicated by the arrows. Also, the values of these influencing factors might be quantified where possible.
4. Internal consolidation within LEVITATE ensures that the identified influencing factors are consistent with respect to the plans and possibilities in WP5 – WP7, but also with further work in WP3 and WP8.
5. Finally, the most promising policy interventions are selected and prioritised, again working backwards from the desired changes in the influencing factors.

Note that the use cases, applications and interventions as described in section 2.5, which have been selected and discussed in the project so far, cover both the medium and the left pillar (influencing factors and policy interventions). It has turned out during the city dialogues that a strict distinction between these two is not always possible or useful.

3.2 Visions and transformation corridors

The challenge of this first step in the backcasting process is the selection of a few key targets and indicators that have top priority in the City strategy and at the same time have the potential to be addressed by CATS. The resulting simplified and focused "vision" is specified by a very small number of LEVITATE indicators and corresponding quantitative targets ("value X in year Y").

It should be stressed here that such a simplified vision is unsuitable for direct ("brute-force") optimisation approaches. This is because optimisations in on over-simplified model might easily lead to extreme (and unwanted) results, e.g. to ban all traffic completely for reaching the vision goals. To avoid such situations, a more comprehensive set of indicators, covering four dimensions (safety, society, environment and economy) has been considered in LEVITATE from the beginning. When trying to improve a few key indicators now (by means of CATS) this does not ignore the behavior of other indicators, but also considers their further development implicitly, based on previous developments. When performing the city dialogues, it has been emphasised to consider all four dimensions, not only when defining the vision, but also during selection and priorisation of influencing factors and policy interventions. As an example, simply speaking, a policy intervention that would ensure to reach a specific environmental goal, but negatively impact economic and societal target indicators, should be handled with great care.

In the context of the proposed backcasting process, the data driven methodologies applied in deliverable D3.2 (Zach, Rudloff, & Sawas, 2019) and corresponding results are briefly revisited here.

As already explained in section 2.2, each geographic entity at a specific point in time could be mapped to a point within an *abstract* indicator space with reduced number of dimensions (i.e. the number of dimensions is less than the number of indicators considered). This abstract space incorporates the independent real "degrees of freedom" within the space of LEVITATE dimensions and indicators, implicitly considering any correlations that can be found from historic data. In this way, a first rough estimate can be given, how an indicator Y is expected to change if indicator X is changed by certain CATS impacts.

In this space, movements of geographic entities over time can be illustrated. An example for Vienna has been given in Zach, Rudloff, & Sawas (2019), where the average values for each decade, from the 1960s to 2010s, have been used as data points. The 2D space selected for illustration was defined by the first two components after a principal component analysis (PCA) in the abstract embedding space. The obtained results showed sufficient statistical significance to identify a straightforward movement over the decades, which also allows a linear projection over the next 10 – 20 years (assuming that the direction of movement in the abstract space stays the same).

On the other hand, as has also been explained, vision points based on specific targets for some indicators (e.g. Vienna 2030, Vienna 2050) can also be mapped to this space; illustrating not only the gap between *current* state and these visions, but also the gap between linear projection (e.g. for 2030) and the corresponding vision for that point in time. The (multi-dimensional) difference vector of these two points can be considered as an indicator of "what has to be changed" in order to reach the defined targets of the vision. (In the physical analogue of a moving body which should be diverted in order to reach a target point, this vector would correspond to the external force that has to be applied.) A schematic illustration of this gap between projected future and vision is shown in Figure 4, where the evaluation of historical data and key targets for the example of Vienna in Zach, Rudloff, & Sawas (2019) has revealed a very similar behaviour.

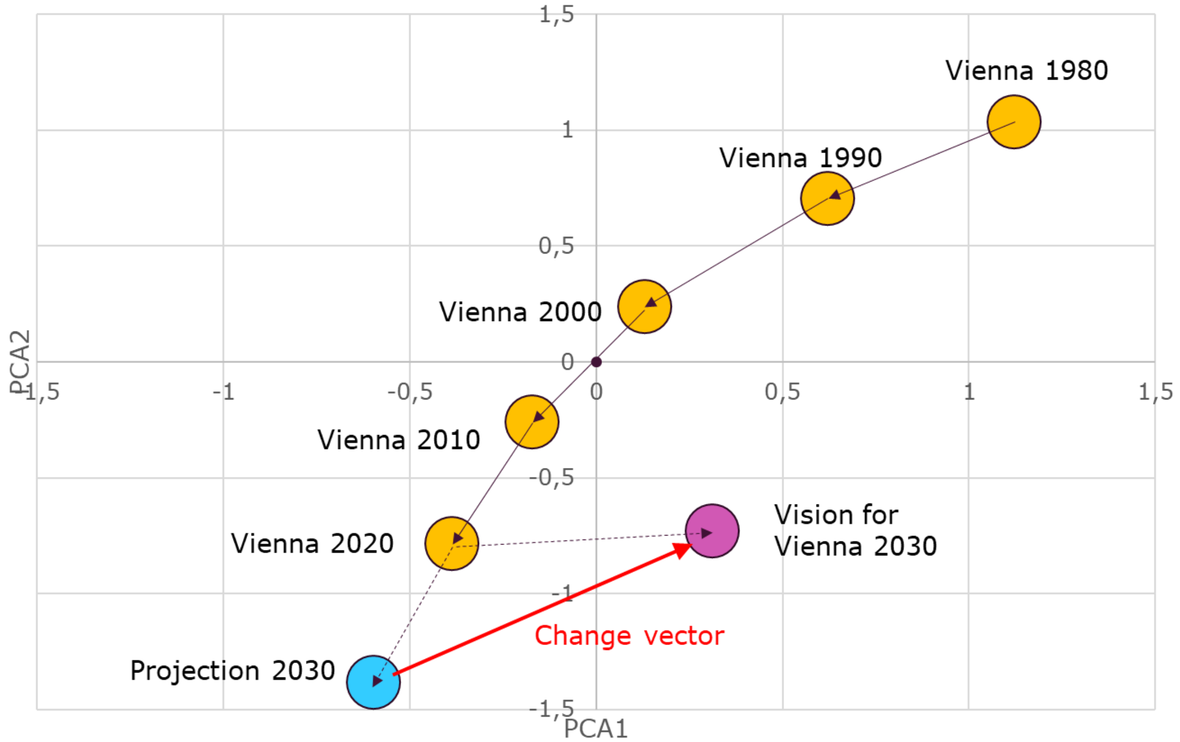

Figure 4: Gap between projected future and vision for a city, and resulting change vector (schematic, based on evaluated data for Vienna, the axes are the first and second principle components in embedding space)

As also indicated already in section 2.2, this change vector can be mapped back to a *change* in LEVITATE indicator values. This addresses the question which indicators should be subject to the greatest changes in order to "correct the course" and reach the targeted vision. Geometrically this can be interpreted as *projection*[3] of the LEVITATE indicators (represented in the same abstract space as the geographic entities) on the change vector in the multi-dimensional space. If this projection is positive then the corresponding indicator should be improved (i.e. enhanced) in order to reach the vision.

For the example of Vienna 2030, based on the statistical analysis of data for LEVITATE indicators, such a projection for selected indicators is shown in Figure 5. The highest positive contribution obviously comes from indicators like BuildingVolume_3 (Buildings with more than 3 floors), Perceived Safety_x (You feel safe in the neighborhood you live in) and Fatalities_1 (People killed in road accidents per 10,000 persons – measured at city level), where other (obviously vision relevant) indicators like CO2 or other particle emissions and energy consumption do not show any significant dependency (or even contribute negatively).

In summary, the statistical analysis definitely can support the identification of visions and provide meaningful inputs for finding feasible transformation corridors from the present state towards the desired vision. The results of these approaches, however, should also be considered with caution, since the amount of available data cannot guarantee reliable conclusions for all indicators or geographic regions. Furthermore, the approach discussed in this section relies on time-independent correlation patterns between indicators, which might not be a valid assumption for the medium-term future; particularly where disruptive technological developments, like CATS, enter the scene. Further efforts within LEVITATE (WP5 -7 and WP8) will be required to guide the backcasting approach and fine-tune possible transformation corridors based on data evaluation. For the scope of this deliverable and the results described in the remaining chapters for the three city case studies, the main basis will be the LEVITATE indicator framework, preliminary analysis of CATS use cases, influencing factors and policy interventions, and finally the dialogue with the cities.

[3] Calculated as cosine similarity between the two vectors (or 1 – cosine distance); values are therefore between -1 and 1.

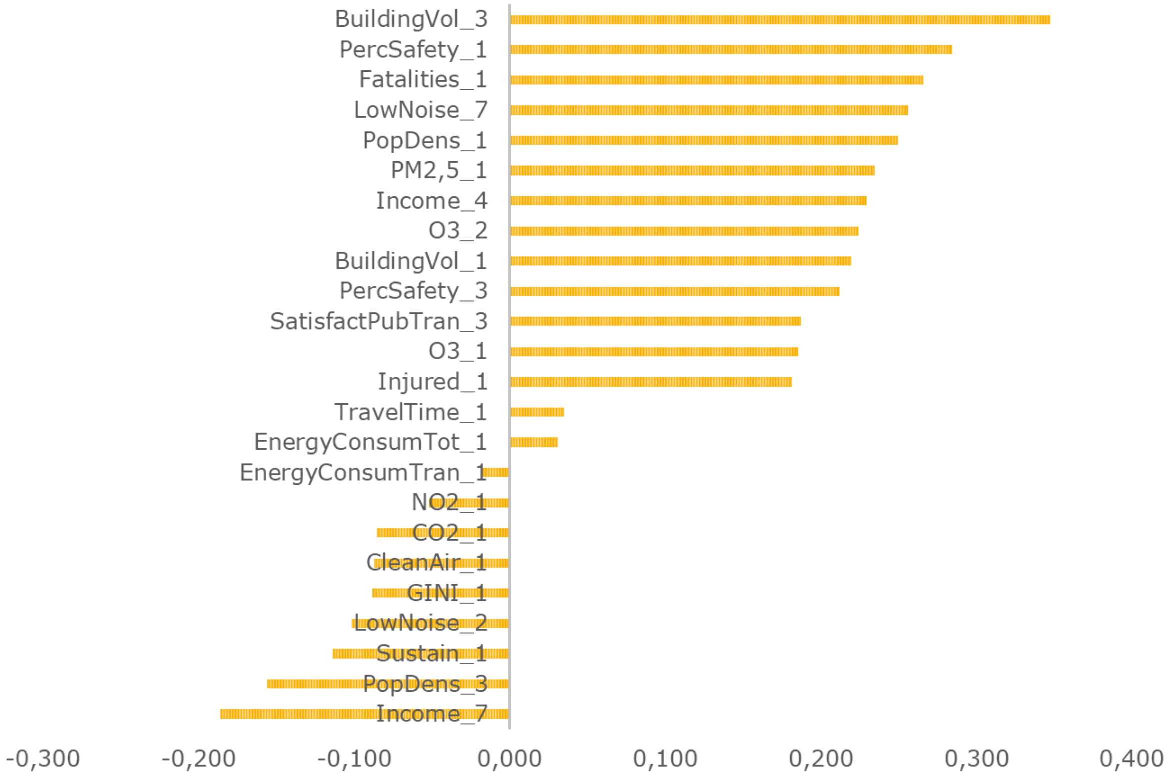

Figure 5: Example for Vienna 2030: Projection of selected LEVITATE indicators on the change vector for Vienna for 2030

3.3 Influencing factors

For the backcasting approach followed in this deliverable, the influencing factors are considered as the link between the vision (defined by means of indicators and final CATS impacts) and the policy interventions – which can be seen as ultimate output of the backcasting process.

As explained in section 2.3, influencing factors are generally not considered as goals themselves, as they are just instruments contributing towards one or several higher-level goals. They are related to the indicators via *expected* impact relationships – and this can be considered as the biggest challenge in this step of the backcasting process: From the initial analysis of impact relationships in LEVITATE, statements on (quantified) dependencies are in most cases not yet possible. Quantitative impacts are also difficult to predict because optimal use of AV's will require a different way of planning for which existing tools and data are inappropriate. Therefore, it will be important to verify the postulated relationships afterwards by means of quantitative methods (like micro- or mesoscopic simulations and system dynamics).

For each indicator that has been identified as key for the vision, one or several factors shall be derived, based on analysis of the inputs described below and common discussion with city representatives. Also, the values of these influencing factors might be quantified where possible. The following main sources are used as input for this selection process:

1. Available documents that describe city visions and strategies: In some cases, the city strategies included ideas on how CATS can support to reach certain goals of the vision.
2. Preliminary work in WP 5, 6 and 7 in LEVITATE for Automated urban transport, Passenger cars and Freight transport and logistics, respectively – as summarised in section 2.5. The parameters considered for the prioritised use cases (Last mile shuttles, Road pricing, Automated urban delivery) are essential for the backcasting process allowing subsequent verification.
3. Preliminary work in WP3: Dependency chain of impacts (direct, systemic, wider) and parameters considered for the dose-response curves; results that have been identified after a literature survey.

However, it should be stated, that the influencing factors identified in this step should not be limited to those already documented and considered in LEVITATE. In the dialogues with the cities any relevant factors derived from the goals can be identified. In particular it has been stressed by city representatives in the initial meetings that these influencing factors (and also related policy interventions) should be as specific (for the city) as possible.

As indicated in Figure 3, the direction from the goals "backwards" to related influencing factors will be illustrated by using arrows going from right to left, when documenting the results of the backcasting dialogue.

As a final note to the relevance of influencing factors, the direct relationship to CATS / AVs is not always so clear, in the end we might face correlations between several influencing factors which impact the targets. Consider for example that electrification of fleets will have a bigger direct impact on environmental goals than just the automation. But in general, it is assumed that most automated AVs will also be electric. If automated vehicles will be shared (as some of the sources cited in chapter 2 assume), then a lower number of vehicles may be expected, but this is conflicting with some opinions that say that mobility will explode when automated (taking them for all trips for which otherwise one would have taken a bus or a bike). Consequently, influencing factors such as the share of EVs, shared mobility or the attractiveness of public transport and active transport modes absolutely should be taken into account.

3.4 Policy interventions

As the final step in the backcasting process, promising policy interventions are selected and prioritised, again working backwards from the desired changes in the influencing factors.

Again, as for the influencing factors, candidates of relevant policy interventions might be derived from existing documents describing city visions and strategies, and they might be related to the use cases analysed in WP 5 – 7 (as already described in section 2.5).

The main goal of the backcasting process as described in this deliverable is to identify the most promising interventions based on the key goals and influencing factors. For these three cities case studies, the policy interventions shall be as specific as possible. As an example, a possible policy intervention would not just be "road use pricing", but discussing which parameters to use for that kind of intervention – in which areas (zones) of the city, during which day time, for which types of vehicles etc.

A typical challenge in this step (but also overall in the backcasting process) is the question how far the considered interventions are specific to CATS (and therefore within scope of LEVITATE). Since the expected impact of CATS has been considered already in definition of LEVITATE indicator framework and feasible visions, relevance to CATS should be ensured to a certain degree "from the start". It can still happen, however, that for a certain goal, influencing factors and, even more, policy interventions can be derived that have no strong (at least no direct) relationship to CATS. Nevertheless, such influencing factors and policy interventions might be considered as relevant because of following aspects:

1. Implementation of CATS leads (or better: is expected to lead) to changes in several other system parameters – within or outside the transport domain; such changes might then require or facilitate adaption of policies. As an example, less need for parking space in certain areas (as consequence of CATS) might allow for re-assignment of public space (as policy intervention).
2. Important and general policy goals like reduction of air pollution and CO2 production can be considered as "weakly" depending on CATS itself (compared to all other influencing factors) – but taking into consideration the possible impacts of CATS on several factors like modal split, additional amount of travel, travel time or propulsion type, significant contributions of CATS towards these goals could be demonstrated. These factors in turn can be controlled by suitable policy interventions.

Feasible policy interventions will of course also be defined by the city's sphere of influence: Several developments (e.g. driven by technology and market) are out of direct control by any federal government, regional government or municipal authorities; other interventions might be controlled only at a higher level (federal government, EU level) but can hardly be influenced on city level. In such case it will still be essential for cities how to respond to corresponding changes (for example in the market penetration of level-5 AVs).

The prioritisation of policy interventions might result from a trade-off between the effect on identified influencing factors and contribution to policy goals on one hand, and the feasibility (in terms of costs, political resistance etc.) on the other.

As a final note, the proposed timeline of policy interventions and possible combinations / sequences will not be handled within this deliverable. This will be addressed on a qualitative level in deliverable D4.4 and investigated in more detail in WP5 – 7. So, the "feasible paths" of intervention as understood within the scope of this deliverable are defined by the connections between the targets of the vision, the influencing factors and areas of promising policy interventions. Only after quantitative investigations of these relationships, more concrete pathways – determined by development of influencing factors as well as indicators as a function of time – may be described.

3.5 City dialogues

The general procedure as outlined in Figure 2 envisages a city dialogue that is based on existing documentation of city strategies and the LEVITATE indicator framework, and is performed in following three steps:

1. Define a Vision
2. Prioritise Influencing Factors
3. Propose Policy Interventions

For Vienna and Greater Manchester, where the main contacts for the dialogue are also partners in the LEVITATE project, discussions on above mentioned building blocks have already been started before the actual backcasting process that is described here. The City of Vienna has also supported to define the LEVITATE indicator framework, according to the four impact dimensions safety, society, environment and economy.

In addition, as part of the first LEVITATE Stakeholder Reference Group Workshop, which was held in Gothenburg, Sweden, on May 28, 2019 [4], experts from different sectors, including stakeholders from municipal authorities, were involved to discuss and adopt the list of goals and indicators and to disclose potential synergies and conflicts regarding efforts to achieve specific goals in the four selected dimensions.

The actual backcasting dialogue with the cities (as reported in this deliverable) has been carried out within a timeframe of close to two months (November - December 2019) and was performed as a combination of workshops / face-to-face meetings, offline reviews and phone conferences.

For the Vienna case study, a first workshop was held in November, addressing step 1 and 2 together (since the definition of the vision by means of indicators was already quite advanced at that time), followed by an off-line review of indicators and influencing factors. After this, a draft description of proposed derived policy interventions was sent to the city contact as base for a discussion and finalisation during a phone conference.

[4] For details refer to https://levitate-project.eu/2019/06/11/what-do-policy-makers-want-to-know-about-the-impact-of-connected-automated-vehicles/

For the Greater Manchester case study, a meeting was held in September to understand their strategies and policy goals. One day, in-person meeting provided an overview of Transport for Greater Manchester (TfGM) operations as well as research and policy-making activities. Further materials regarding their 2040 transport strategy and their delivery plans and various other activities was provided. This was studied and overall relevant backcasting was extracted using these documents. This was further refined through a teleconference meeting with TfGM employees concerning policy and operations.

For the Amsterdam case study, a first meeting was held in December. During this meeting the vision, factors and potential interventions were discussed. Before the meeting an off-line review of standing vision documents and influencing factors took place. After the December meeting, a draft description of the vision, influencing factors and policy interventions was sent to the city contact for review and discussion. A phone conference was held to discuss final adjustments and ensure a correct representation of the city's view.

4 Vienna

The aim of this chapter is to apply the backcasting steps described in the previous chapter to a city dialogue with the city of Vienna. Dialogue with stakeholders in order to define feasible paths of intervention towards the vision. Through the discussions with the city, the vision relevant for LEVITATE were identified, which represent the city goals and influencing factors for a specified point in future. Subsequently, specific policy interventions are proposed to achieve the city goals.

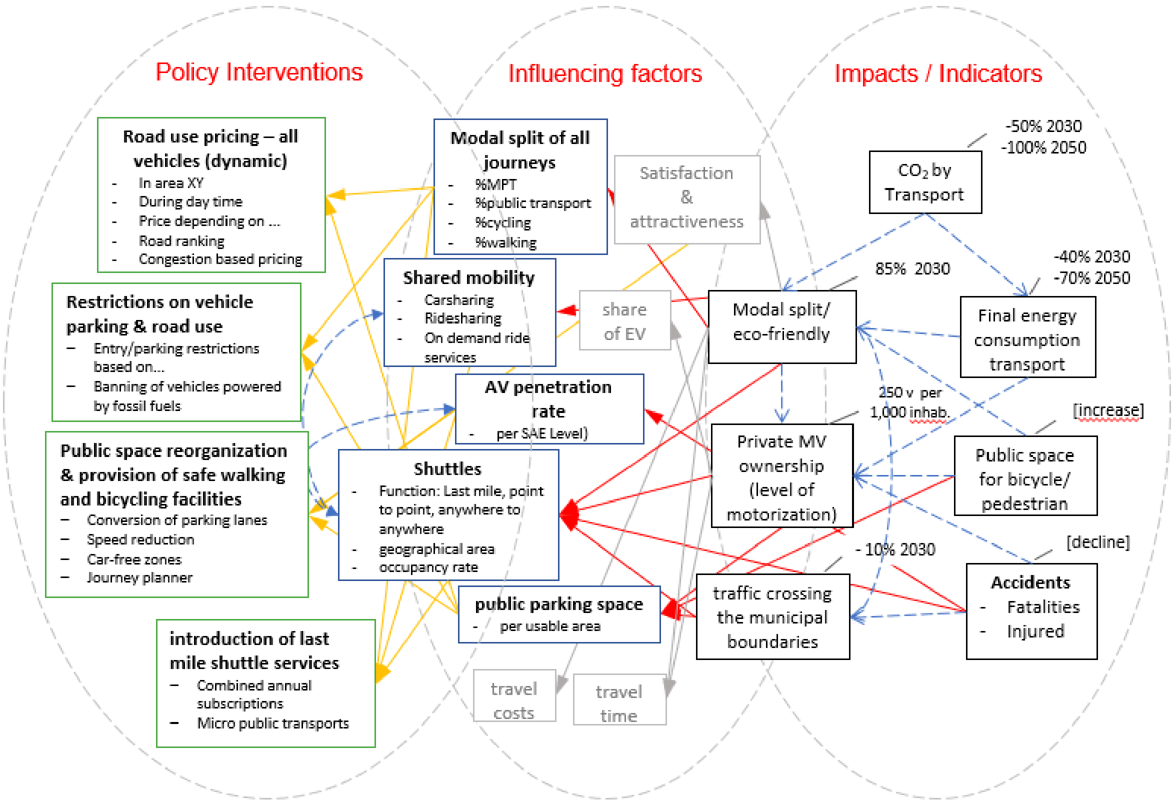

Figure 6: Backcasting for Vienna – Overview

Table 7 illustrates the Backcasting approach in several steps. It shows a network of dependencies that will be further explored in this project. These steps are split into three pillars, starting from the right pillar with the vision moving to the left pillar with the policy interventions. The illustration shows a link between the city goals, influencing factors and the relevant policy intervention.

At the first dialogue with the city of Vienna there are seven goals identified, especially those which are relevant for LEVITATE. These targets are mapped to the indicators and impacts, which were mentioned in various working papers of LEVITATE Project. The blue arrows in the first pillar symbolise the influence of the goals to each other. The approach of selected indicators shows positive correlations.

In a further and last city dialogue – the appropriate policy interventions for each goal is defined. This is a required step to be able to achieve the city targets.

4.1 Vision

Vienna is growing, and so is the total number of routes that are covered by residents. Responsible for the steadily increasing traffic emissions are the increasing speeds and longer distances made possible by the motorisation. Short distances can easily be covered by bike or on foot. Conversely, a shift in traffic towards walking and cycling can strengthen a settlement structure with diverse offers in the surrounding area in the long term.

The goals determined through the City dialogue by a combination of the selected indicators and specifies the target direction for further development. The targets are aligned with the Vienna Smart City Strategy document of 2019 (Wien M. d., 2019) which presents some quantitative targets for 2030 as well as for 2050.

Vienna's Smart City 2050 goal is therefore: "the best quality of life for all Viennese with the greatest possible conservation of resources. This is achieved with extensive innovations." Therefore, the following three dimensions of the smart city Vienna arise:

1. Resources (Mobility, Infrastructure)
2. quality of life (environment, social inclusion) and
3. innovation (research and technology)

The overall city goal of Vienna is to reduce greenhouse gas emissions per capita by 35% by 2030 and 80% by 2050 (compared to 1990). The main sub-goals in the field of mobility that belong to the resources and the main targets of the city related on LEVITATE are:

1. Per capita CO_2 emissions in the transport sector fall by 50% by 2030, and by 100% by 2050
2. Per capita final energy consumption in the transport sector falls by 40% by 2030, and by 70% by 2050
3. By 2030, private motor vehicle ownership falls to 250 vehicles per 1,000 inhabitants.
4. The share of journeys in Vienna made by eco-friendly modes of transport, including shared mobility options, rises to 85% by 2030, and to well over 85% by 2050
5. The number of traffic casualties and persons injured in traffic accidents declines further (even if no further specified target is given)
6. The share of green space in Vienna is maintained at over 50% until 2050
7. The volume of traffic crossing the municipal boundaries falls by 10% by 2030

The absolute final energy consumption in Viennese traffic (according to the EMIKAT definition) is expected to decrease by approx. 20% to around 7.3 TWh by 2025, compared to around 9.1 TWh in 2010.

A prerequisite for achieving this is a significant increase in the bicycle traffic share. Bicycle availability is increasing: by 2025, 80% of households should have a bicycle available, and 40% of the population should be able to reach a rental bike station within 300 meters. By 2025, 50% of the population should be able to reach a car sharing location within 500 meters.

The Viennese Urban Mobility Plan, under the “STEP 2025 Urban Development Plan” (Vienna, 2015) sets out the goals of the City of Vienna for a viable transport system of the future. Figure 7 shows the fields of action for mobility in Vienna and the goals of activities in this fields.

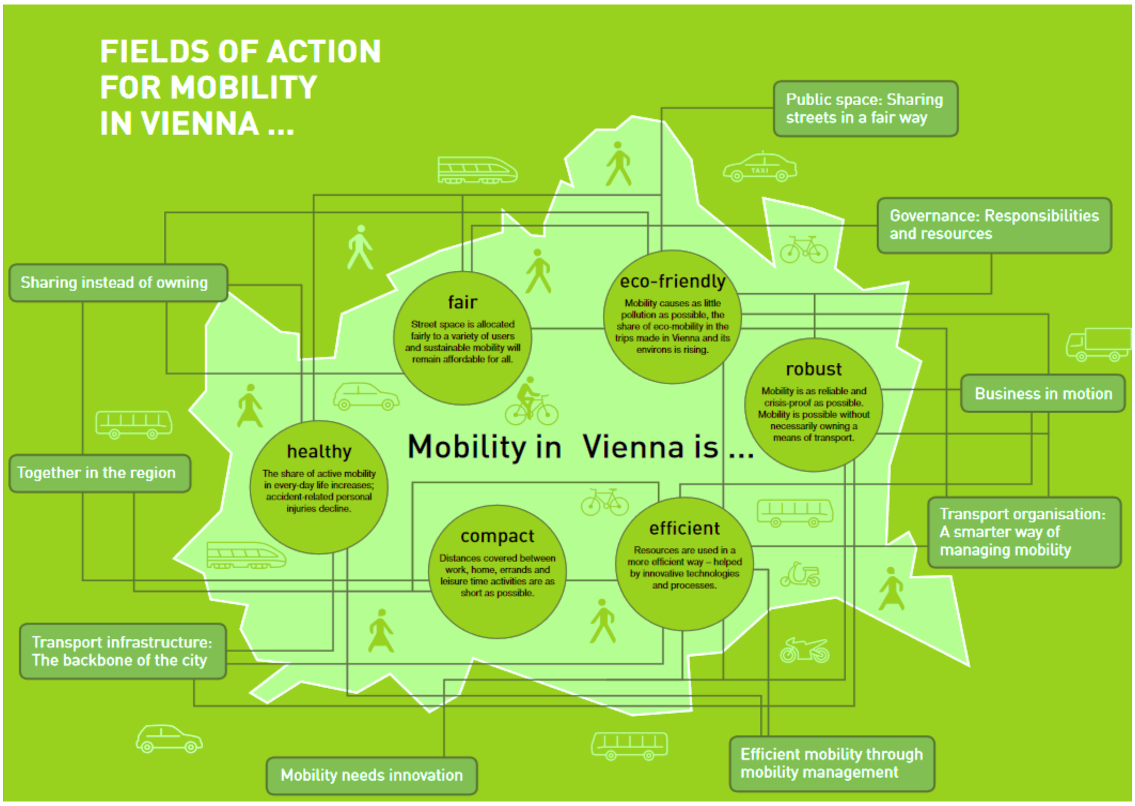

Figure 7: Fields of action for mobility in Vienna

In Table 8, a mapping for the goals is presented, for most relevant indicators along with their specified target values (note that for some indicators quantitative target values are available, for others only qualitative statements development sought are available: rise, decline or maintain level – in this case a rise / decline might be assumed by 20% until 2025, compared to 2010 values). The LEVITATE indicators are divided into four dimensions safety, society, environment and economy. The table indicates a focus on only three dimensions, namely on environment, safety and society.

Table 8:Indicators with their specified target values

Indicator	***Definition***	***Most recent value available***	***Target value (2025)***	***LEVITATE Indicator(s)***
Mobility Behaviour				
Average distances covered [km]	Average distances the Viennese cover in Vienna [km]	2013: 4.1 km	decline	TravelTime
	Share of errands which Viennese population does on foot within walking distances (1 km)	2013: 25.0%	rise	EnergyConsumption Transport

Modal split in passenger transport	Modal split for the Viennese population, referring to the number of trips (eco-mobility: MIT)	2013: 73:27	80:20	EnergyConsumption Transport
Multimodality	Percentage of population using at least two modes of transport within a week	2013: 52%	rise	(relationship to LEVITATE indicators, but not covered explicitly)
Mobility Services				
Satisfaction with transport	Satisfaction with public transport (school marks 1-5)	2013: 1.70	rise	SatisFactPubTran
Degree of motorisation	Passenger cars per 1,000 inhabitants	2014: 386	decline	(relationship to LEVITATE indicators, but not covered explicitly)
traffic safety				
Accidents	Number of traffic casualties per year	2013: 17	decline	Fatalities
	Number of persons injured in traffic accidents per year	2013: 6,979	decline	Injured
Energy and environment				
Energy consumption	Final energy consumption of the transport sector in Vienna 1999: 7,474 7.300 per year, adjusted for EMIKAT calculation [GWh]	2012: 8,647 GWh	7,300 GWh (minus 20% comp. to 2010)	EnergyConsumption Transport
CO2 emissions	Traffic-related CO2 emissions in Vienna, according to EMIKAT	2012: 2,062 kt.	1,700 kt. (minus 20% comp. to 2010)	CO2

Figure 8 shows how the city goals can interact with each other. The three city goals in the boxes on the right side are the main goals, that should be linked to the three goals on the left side to reach these goals.

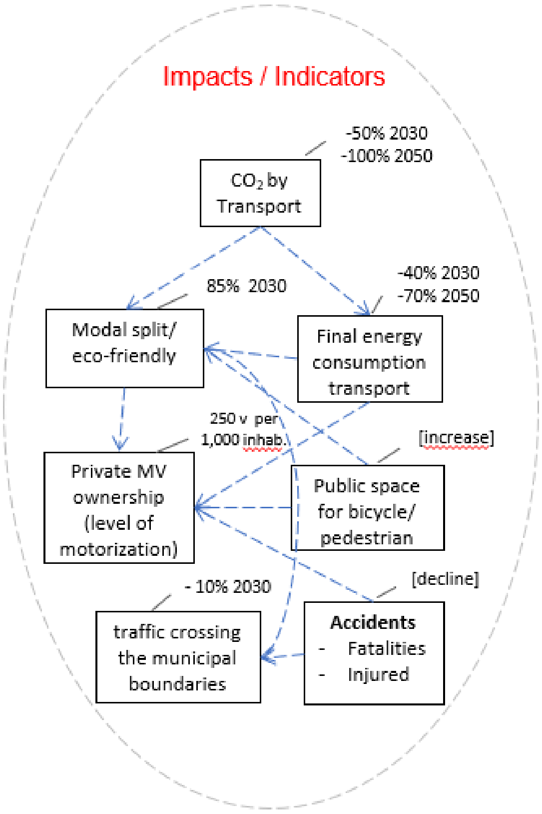

Figure 8: Impacts/indicators-Vienna

The most upper goal of the city of Vienna is to reduce CO2 emissions per capita by 50% in 2030 and 100% in 2050. The increasing emissions in the transport sector are a global problem and especially in Vienna is a central issue. As shown in the figure, this target links with another three goals, that means they are related to each other. The reduction of CO2 contributes to reduce the energy consumption and the volume of traffic, as well as to increase the share of Eco-friendly journeys.

A further city target is to reduce the final energy consumption in the transport sector by 40% in 2030, and by 70% in 2050. If more trips are made by bicycle, on foot or by public transport, and the number of car owners decreases, then the final energy consumption will be decline.

A fair division of the public space is one of the required goals to achieve other goals. Up to 120.00 additional apartments are to be provided in Vienna in the year 2025, in addition there must be areas for social infrastructure (Wien M. d., 2019). For planning this process, the pedestrian accessibility of public transport stops within 300 m is to be strived for.

As a next step, the city of Vienna wants everyone to be able to reach the next free space within about 250m. The preservation and expansion of large recreational areas helps to offer more attractiveness in the city. This can prevent suburbanisation and associated commuter traffic flows (Wien M. d., 2019).

In order to give people the opportunity to walk or cycle, there must be enough space for them on the road. This goal can influence the share of modal split by cycling or walking and the number of cars on the streets. An essential aspect to increase the share of journeys in Vienna with eco-friendly modes, the relocation potential to public transport in Vienna should be always possible.

In the city dialogue, it was pointed out to a quality of life study. In this study the question was asked, whether people in Vienna can get along without a car. 90% of respondents agree with this statement. This shows that there is a very high possibility in Vienna to relocate existing motorised private transport traffic on public transport. Here the attractiveness and satisfaction of the people plays an important role.

Another city target set out at the city dialogue is to decline the volume of traffic crossing the municipal boundaries by 10% in 2030. In Vienna the commuting, especially in the morning, causes congestion on the street, because many people live at the city boundary and work in Vienna. As shown in Figure 1, this goal has a link between two goals - modal split and private motor vehicle ownership. For example, if the most daily journeys made by private cars relocate to the eco-friendly transportation, then the volume of traffic will be decrease.

The next city goal is to decrease the rate of private motor vehicle ownership to 250 vehicles per 1,000 inhabitants in 2030. There are many reasons for the growth in traffic - cars become more powerful, more comfortable and more efficient. Individual mobility is one of the basic human needs for which there is a high willingness to pay. Other reasons are the population growth and the problem of urban sprawl. The decline in the number of private cars is not to be understood as a renunciation, but as an opportunity for a change to an attractive, cost-effective and city-compatible transport system.

The number of traffic casualties and persons injured in traffic accidents must decline further. There is no target for traffic deaths, but it should be reduced as much as possible. A boundary condition for introducing autonomous driving is to reduce traffic accidents. Once this technology reaches this goal, AV will be performed.

4.2 Influencing factors

The influencing factors are the main parameters that were defined to estimate the impacts of CATs. These factors are expected to be affected by the policy interventions under consideration and will ultimately result in impacts. Figure 9 presents the relevant influencing factors, which were determined at the city dialogue. The question that arises here is, which parameters have the greatest potential to influence the identified city goals.

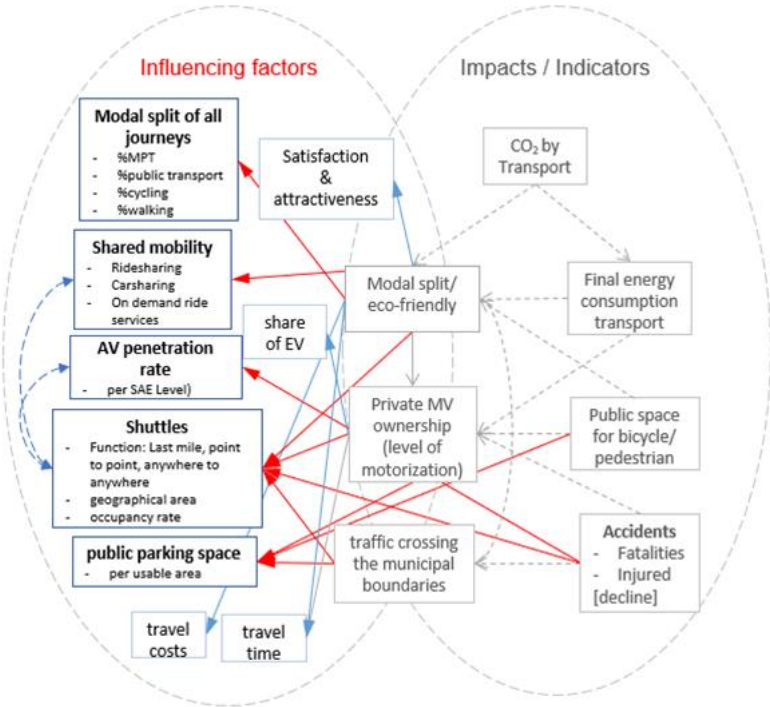

Figure 9: Influencing factors-Vienna

In the following section an overview of the individual influencing factors will be given:

AV Shuttles

In the Figure 9, the link between the city goals and the influencing factors is shown. Shuttle buses are regular, defensive and low in emissions. This opens up new opportunities for attractive public spaces for strolling, chatting and offering the opportunity to make the journey on the way e.g. to work useful. The use of AV shuttles contributes to reduce the number of traffic accidents, because they drive autonomously and, in contrast to human-driven vehicles, they cause fewer traffic accidents. This is because most of the traffic accidents are due to human error.

Additionally, shuttles can have significant impacts on modal split and motorised private vehicle ownership. They also might have positive effects on the volume of traffic crossing the municipal boundaries. For example, shuttle buses could pick people up from home and they are able to drive other people back who live in the same area without taking an extra route.
Furthermore, there are three key points, that are arguably important to be addressed, these are:

1. function
2. occupancy rate
3. geographical area

Shuttles have several functions for example: last mile, point to point or anywhere to anywhere. For Shuttles, it is important to define the area and the way they work- are

shuttles supportive and complementary to public transport or are these the only mean of transport?
Another important aspect is the need to determine the number of shuttles needed for the journeys and the occupancy rate, which is assessed by the number of passengers per shuttle. They can be influenced by various parameters such as price, waiting time, etc. In addition, the size of the fleet cannot be estimated immediately – it will be developed over time. The occupancy rate per shuttle such as rob taxi or shuttle buses are an enormous lever to avoid congestion, energy consumption and emissions.
The next aspect is the geographical area, where the shuttle buses are to be used. For example, if they will drive in areas, where the connection to the public transport is very weak or in areas, where there is very good transport connection. There are also individual use cases, where people need shuttle buses because of mental and/or physical disabilities (e.g. people want to go directly to a destination or they have broken a leg). So, shuttles can drive in areas that are very good connected with public transport or in corridors which are not. Consequently, they can be used as feeders to the outskirts or directly to the end destination. The pricing and allowances should be so that individual use of AV's is not the main option but comes at a higher price.

Car sharing
Car sharing and ride sharing are becoming increasingly popular in cities. Shared mobility contributes to less car journeys and a reduction in the number of vehicles parked in the street. Car sharing customers generally change their mobility behavior. They are on the way more often on foot, by bike or public transport. For such classic car-sharing systems, international studies find that car sharing vehicles replace about 4-8 private cars. In Vienna there are two systems of car sharing: classic car sharing systems and -floating. The first one offers vehicles at fixed locations and previous reservation. On the contrary, the -floating system offers vehicles, which are available for spontaneous use within a defined zone and can be rented on a minute-by-minute basis and pre-booked just 15 minutes before use.
Therefore, ridesharing solutions, the use of free seats by passengers are to be extended by the city. These are economically and ecologically sensible.
of automated spend more time with transport services than with unproductive parking. At constant driving performance, the fleet size and the parking space requirement thus decrease.

AV penetration rate
If the share of AV increases, then the traffic safety can increase. The greatest utility in AV is to reduce the number of traffic accidents. Note that AV can only be used if they are safer than human behavior, therefore new technologies must be developed. This factor is also related to shuttles.
Vienna has already started with the first autonomous shuttle "auto-bus Seestadt", which was funded by the Ministry of Transport as part of the "Mobility of the Future" program. These autonomous shuttles have been running in a residential area since July 2019, where an Urban Lab or test area of the Smart City Vienna is located.

Shared mobility
Shared mobility includes various services like carsharing, bike sharing, ridesharing, e-Hail, micro transit, scooter sharing, etc. Carsharing, and ridesharing are becoming increasingly popular in Vienna. Shared mobility contributes to less car journeys and a reduction in the number of vehicles parked in the street. It is very likely that the future of urban transportation will be dominated by connected, automated, electric and shared

vehicles. Bringing these technologies together could bring benefits to the power grid and help to reduce CO_2 emissions. A future scenario could look like this: Carsharing users can reserve a driverless car using an app, the AV takes them to a desired destination and then drives to the next charging station in order to prepare for the next reservation.

Carsharing customers generally change their mobility behavior. They are on the way more often on foot, by bike or public transport. For such classic car-sharing systems, international studies find that car sharing vehicles replace about 4-8 private cars. In Vienna there are two systems of car sharing: classic car sharing systems and carsharing – free-floating. The first one offers vehicles at fixed locations and previous reservation. On the contrary, the free-floating system offers vehicles, which are available for spontaneous use within a defined zone and can be rented on a minute-by-minute basis and pre-booked just 15 minutes before use.
Therefore, ridesharing solutions, the use of free seats by passengers are to be extended by the city. These are economically and ecologically sensible.
Fleets of shared automated vehicles are expected to spend more time with transport services than with unproductive parking. At constant driving performance, the fleet size and the parking space requirement is thus expected to decrease compared to regular car-sharing services.
But some people are not quite ready to share their vehicle and only small numbers of people see car sharing as an alternative to private owned vehicles. It is because sharing a vehicle have different requirements than owning a vehicle. These requirements are e.g. price, reliability of service (such as waiting time), cleanliness, privacy, comfort, accessibility for people with disabilities, children, older adults, etc. When more people are incentivised to use car sharing then the share of modal split of shared vehicles will be possibly increase.

Modal split of all journeys
Modal split of all journeys means the percentage of motorised private transport, public transport, cycling and walking. Automation is intensifying competition between the various modes of transport. A change in the modal split is the likely consequence. The choice of modes of transport can depend on travel times, prices, and comfort.
Modal split in the future could be defined like:
% trips made in single occ cars (AV and regular)
% trips made in shared cars (Av and regular)
% trips made by 'normal' PT (Av and regular)
% trips made by bike or on foot (e-bike included)
% trips made by e-scooter
% trips made by shuttles

Public parking space
There are people who own one or more vehicles and they do not use them, so they park their cars for a long time. Therefore, they use a lot of parking space and the parking facilities will be increase. It can thus be concluded that the volume of traffic will increase, when the share of parking spaces increases. If part of the parking lanes, especially those reserved for long-term parking, are transformed into pedestrian and cyclist lanes, more traffic activities can be offered.
The reduction of parking spaces can have a significant impact on the road structure. AV and AV shuttles, in particular when shared can reduce the need for on street parking, as it is expected that they will be on the move instead of standing still.

Satisfaction & attractiveness
The influencing factors satisfaction & attractiveness can also be considered as city goals. They are illustrated in the Figure 9 in the borderline to the impacts and indicators. They can also be considered as goals, because the city wants to increase the share of modal split. This can happen if the city manages to offer good AV interventions, with the market, then the % of shared AV's may increase, and if done properly this may lead to citizen satisfaction.
It should also be mentioned that recently the satisfaction of public transport users has been increased. This happened for example, because the average distance between the stations is only 700 m and the number of stations within 2 km radius is just under 22 in Vienna.

Share of electric vehicles
Electric vehicles including E-bike and E-Scooter will *probably* lower CO_2 emissions (well to wheel) but will *definitely* lower local air pollution. EVs can also reduce some of the environmental impacts of mobility especially air pollution and greenhouse gas emissions. However, the share of electric vehicles does not aim to increase the number of private motor vehicle ownership but replace conventionally fueled vehicles by an EV. It is important not to adversely affect the share of journeys made by eco-friendly modes of transport (i.e. cycling, walking), but to make them even more attractive. In the near future, one of the city's goals is to ban vehicles that emit more emissions, and this influencing factor should be seen an eco-friendly alternative. Nevertheless, the following question arises as to how far the CO2 balance of electric cars is better than that of conventionally fueled vehicles. Most studies conclude that electric cars have lower CO2 emissions over the entire value chain than diesel cars and gasoline.

Travel time
Travel time can be considered as a goal. As an influencing factor, travel time can influence the proportion of modal split, as people decide for the faster mobility option.

Travel costs
Travel costs can be also influenced by whether people will use eco-friendly modes of transport. However, it should be noted that lower public transport costs do not always mean, that people do not want to own a car. Here, other factors play a major role, such as satisfaction, comfort, weather conditions and travel time.

4.3 Policy interventions

The aim of this paragraph is to elucidate the discussion with the city of Vienna. The relevant policy interventions for LEVITATE were proposed by the city.
Figure 10 shows the overall working scheme: policy interventions (on the left) influencing factors (in the middle) and the city goals (on the right). The interventions serve to ensure, that the city goals listed can be achieved.
In the next section the individual interventions are described in detail. The city of Vienna suggested even examples of, where these interventions should be set out. These examples are aimed at regions in Vienna, that are currently considered critical.

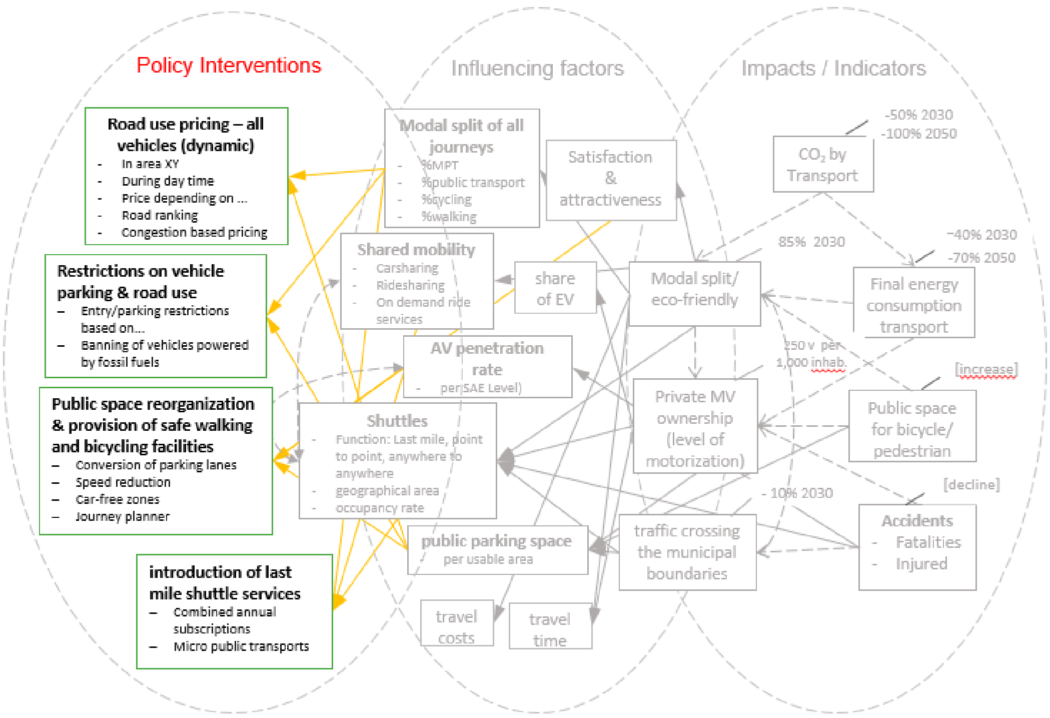

Figure 10: Policy interventions-Vienna

In this project the following fields of policy interventions are considered, which are divided into:

- Road use pricing-all vehicles (dynamic)
- Restrictions on vehicle parking & road use
- Public space reorganisation & provision of safe walking and bicycling facilities
- Introduction of last mile shuttle services

Road use pricing-all vehicles (dynamic)

An important policy intervention, which was discussed in the City dialogue is the road use pricing. This measure could be linked with several influencing factors such as shuttles, modal split of all journeys and AV penetration rate. It is conceivable that it will be used to achieve some of the city's goals in 2030-2050. These goals are for example decreasing the share of private MV ownership and the volume of traffic crossing the municipal boundaries.

This measure might be influenced by area, time of day, price, road ranking and congestion. Therefore, road use pricing should be carefully considered by the city to determine, in which areas and at what time of day a road pricing is most convenient? It could be conceivable in areas such as the city center, in a certain residential area or in a certain district, because these areas are most at risk.

There are different types of road use pricing system, where the price is depending on several factors such as:

- the type of vehicle and the level at which is levied (national, regional or local level)
- weight-based vehicle taxes for AV with conventional vehicles
- occupancy rate of AV vehicles/shuttles

The road rankings differentiate between high ranking and low ranking. High ranking has the lowest price and "30 zones" have highest price -to avoid traffic on lower-ranking roads e.g. in residential and in school areas. If there are high costs in high-ranking roads, then all vehicles will deviate on low-ranking roads, which can lead to more congestion and traffic accidents.
Another example of road use pricing is the congestion pricing. It is a type of dynamic pricing, that requires charging for the use of inner-city transport infrastructure. This can be either area-based or carbon-based pricing. Cordon and area pricing include either variable or fixed tax for travel within or to a congested area within a city.
A final example of road use pricing is the handling of commuter allowance. The Commuters on working days receive various forms of tax relief, most of which are aimed at car commuters and this should be changed in order to reduce the number of commuter traffic.

Restrictions on vehicle parking and road use
Parking is one of the main problems when using a car in Vienna. The higher the proportion of MV owners, the more parking spaces and more space for car traffic will be required. In the downtown, the problem is even bigger, because of the search for a parking space, which creates many empty runs that cause more traffic jam and air pollution. A restriction on parking can happen similar to the measure road use pricing, namely pricing the parking lot or even prohibiting it. In Vienna and many other European cities there is so-called "short-term parking", where drivers are only allowed to park their cars for a limited time. Another parking system is the "district pimple", which only the residents of each district can park their own car and they must pay for it.
It is still not enough to have less traffic with these current measures. Therefore, the measure "Restrictions on parking vehicles and restrictions on road use" was discussed with the city. This measure is based on area, time, vehicle type, etc. Finding parking spaces in the future with AVs should be done automatically. There are three different strategies for parking the AVs: 1. conventional search for a parking space, 2. Parking in a designated AV parking lot and 3. empty runs, where vehicles do not use a parking lot, but continue to drive.
Another policy intervention is the restriction of road use in residential areas and banning of fossil fuel vehicles.

Public space reorganisation & provision of safe walking and bicycling facilities
One of the main goals of the city of Vienna is to distribute the public space fairly. Some measures are necessary to achieve this goal. The "public space" is the space, where people can be active and participate in mobility activities. Therefore, an important measure to increase the attractiveness of road users to active traffic modes is a restructuring of public space and the provision of safe facilities for pedestrians and cyclists. The modes of public transport and active mobility should be strongly emphasised and the number of MV should decrease. This policy intervention involves several influencing factors, such as: satisfaction & attractiveness, public parking space and modal split of all journeys.

Some ideas discussed with the City of Vienna on restructuring of public space related to CATs are:

- a conversion of parking lanes into areas for walking, cycling or other permanent or temporary functions ("flexible zones"). Another option is the conversion of parking strips for flowing traffic. This option is not relevant for this backcasting because one of the city's goals is to offer more public space for pedestrians and cyclists. As currently, over 65% of the street area is used by flowing motorised traffic or as parking space. Nowadays more people are walking, using public transport or cycling, so the needs of non-motorised transport are constantly increasing.

- provision of multifunction zones and occupied zones (e.g. hop on hop of zones)
- speed reduction in residential areas, shopping streets and school streets with AVs so that pedestrians can cross the street without any risks.
- car-free zones with restrictions (e.g. at certain time and vehicle types, etc.)
- Rezoning / changes in intended land use
- journey planner (focus on active modes of transport)

Introduction of last-mile shuttle services

The last measure that was discussed through the conversation with the City of Vienna is the provision of faster, more cost-effective and convenient public transportation. The influencing factors, that associated with this measure are: shuttles, AV penetration rate and modal split of all journeys.

This policy intervention focusses on the following sub-measures:

1. (public) last-mile shuttles
    a. e.g. U1 northern stations – which area should be covered by shuttle…
    b. AV service instead of B Buses
2. Combined annual subscriptions, multimodal public transportation packages
3. Better coordination between different modes of transportation
4. Micro public transport (covered by last-mile shuttles)

Last-mile shuttles are used on the last mile as feeders to public transport stops independent on time and pick-up location. Automation of the last mile of public transport shuttles and battery electric shuttles are an important aspect in order to reduce the development of car traffic, increase road safety and improve air quality. It is also important to determine, where the public last-mile shuttles should be used and in which regions in Vienna or e.g. in urban, suburban, area with good public transport connections or area with poor public transport connections.
The aim is to replace the so-called "B" bus with last mile shuttles, where a need would be necessary. The "B" buses mostly drive in low-load areas (less densely populated areas), so they drive at large intervals and therefore they are not very attractive. This leads to the fact, that people drive with a motorised mode of transport. It should be considered, that by introducing last mile shuttles, they should not offer a direct trip to the city center, otherwise congestion problems will be expected. A restriction of last mile shuttles could be a solution - these shuttles drive only to fixed destinations, for example to the subway or a tram node, and people can change the modes of transport.

In this section two proposal examples are pointed out of where these last-mile shuttles can be used in Vienna. The first variant is the simple variant, which mean the bus line 41 A can be replaced by an AV shuttle. This bus line is characterised by: long intervals, short distance, enough space, little traffic; 1 clear goal: Pötzleinsdorf (see Figure 11).

Figure 11:Example proposal for last-mile shuttle in Vienna

The second variant is the more ambitious variant. Lines 17A and 19A during off-peak hours and at the weekend can be replaced by shuttles (see Figure 12).
Long lines; several potential goals (U1 Alaudag., U1 Neulaa, U1 Oberlaa); at the off-peak times and on weekends: long intervals; Mixed traffic can be demanding.

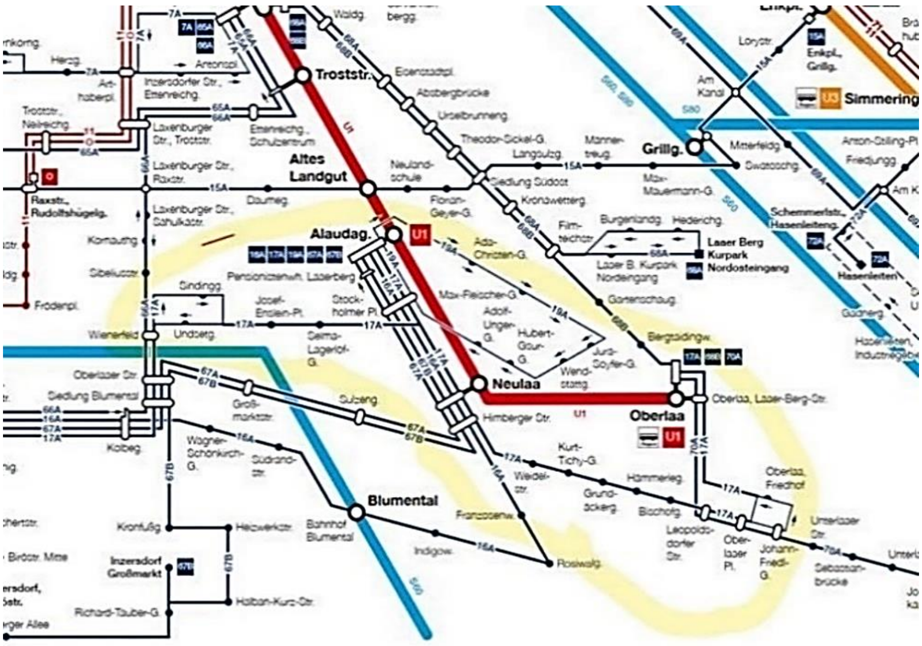

Figure 12: Alternative proposal for last-mile shuttle in Vienna

Figure 13 shows the areas of the public transport quality levels with population density to show some examples of bus routes in Vienna with sparsely populated regions that could be replaced by last-mile shuttles. For this illustration, two data sources were used: the data of the public transport offer at every stop in Austria and the routable network graph GIP. In order to analyse the supply of locations with public transport across Austria and present them uniformly, the public transport quality system was developed. Table 9 shows the public transport quality classes are formed from the combination of the previously determined stop category (Roman I to VIII) and the distance classes defined for each stop category (Raumordnungskonferenz, 2017). There are seven public transport quality classes (A to E) with public transport development qualities and spatial allocation (urban / rural). These are indicated by colors in 13 and are:

- dark brown = basic development in rural areas
- light brown = high-level public transport access
- dark blue = densely populated
- light blue = sparsely populated

Finally, in the Figure there are also many dots with different colors that symbolise the depicted stations (purple = bus, orange = subway, etc.).

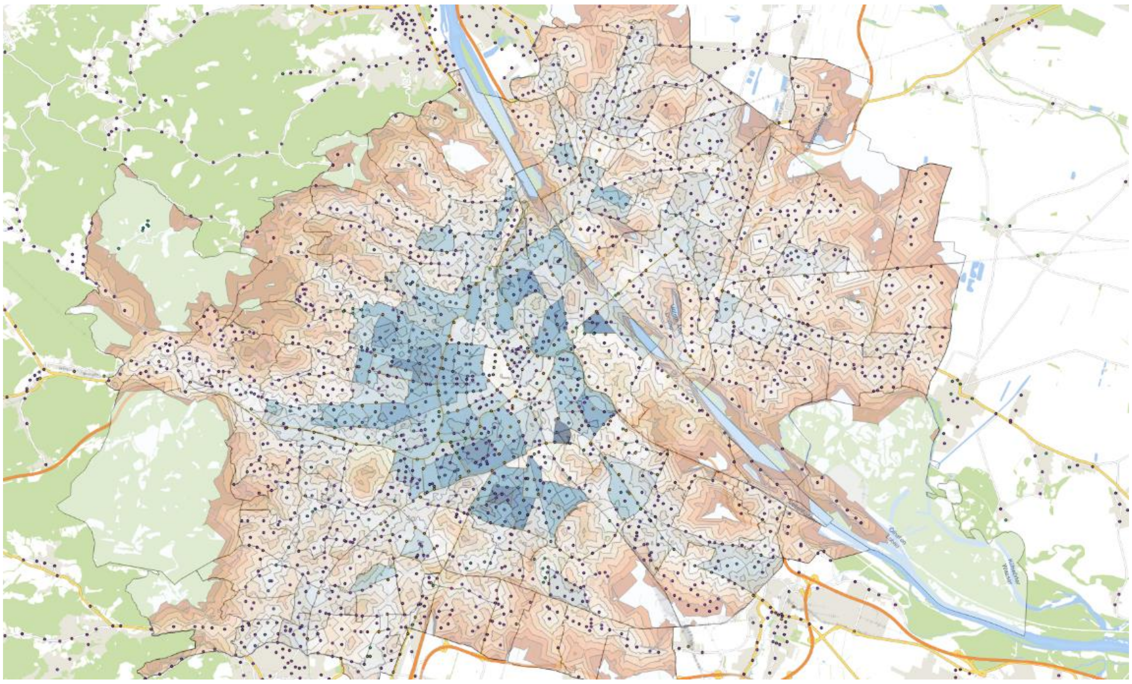

Figure 13: Public Transport Service Quality Level with population density

Table 9: quality level - quality description and spatial assignment (Raumordnungskonferenz, 2017)

Quality level	Quality description	Spatial assignment
A	highest-ranking public transport development	urban
B	high-level public transport development	urban
C	very good public transport development	urban/rural, PT-axes, PT-nodes
D	good public transport development	urban/rural, PT-axes, PT-nodes
E	very good basis development	rural
F	good basis development	rural
G	basis development	rural

The ticketing system in Vienna and Vienna's surroundings should be improved: the better and cheaper the prices for public transport, the higher the attractiveness and satisfaction of public transport users. Today's price model for public transport makes occasional trips expensive, which means that fewer people use public transport. The current pricing model is critical for people who rarely use public transport. It may also be that some people only have a tangential target, e.g. if someone lives in an area and want to use the bus for only two stops to visit their neighbor. One possible solution can be the so-called "Oyster Card". This card system enables passengers to pay per trip. There is even a daily price limit, which means that once you have reached the daily limit, all other trips are free. This system has already been successfully used in London.

Micro Public Transport is another policy intervention to have less traffic in rural areas. Micro public transport can help to improve and strengthen the existing public transport system. It is to be integrated into the transport concept, especially to deal with the problem of locomotion in rural areas. This raises the question of how to get to the last mile to the train / S-train?
Micro Transport can be the solution without a fixed schedule, therefore it is based on customer needs. With the help of intelligent software via an App, the trip can be booked online. In this way, the Micro public Transport can be seen as an alternative to private vehicle.

5 Greater Manchester

Greater Manchester (GM) is formed of eight boroughs (towns with limited self-governing administrative power) Bolton, Bury, Oldham, Rochdale, Stockport, Tameside, Trafford and, Wigan, and two cities, Manchester and Salford. Greater Manchester is governed by Greater Manchester Combined Authority (GMCA) and transport within the GM is co-ordinated by Transport for Greater Manchester (TfGM), a government body. TfGM's important function is also to propose visions and strategies for transport and deliver those.

TfGM has recently published their transport strategy 2040 that spans 25 years from 2015 (Transport for Greater Manchester, 2017). This document outlines visions, principles and policies, challenges and interventions. This was considered as a starting point for this work and backcasting was outlined based on this document. City dialogues with TfGM was utilised to align and refine the backcasting with recent developments. The overall backcasting for GM is shown in Figure 14 below. It should be noted that this picture does not show a complete set of interventions and influencing factors that GM have but only a subset that is deemed relevant to CATS. Boxes with bold text show interventions and influencing factors either directly or indirectly related to CATS.

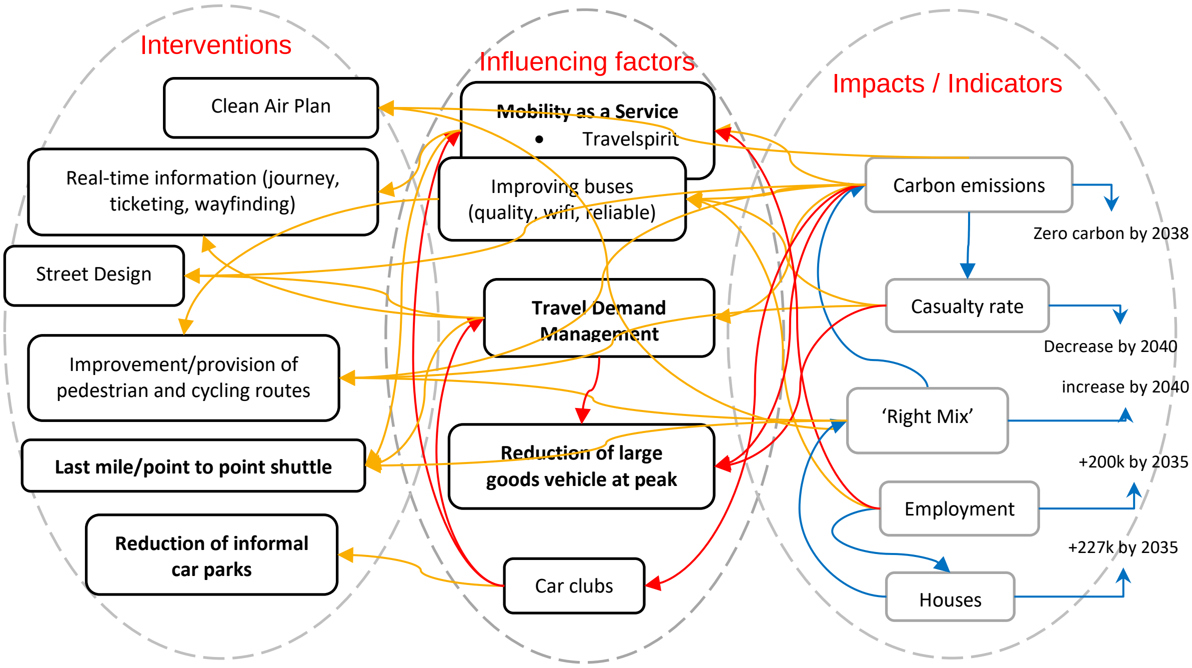

Figure 14 Backcasting for Greater Manchester.

5.1 Vision

As stated in their strategy document, GM's vision for the transport is to have "*World class connections that support long-term, sustainable economic growth and access to opportunity for all*". This is aimed at connecting people to opportunities and information, entrepreneurs to ideas and capital and employers to talent and skills. The strategy is thought to play a role in creating better places in terms of supporting developments, reduction in dominance of cars and goods vehicles and improving the environment. The vision can be illustrated as shown in Figure 15 taken from (Transport for Greater Manchester, 2017).

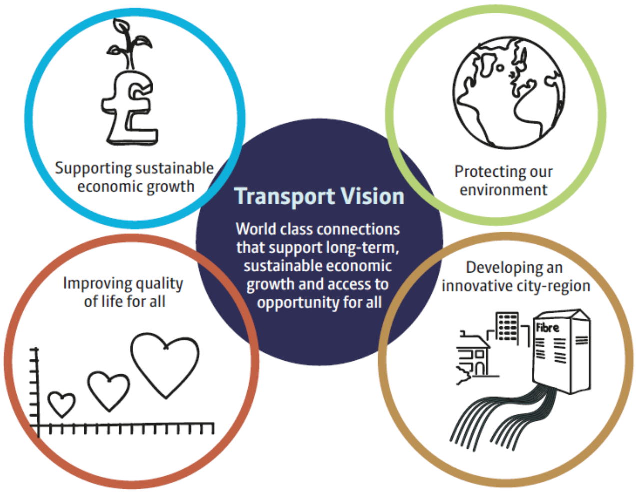

Figure 15 Transport vision for Greater Manchester (Transport for Greater Manchester, 2017).

This vision is accompanied by a few challenges. These are listed below.

- GM has ambitious economic growth plans leading to an increase of 199,700 jobs. This combined with rapidly growing population will require around 227k dwellings across the GM leading to increase in transport demand.
- Quality of life: Around 20% of the GM population lives in deprived areas and 31% of households do not have a car. By 2040, around 25(17) % adults will be over 60 (70). Nearly half of all trips are less than 2 km of which 38% are by car. Nearly half of all adults do not get recommended level of physical activity. Whilst the casualty rate (26 per year) is below the national average (39 per year), pedestrian and cyclist injuries are still high, 1000 (in 2014) and 569 (in 2013), respectively.
- Transport is responsible for around 1/3rd of carbon emissions which is cause of increased winter rainfall, deaths caused by air pollution, increase in annual mean temperature and economic costs.
- Digital systems and devices are increasingly becoming part of daily lives and connected devices and services are growing exponentially.

Furthermore, the relevant indicators from above visions and challenges can be summarised in Table 10, below. Subsequently, corresponding indicators within LEVITATE project are identified and mentioned in the right most column. It should be noted that housing is considered as an impact/indicator since it could be used to gauge the increase/decrease in economy. Also, housing and employment are closely inter-linked, and GM is actively engaged in increasing housing for the residents (GMCA, 2019).

Table 10:indicators with their specified target values for Greater Manchester.

Indicator	Definition	Most recent value available	Target value (2040 unless otherwise stated)	LEVITATE Indicator(s)
Mobility Behaviour				
'Right Mix' (Modal split in passenger transport)	Modal split for the GM population	39:61 (sustainable[5]:car) Year 2014-2016	50:50	Energy consumption, Transport mode split
Economy				
Employment	Number of jobs	1.25 million in 2011	Increase to 1.4 million by 2035	Employment
Housing	Number of dwellings available within GM	1.2 million in 2011	Increase to 1.4 million	Economy, land use
traffic safety				
Accidents	Number of traffic casualties per year	25 per 100k population per year (as of 2013-2015)	Decline	Casualty
Energy and environment				
CO2 emissions	Traffic-related CO2 emissions in GM	16.5 MtCO_2 (year 2010)	Zero CO_2	CO_2 emissions

The above-mentioned indicators for the vision can be illustrated in Figure 16. Their inter-dependencies in terms of influencing one-another have been identified and is shown in Figure 16. This is in line with Table 1 where each dimension, society (mobility behaviour in this case), economy, safety and environment are addressed to maintain a balanced approach.

[5] Here, sustainable transport includes public transport, cycling and, walking.

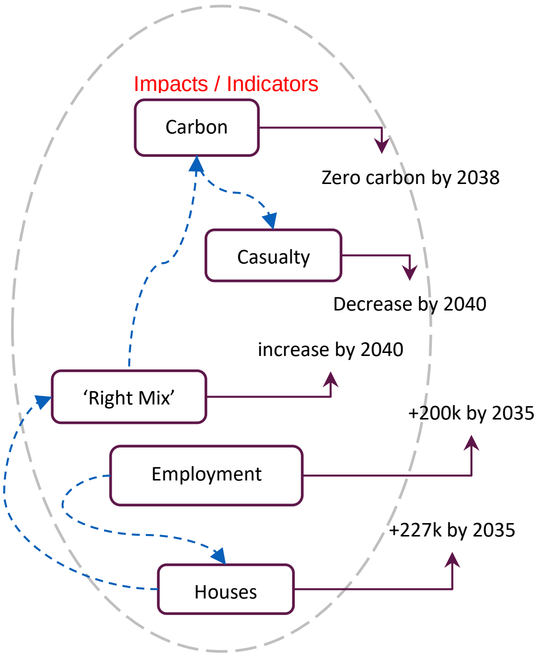

Figure 16 Indicators and their inter-dependencies identified for Greater Manchester.

5.2 Influencing factors

The parameters that were considered to be influenced by interventions and further influence on impacts/indicators were considered as influencing factors. These are shown in Figure 17.

Mobility as a Service (MaaS)
TfGM seeks to deliver integrated pricing and payment systems across the transport network including smart ticketing for public transport to support delivery of 'mobility as a service (MaaS)' concept. MaaS is widely considered as a service that is directly linked to connected transport. As a starting step, TfGM supports TravelSpirit (About the TravelSpirit Foundation, 2020), an organisation that connects individuals, businesses and organisations to facilitate and support the growth of sustainable MaaS. Within the context of LEVITATE, we think that this will have direct impact on carbon emissions and employment.

Improving buses
Buses are very effective road transport for people mass movement as they do not require large road space as compared to cars with equivalent passengers. Despite their operating efficiency, the bus patronage has declined in post-war UK. By introducing, Transport Act 1985, the UK government, then, tried to increase bus patronage by increasing competition amongst bust operators through deregulation of services. Recently, UK government introduced Bus Services Act 2017 (Archives, 2017), that provides elected mayors and local authorities with powers to improve bus services through regulation (or re-regulation). This act states that the co-ordination of bus services is to be provided by

local transport authorities can decide on awarding bus service contract to the operator who meets to requirement of bus service network, timetables and ticketing on competitive bases. As GM falls under this category, they have taken this opportunity to improve bus services by various means.

- GM has plans to include bus services across various networks.
- Introduction of bus priorities at various junctions.
- Improvement in passenger comfort, provision of Wi-Fi services
- Integrated ticketing to make travel easier

Improvement in buses will support employment opportunities and also take part in reducing emissions through less reliance on private car transport. This will have further positive impact on road safety.

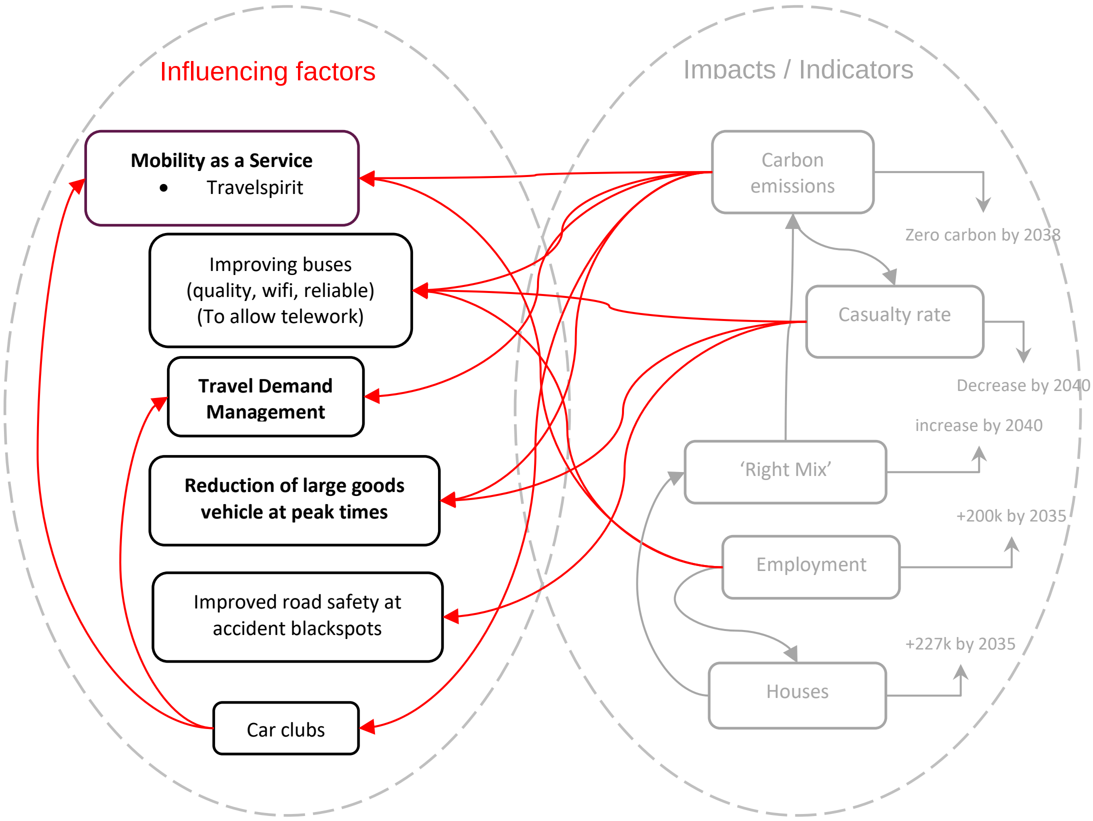

Figure 17 Influencing factors and their inter-dependencies identified for Greater Manchester.

Travel Demand Management

GM seeks to apply Travel Demand Management (TDM) to make better use of the highway's capacity in GM. This will also implement any lessons learnt from the M27 TDM pilot scheme in Hampshire in the UK. The TDM will consider any measures that will contribute towards objective of managing demand. This will include influencing travel behaviour through various means such as, marketing and communication with travellers and engagement with businesses to encourage retiming of journeys and car-pooling/car share; provision of information on modal choices and appropriate facilities within new development to support non-car modes; constraints on long-term parking in our key centres; and measures to enhance the priority for sustainable modes.

Reduction of large goods vehicle at peak times
As mentioned in their Streets for All agenda in 5-year delivery plan (Transport for Greater Manchester, 2019), GM is considering following options in relation to reducing large goods vehicle at peak times.

- Work with retailers to reduce number of delivery vehicles at peak times
- manage the impact of major construction sites on our roads and local communities, through the implementation of construction logistics plans
- introduce sustainable distribution where possible, including the consolidation of freight movements in urban areas and for public sector organisations
- Move more freight by rail where possible. The opportunity to introduce rail freight into Port Salford will be key to facilitate the delivery of Port Salford as a tri-modal logistics hub.

Car clubs
Some parts of GM have under-developed public transport system, making car travel essential for those residents. The rise in popularity of "shared economy" makes it possible for any individual to access car when needed without having to own one. This concept is known as "car clubs" in GM. GM supports this activity (Manchester City Council, n.d.) and believes that it has potential to reduce number of cars on the roads and parking provision needed. As of 2015, there were 1941 members of car club (comouk, n.d.).

GM will develop pricing and payment system that will enable customers to search and pay for a range of travel services through "account-based travel" known as "mobility as a service". These travel services include car clubs amongst others such as public transport, cycle hire and parking. This will be delivered through smartcard, credit/debit card, mobile phone or other cashless technology. This concept will also support Traffic Demand Management to manage demand across GM's transport networks.

5.3 Policy interventions

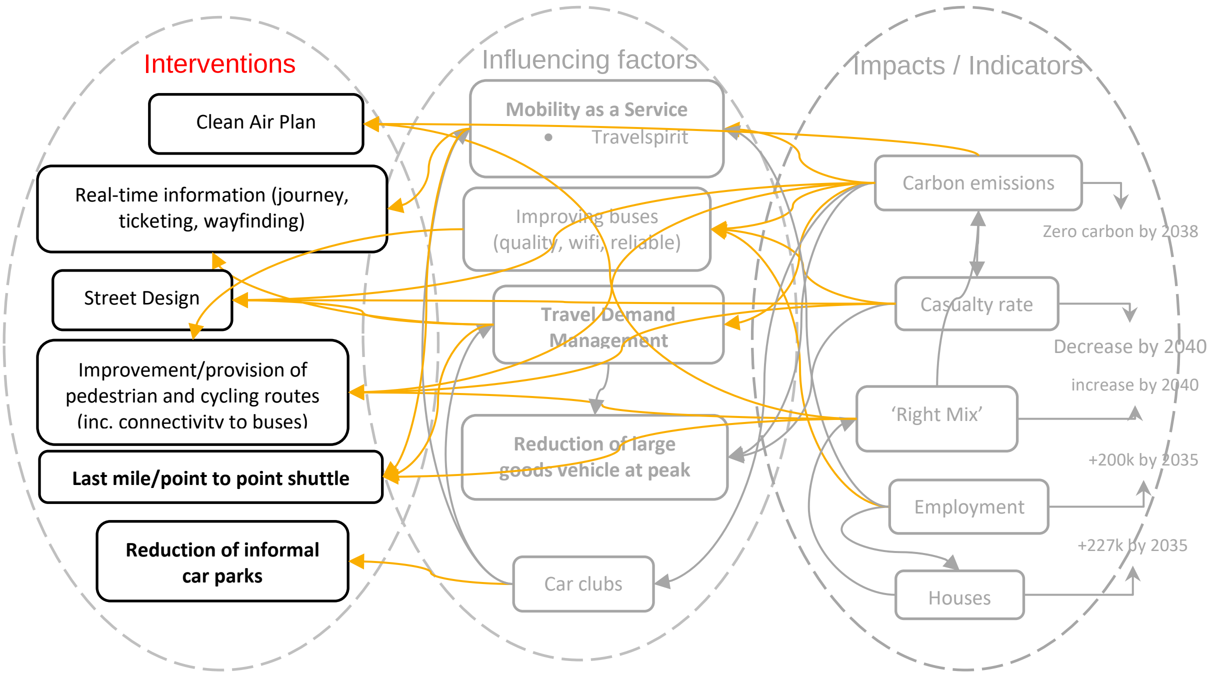

Figure 18 Interventions identified for Greater Manchester.

Last mile/point to point shuttle
GM supports testing of new technologies such as autonomous last mile and point to point shuttles. Currently, pilot projects (Synergy CAV, n.d.) have been planned to test CAV shuttles between Stockport and Manchester Airport and, a Salford University campus CAV shuttle.

When considering last mile shuttles, priority will be given to the group who needs it most including old age, children and disabled. The priority can be provided in terms of exempt passes to discourage competition with active travel.

Reduction of informal car parks
As stated in their strategy (Transport for Greater Manchester, 2017), informal car parks that provide low-cost parking near The Quays and the MSIRR will be converted to high-quality and high-density development. The loss of informal parking provision will be a major catalyst in reducing the attractiveness of car travel to the Regional Centre and will need to be supported by provision of alternative attractive travel options. This will encourage people travel behaviour to achieve 'the right mix' vision and contribute to lowering carbon emissions as well. It is widely believed that CATS will need less parking space as their usage is optimised due to their connected and autonomous nature which allows users to share the vehicle at same time or sequentially.

Clean Air Plan

As mentioned in their Clean Air Plan (Clean Air Greater Manchester, n.d.) and 5 year delivery plan (Transport for Greater Manchester, 2019), GM considers following options to meet their target of zero fossil fuel based emissions by 2040. The list below shows CATS related interventions only. The fuller list is available in (Transport for Greater Manchester, 2019).

1. Clean air zone (CAZ) has been proposed to be introduced in two phases, from 2021 and from 2023 (Clean Air Greater Manchester, n.d.). The exact boundary is still in public consultation. However, it is clear that the zone will cover local roads but not motorways and main trunk roads that are managed by Highways England. The penalty will be on daily basis, 24/7, for some buses, coaches, lorries, vans, taxis, private hire vehicles, minibuses, motorhomes and motorised horseboxes. Although this intervention is not CATS related, this will influence the travel behaviour and therefore can influence the adoption of CATS, positively or negatively.
2. Differential parking charges - different charges for times of day, vehicle type, car-sharers and could include a workplace parking levy. Parking charge will affect the usage of AVs and it will influence on people's decision on car sharing.
3. Congestion Deal – network management - Changing traffic signal timing to optimise flows, reducing congestion. CATS is believed to enhance the network management due to its connected feature.

Real-time information

In support of 'Mobility as a Service' concept, TfGM provides an app known as 'My TfGM' for mobile devices that allows users to do wayfinding that includes multimodal journeys, including active travel modes. It also allows users to look at timetables and live journey information, live service updates and so forth. It provides contact information of transport operators in Greater Manchester. With the app 'get me there', the users are able to book and use tickets to use metrolink in Manchester through their mobile phone devices. For 'Mobility as a Service' to work seamlessly, a 'one stop shop' type app will enable users to access multiple modes of transport through single ticket. This is seen as a step closer towards connected transport.

TfGM supports open data and mobile phone app developers can access the real-time data through API. This will foster high quality mobile apps to help travellers make informed and smart choices (Transport for Greater Manchester, n.d.).

Improvement/provision of pedestrian and cycling routes (incl. connectivity to buses)

TfGM has proposals in improving road network significantly as shown in Beeline report, creating walking and cycling routes aggregating to 1800 miles across GM (Boardman, n.d.; Transport for Greater Manchester). The plan includes creation (in some cases upgrading) of cycling lanes, crossings, segregated routes that connect communities to schools, employers, town and city centres. Consideration will also be given to providing filtered neighbourhoods through street designs such as cul-de-sac to block the through motorised vehicular traffic but allowing walking and cycling. This will provide safer environment for socialising.

Bike parking and storage facilities will be created/increased near bus stops and stations encouraging active transport from home to public transport. This intervention is related to connected micro-transport system where e-bikes and e-scooters can be used to provide first/last mile journeys.

Street Design
As mentioned in their strategy document, (Transport for Greater Manchester, 2017), 'Streets as places' is a concept where streets function as a link where users can pass through and also as a place in its own right. TfGM recognises that there is a balancing need between link and a place in terms of streets' function and so the interventions will differ according to the requirements of users. Their 'Street for All' agenda sets out more detailed interventions across GM that supports improvement in streets identified as its major function as moving vehicular traffic as well as streets identified as places, to provide safe environment for pedestrians and cyclists (Transport for Greater Manchester, 2019). TfGM also have plans for improvement in junctions to provide higher priorities for buses to make public transport more attractive. This intervention is related to CATS and in particular autonomous vehicles (AVs) where the traffic should be directed to those streets identified as link (traffic bearing streets) function rather than places (such as residential or town centre streets). Directing traffic to desired streets can also be achieved by cul-de-sac design mentioned in previous intervention such that AVs cannot be misused to follow longer routes through residential areas to avoid congestion.

While actively supporting the development and deployment of CAVs in the UK is a strategic goal on country level (Centre for Connected and Autonomous Vehicles - About Us, n.d.), the main geographic focus of corresponding research and development activities seems to be concentrated around midlands and south of the UK (Centre for Connected & Autonomous Vehicles). This may be due to existing infrastructure and concentration of automotive industry in the area. However, there are ongoing efforts from other parts of the country to secure funding for the CAV activities which will likely change this landscape. The city strategy of Greater Manchester (similar to many other European cities) does not mention the deployment of CAVs as a priority goal by itself, nevertheless this topic is seen as relevant for achieving the high-level goals.

6 Amsterdam

The aim of this chapter is to apply the backcasting steps to a city dialogue with Amsterdam. Through the discussion with the city, the vision relevant for LEVITATE were identified. The vision represents the city goals and influencing factors for a specified point in the future. Afterwards, specific policy interventions are discussed to achieve the city goals.

Figure 19 illustrates the backcasting approach in several steps for the city of Amsterdam. It shows a network of dependencies split into three pillars that will be further explored. The pillars start on the right with the city vision, moving to the left pillar that represents possible policy interventions. The arrows indicate links between the city goals, influencing factors and the relevant policy interventions.

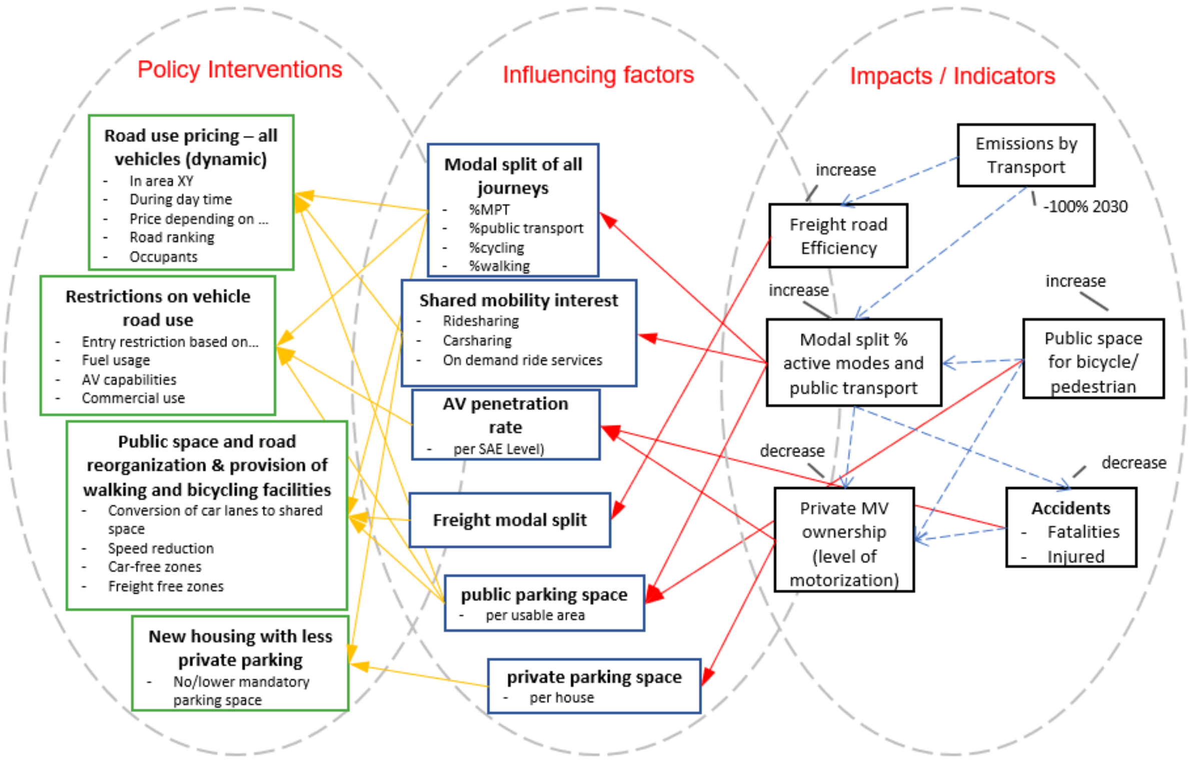

Figure 19: Backcasting for Amsterdam - Overview

During the dialogue with the city of Amsterdam six main goals were identified that are especially relevant for LEVITATE. These goals are mapped to the indicators and impacts which were mentioned in various working papers of the LEVITATE project. Appropriate interventions for each goal were discussed and potential options of interest are identified.

6.1 Vision

As Amsterdam grows, the amount of traffic and routes grow in a similar manner. With this expansion comes a steady increase in emissions. Short distances can be travelled by bike or on foot, and the introduction of electrical bikes increases the range of these trips even further. Keeping these active modes of transport appealing will allow a city to sustainably grow for a long time.

The city of Amsterdam therefore states its goal in 2040 as: “economically strong and sustainable” (Gemeente Amsterdam, 2011). In order to achieve this goal, the following pillars are introduced:

- More intensive use of the existing city
- Paradigm shift for public transport
- High quality public space
- Investments in green and water
- Post-fossil era

The overall goal of Amsterdam is to reduce emissions from inner city transport to zero by 2030. The main sub-goals in the field of mobility related to this are:

- An increase in active modes of transport (bike and pedestrian) and public transport.
- A reduction of private transport by shifting toward other modes.
- A reduction in freight emissions by implementation of alternative modes or new methods of propulsion such as hydrogen and electromotors.

The Amsterdam mobility-approach for 2030 (Gemeente Amsterdam, 2013) sets out the goals of a viable Amsterdam transport system in the future. In addition to the mobility-approach, an approach for “Amsterdam autoluw” (Amsterdam car-shy) sets out further goals and methods (Gemeente Amsterdam, 2019). Figure 20 and Table 11 below give an overview of the different goals.

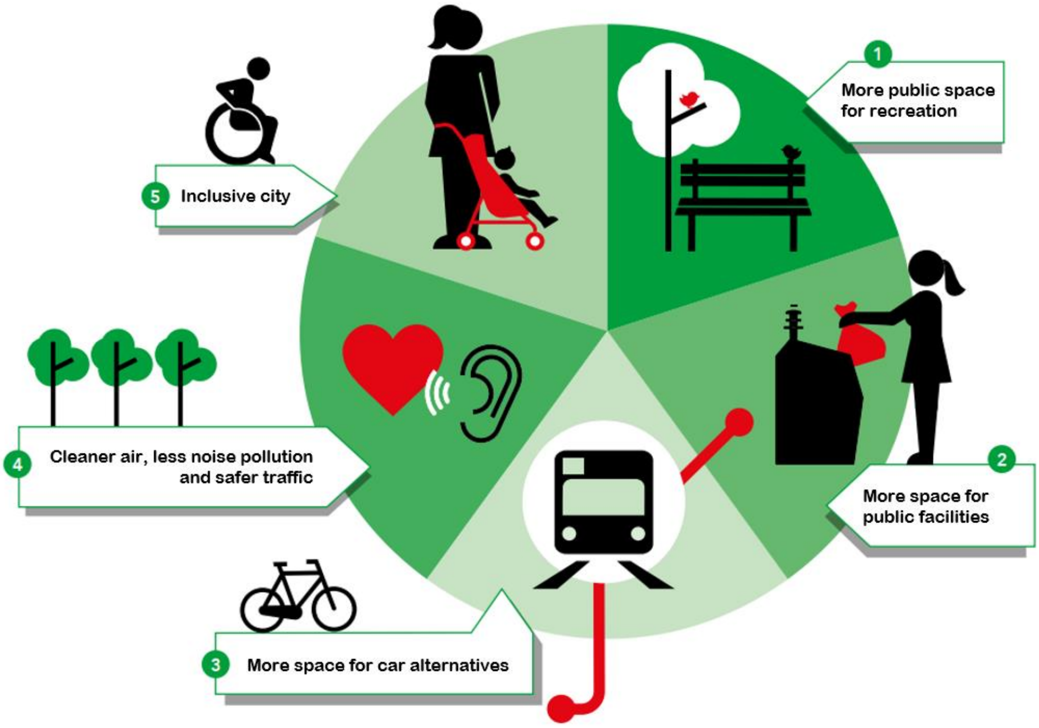

Figure 20: Amsterdam autoluw goals translated from the original Dutch source

Table 11: indicators with their specified target values for Amsterdam

Indicator	***Definition***	***Most recent value available***	***Target value (2030)***	***LEVITATE Indicator(s)***
Mobility Behaviour				
Modal split in passenger transport	Modal split for the Amsterdam population, referring to the number of trips (eco-mobility: MIT)	2017: 81:19	rise	Energy consumption Transport
Modal split active mode	Percentage of population using bike or walking	2017: 59%	rise	(relationship to LEVITATE indicators, but not covered explicitly)
Mobility Services				
Degree of motorisation	Passenger cars per 1,000 inhabitants	2017: 400	decline	(relationship to LEVITATE indicators, but not covered explicitly)
Public space				
Public space	Share of land (%) designated as public space	2018: 61%	rise	Land use
Traffic safety				

Accidents	Number of traffic casualties per year	2015: 11	Decline	Fatalities
	Number of persons injured in traffic accidents per year	2009: 957	decline	Injured
Energy and environment				
CO_2 emissions	Traffic-related CO_2 emissions in Amsterdam	2016: 360 kt	0 kt	CO_2

The goals determined during the City dialogue are a combination of the selected indicators and help specify the target direction for future development. The targets are aligned with the Design and Structure Vision Amsterdam 2040 (Gemeente Amsterdam, 2011). The vision broadly follows the three of the four dimensions (Safety, Society, and Environment) that are also discussed in Table 1 of chapter 2.2.
The main targets of Amsterdam related to LEVITATE are:

- Emissions from transport are reduced to zero by 2030
- The efficiency of road-based freight transport is increased by 2040
- The modal split percentage of active modes and public transport increases by 2040, reducing the percentage of motorised private vehicle travel
- Public space available for bicycle and pedestrian usage increases by 2040
- By 2040 private motor vehicle ownership has decreased even further
- The number of traffic casualties and injuries declines further

Figure 21 shows how the different goals are related to each other. The three city goals in the boxes on the right side are the main goals, that should be linked to the three goals on the left side to help reach these goals.

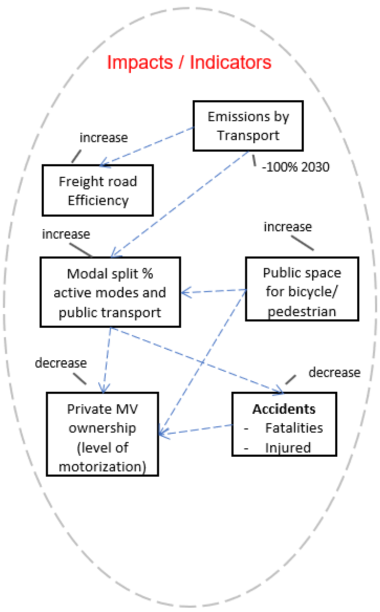

Figure 21: Impacts/indicators-Amsterdam

The most upper goal of Amsterdam is to reduce CO_2 emissions by transport to zero within the inner city by 2030. As can be seen in the figure this target relates to two other

goals. The reduction of CO2 is helped by an increase in freight efficiency and usage of active and shared modes of transport.
Increasing the efficiency of road-based freight transport is another city goal. If a higher efficiency can be reached, less travel is needed to supply the same amount of freight. This becomes especially relevant in the busy inner city.
A change in modal split to a higher percentage of active and public transport is a goal that assists in achieving the emission reduction and ensuring a safe and accessible city centre. In order to achieve this goal, the distribution of public space plays an important role.
As a next step, Amsterdam wants to increase the public space available for bicyclists and pedestrians. Current methods to achieve this goal are to redistribute space currently allocated to cars and parking into spaces suited for cyclists and pedestrians.
Decreasing the number of private motor vehicles per inhabitant is a further goal. This is in part achieved by promoting other methods of transport above private car travel.

Underlying each of the above-mentioned goal is the decline in traffic casualties and injuries. While there is no target for Amsterdam traffic deaths, getting as close to zero should be the goal.

6.2 Influencing factors

As the next step after defining the vision, the influencing factors are defined. The influencing factors are the main parameters that were defined to estimate the impacts of CATs. These factors are expected to be affected further by the policy interventions that are under consideration and will ultimately result in the impacts discussed above. The following Figure 22 presents the relevant influencing factors as determined by the city dialogue and policy documents.

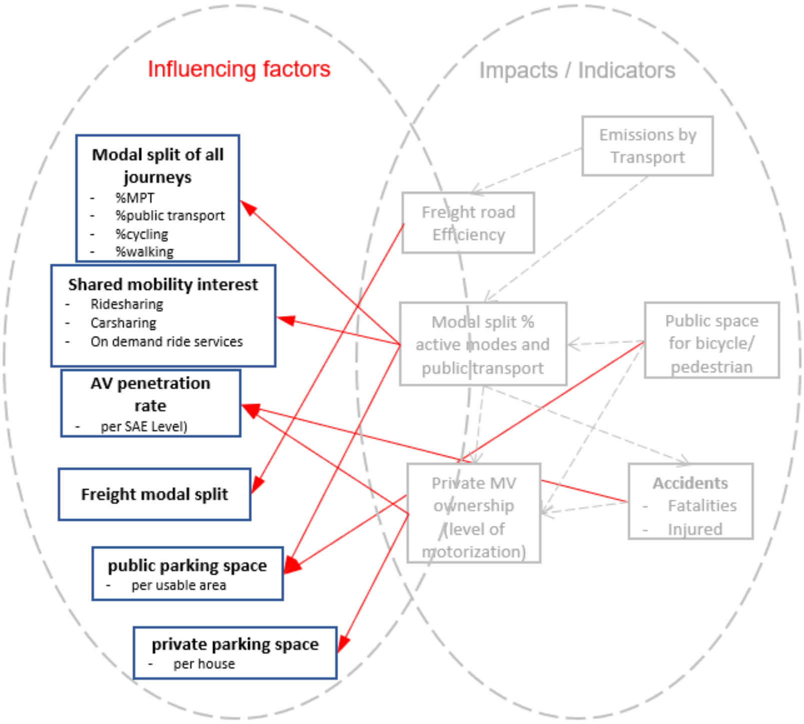

Figure 22: Influencing factors-Amsterdam

Shared mobility
As stated in paragraph 4.2, car sharing has the potential to contribute to a decrease of car journeys, ownership and parked vehicles. While there are some options already available in Amsterdam, interest in car sharing is still low. Plans to increase the adoption of car sharing systems are being developed (Gemeente Amsterdam, 2019). Trips made by car sharing are replacing not only trips made by private car, but also trips previously made by public transport or bike. Increased access to car sharing could therefore negatively influence usage of active transport modes and public transport.

AV penetration rate
Just as stated for Vienna in paragraph 4.2, an increase in AV penetration rate will likely increase traffic safety. It might be possible that AVs will not be able to safely function within certain parts of the city, requiring other solutions for transport in those locations. This becomes especially relevant in the inner city of Amsterdam, with many pedestrians and cyclists all moving in irregular patterns.

Public parking space
The availability of public car parking space influences the share of private vehicle ownership and the share of public space. If the availability of parking decreases, people will be more likely to worry about parking their car and choose public transport or active modes more often. Sufficient parking availability for bicycles influences the usage of bikes as a mode of transport.

Private parking space
The availability of private parking space will influence the share of private vehicle ownership. When there is no option to park a car close to home, the attractiveness of

owning a private car decreases. If no attractive alternatives to private car transport are available, private car ownership will not be affected as much.

Modal split of all journeys

Modal split of all journeys means the percentage of private transport, public transport, cycling and walking. A decrease in private vehicle transport will influence desired goals in different ways. Less individual car use helps free up space for active modes, public space and can increase the usage of public transport. An increase in private car use will most likely exacerbate the issues with road use already present.

Modal split of freight

Modal split of freight means the percentage of freight by truck, alternative road transport, and possible transport by water. The lower the share of traditional road-based transport, the higher the influence on emission, road use and freight kilometers.

6.3 Policy interventions

The following chapter describes the individual interventions discussed during the city dialogue in more detail. Figure 23 shows the overall scheme with the policy interventions on the left side. In some cases, the city of Amsterdam suggested examples of where interventions could be set out. These examples are aimed at critical regions within Amsterdam and follow a similar pattern to current approaches.

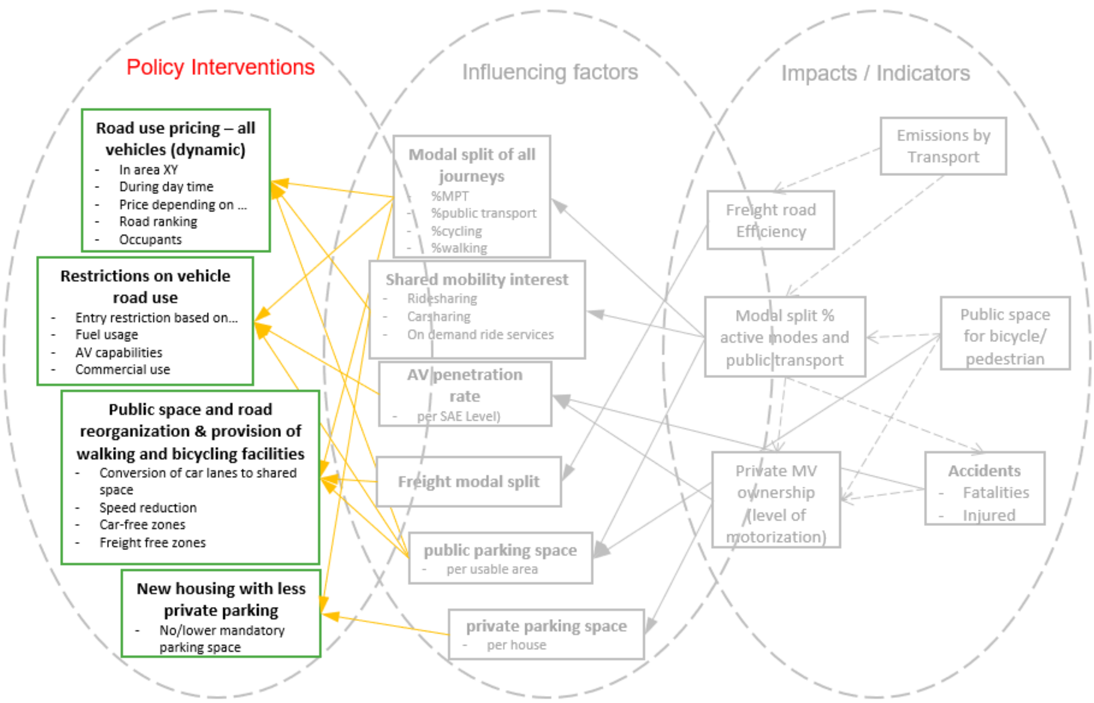

Figure 23: Policy interventions-Amsterdam

The following policy interventions are considered within this project, divided into:

- Road use pricing for all vehicles (dynamic)
- Restrictions on vehicle road use

- Public space and road reorganisation & provision of walking and cycling facilities
- New housing with less private parking

Road use pricing for all vehicles (dynamic)

Road use pricing is one of the important policy interventions discussed in the City dialogue. This intervention is linked with several influencing factors such as the modal split, interest in shared mobility, and the modal split for freight. With the reduced impact of parking prices as a way to control these factors, it is conceivable that road use pricing could be used to help achieve the city's goals in 2040. These goals are for example the usage of active modes, freight road kilometres, and private motor vehicle ownership. Pricing might be influenced by time of day, location, number of people in the vehicle, road ranking, and the amount of congestion present. When considering this intervention, it is important to carefully determine what is most convenient and effective.
While a national implementation of road use pricing is possible, a more local approach can be used within the city. Areas such as the city centre, residential areas or roads with more cycling activity could be targeted, as these areas are most at risk.

Restrictions on vehicle road use

To increase the level of safety on city roads is one of the main underlying goals of Amsterdam. While automated vehicles will only be permitted if they are proven to be safe, possible issues arise within the very busy city centre. The sheer complexity of the inner-city traffic system may make it impossible for AVs to function effectively, resulting in slow or even completely immobile traffic. It might therefore be necessary to develop a suitable measure to ensure future goals can be achieved. A restriction of vehicles in certain areas can be implemented in a similar fashion as road use pricing.
Restricting freight vehicles from using residential roads or only allowing freight movements during selected time windows, placing restrictions on AVs without passengers or AVs in general within the inner city are examples of possible implementations. Current restrictions for diesel trucks are an example of area restrictions based on emissions. Possible extensions of these environmental zones to other areas or other types of vehicles could be put in place in the near future.

Public space and road reorganisation & provision of walking and cycling facilities

One of the main goals of Amsterdam is a redistribution of public space to allow for more space for active modes of travel and public transport. In order to achieve this goal, some interventions are proposed. These interventions are aimed at redistributing space currently allocated to motor vehicles into space attractive for active modes and other public use. These interventions include a number of influencing factors, such as parking spaces and the modal split.

Potential ideas for restructuring public space discussed during the dialogue with the city of Amsterdam are:

1. A conversion of above-ground parking spaces into areas designated for walking, cycling or other functions such as bicycle parking or utilities. This could mean the changing of parking lanes into pedestrian walkways or biking lanes. In order to still facilitate parking within the city, new parking structures could be created underground. These underground parking facilities could be designed with automated vehicles in mind, potentially allowing for higher capacity than current parking structures.

2. Redesigning of certain roads into “fietsstraten” (bicycle-roads). These roads no longer have a separate lane for cyclists but are designed primarily for cyclists. This means a reduced speed of 30 km/h, wide lanes with a priority for cyclists and cars as “guests”. These roads are paved in the same red colour as normal cycle paths and have priority over crossing roads (Gemeente Amsterdam, 2018). This way the roads can be seen as an efficient route for cyclists where their comfort and safety are improved. The shared character of these roads could make it difficult for AVs to function, possible making these roads unusable for automated vehicles.
3. Speed reductions in residential areas, shopping streets and school streets to allow for safer pedestrian crossing and cycling.
4. Car-free zones with access restrictions. Zones with restrictions on full sized freight vehicles are also possible. The introduction of automated freight transport could see a change from full sized vehicles to smaller vehicles in greater numbers. Restricting vehicles above certain size can help to improve traffic flow.

New housing with less private parking
With the expansion of the city of Amsterdam in the coming years, new housing will be realised. When implementing new housing solutions there are requirements for a minimum number of parking spaces. In order to achieve the goal to reduce private motor vehicle ownership it might be necessary to take measures when constructing new parking.

A reduction or complete removal of the minimum required parking spaces for new neighbourhoods allows for less private parking spaces to be constructed. This intervention could decrease the attractiveness of private motor vehicle ownership. Further design choices should be focused on facilitating alternatives to private cars to ensure that mobility is not negatively impacted. Availability of public transport and the creation of a good cycling network are examples of compensatory measures. The introduction of AVs capable of self-parking might decrease the effectiveness of this measure.

7 Discussions and conclusions

7.1 Common findings and identified discrepancies

The results of the city dialogues for Vienna, Amsterdam and Greater Manchester as presented in the last chapters show a high degree of congruence (for example regarding environmental goals), but also exhibit different priorisation of key targets and influencing factors. Table 12 tries to summarise the key findings, showing overlaps and common goals, influencing factors and policy interventions.

Table 12: Comparison of the cities Vienna, Amsterdam and Greater Manchester by LEVITATE backcasting steps – city goals, influencing factors and policy interventions

<table>
<tr><th></th><th>Vienna</th><th>Amsterdam</th><th>Greater Manchester</th></tr>
<tr><td rowspan="7">City goals (Vision)</td><td colspan="3">reduction of CO2 emissions by transport</td></tr>
<tr><td>decrease final energy consumption transport</td><td>decrease freight road kilometres</td><td>increase the number of dwellings</td></tr>
<tr><td colspan="2">increase public space for bicycle/pedestrians</td><td>increase employment</td></tr>
<tr><td colspan="3">increase modal split/eco-friendly ('right mix')</td></tr>
<tr><td colspan="3">decline accidents fatalities and injured</td></tr>
<tr><td colspan="2">decrease private MV ownership (level of motorisation)</td><td></td></tr>
<tr><td>decrease traffic crossing the municipal boundaries</td><td></td><td></td></tr>
<tr><td rowspan="6">Influencing factors</td><td colspan="2">modal split of all journeys</td><td>mobility as a service (MaaS)</td></tr>
<tr><td colspan="3">shared mobility/ travel demand management</td></tr>
<tr><td colspan="2">AV penetration rate</td><td>improved road safety at accident blackspots</td></tr>
<tr><td></td><td>freight modal split</td><td>reduction of large goods vehicle at peak times</td></tr>
<tr><td colspan="2">public parking space</td><td>car clubs</td></tr>
<tr><td>shuttles</td><td></td><td>improving buses</td></tr>
<tr><td rowspan="6">Policy interventions</td><td colspan="2">road use pricing -all vehicles (dynamic)</td><td>clean air plan</td></tr>
<tr><td colspan="2">restrictions on vehicle parking & road use</td><td>street design</td></tr>
<tr><td colspan="2">public space reorganisation & provision of safe walking and bicycling facilities</td><td>improvement/provision of pedestrian and cycling routes (incl. connectivity to buses)</td></tr>
<tr><td rowspan="2">last-mile shuttle/ Micro public transport/ multimodal public transportation packages</td><td rowspan="2"></td><td>last mile shuttle</td></tr>
<tr><td>real-time information (journey, ticketing, wayfinding)</td></tr>
<tr><td></td><td colspan="2">new housing with less private parking/ reduction of informal car parks</td></tr>
</table>

One striking difference that has been observed is the significance of economic goals, like increase in employment, in city strategies – and the relevance of related factors, e.g. housing and road capacities between cities. This is quite important for the Greater Manchester area, but is not seen as high-priority topic for Vienna and Amsterdam.

7.2 Conclusions

The results reported in this deliverable, in particular those of the city dialogues covered in Chapters 4 – 6, have provided the foundations for backcasting in the LEVITATE project, linking the high level goals and corresponding target indicators to possible CATS related influencing factors, and further linking these factors to the most promising policy interventions. This approach outlines "feasible paths of intervention" in a first, qualitative way; they are left to be verified through quantitative methods in further course of the project.

One of the starting points was an approach for defining quantitative *visions* in terms of indicators and targets that are related to CATS (i.e. CATS are expected to contribute towards these goals in some way), considering a wider range of indicators across four dimensions (safety, society, environment and economy). This approach ensures that the complexity of the high-dimensional indicator space is considered and dependencies between goals (whether supporting each other or conflicting) are not ignored.

The main contribution reported in this deliverable was to connect this formal definition of visions to the city strategies in three case studies, and to perform an interactive qualitative backcasting in three main steps. CATS influencing factors have been identified that are expected to support cities in reaching their specific targets. These influencing factors are closely related to the various use cases that have been selected in LEVITATE. Finally, policy interventions, some of them very specific for the city under consideration, have been proposed and discussed with city representatives.

Some policy interventions discussed here might not be directly related to CATS or automated vehicles (AVs) – for example, related to street design, parking space, EVs or active modes of transport – but have certain links with CATS related factors. On the one hand, rise of AVs might allow for some policy interventions which are not useful right now, on the other hand cities might have to react to prevent negative impacts from misuse or overuse of AVs.

For some high-level goals (CO2 emissions by transport, Public space for active modes …) it is also clear that CATS can only distribute to a certain (in some cases only to a small) degree. It might even happen that some proposed policy interventions lead "directly" to the target goals of the vision, without going through the CATS influencing factors discussed here. Note that such interventions are not in main scope of the project, but they were not completely ruled out in the city dialogues as they are still very relevant for the cities.

It has also become clear that, due to uncertainties in the expected impacts of uptake of AVs, it is a challenge to define quantitative pathways. Several different scenarios could be further considered here for further investigations and each of them would result in different policy interventions needed at a particular time. Finally, quantitative impacts are also hard to predict because optimal use of AVs might require a different way of planning for which existing tools and data are inappropriate.

7.3 Outlook

As discussed, the backcasting process so far has delivered mainly qualitative results. The "feasible paths" of intervention as understood within the scope of this deliverable are defined by the connections between the targets of the vision, the influencing factors and areas of promising policy interventions.

What remains to be analysed in more detail is the (timely) development of influencing factors and the dependencies between these factors, as well as the sequence, timing and combination of policy interventions. Only after quantitative investigations of the relationships documented in this deliverable, more concrete pathways – determined by development of influencing factors as well as indicators as a function of time – may be described.

It will be one of the objectives of task 4.4 to refine the paths of scenarios that need to be tested in the WPs 5-7 for the different applications of CATS, by defining the timewise implementation of different interventions and the forecasting scenarios that need to be run to test the detailed short-, mid- and long- term effects. The final selection of sub-use cases and interventions will also be influenced by the capabilities of applied methodologies: Historical or retrospective methods, Delphi surveys, micro- and mesoscopic simulations, system dynamics, etc.

It will also be further investigated in the WPs 5-7 which of the selected use cases and related policy interventions can be combined, providing recommended bundles of interventions.

The main purpose of the city dialogues reported in this deliverable is to provide the base for further quantitative backcasting in the case studies, for one or several of the cities considered here. This is also referred to as *static* backcasting in LEVITATE: Based on the analysis of current situation, vision and planned policy interventions for a city or region, and by applying suitable modelling and simulation methods, quantitative results are obtained (for example, "*The intended policy packages are viable, but should be applied 3 years earlier than previously assumed.*"). These results can then be summarised in a specific report that gives clear recommendations for reaching a certain vision (at specified point in time) from current perspective. It would not be possible for stakeholders, however, to further adapt such a scenario directly in a dynamic way, for example change some parameters for specifying the vision, change the selected policy interventions or their timing, or update the scenario at some point in the future. A new backcasting process would have to be set up based on the changed inputs, followed by quantitative re-evaluation of feasible pathways (for example by numerical simulations).

On the other hand, however, *dynamic* backcasting is also within the final scope of LEVITATE, by integrating it into the policy support tool (PST) which can be considered as the main output of the project. This should build on top of the case studies, but generalise the results where possible, for use by other cities. Essentially, if the key relationships between policy interventions, influencing factors and target indicators can be estimated with sufficient confidence, this knowledge can be exploited for backcasting.

In such a way, after specifying the vision of a city in PST based on a set of indicators, suitable policy interventions might be selected manually, semi-automatically or automatically, ensuring that the forecast considering their impact lies within the calculated corridor towards the vision. A simplified illustration of this approach is given in Figure 24.

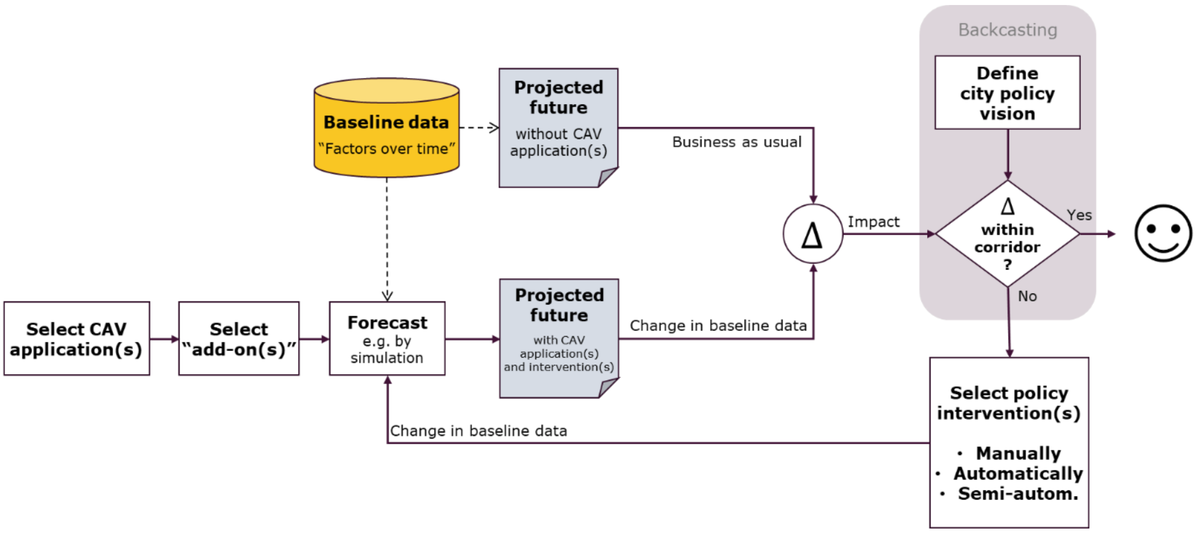

Figure 24: Dynamic backcasting integrated into LEVITATE PST

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Appendix

Used Terminology

Following definitions that have been discussed in LEVITATE across the work packages are relevant for this deliverable; these are the terms that are proposed to be used throughout the project:

Term	***Description***	***Examples***
Impact categorisation	In order to simplify the categorisation of CATS impacts, two main categories are identified: (1) Direct impacts: impacts that are produced directly from the introduction of CATS on the transport system such as vehicle design and driving behaviour. (2) Indirect impacts: impacts that are a by-product of the direct impacts of CATS. For example, driving behaviour will affect road user interaction and therefore road safety which is an indirect impact.	
Policy	Definition: A set of ideas or a plan of what to do in the future in particular situations that has been agreed to officially by a group of people, a business organisation, a government or a political party.	Environmentally friendly, social equity, increase in health, liveability
Policy goals / Policy objectives	Definition: A single target within the whole policy (should be SMART) Should be third order impacts, which are wider impacts e.g. societal and are usually not directly transport related.	One of the European 20-20-20 Targets: The 2020 energy goals are to have a 20% (or even 30%) reduction in CO2 emissions compared to 1990 levels.
Policy interventions / measures	Definition: An intervention is an action undertaken by a policy-maker to achieve a desired objective. Interventions may include educational programs, new or stronger regulations, technology and infrastructure improvements, a promotion campaign.	Introduction of a city toll, conversion of driver license training, dedicated lanes for automated vehicles
Vision	Definition: Description of a future situation defined by a bundle of vision characteristics and dedicated at a specific point in time. Note that this term is used instead of the term “desired future scenario” that was used in the project proposal, in order to avoid any confusions with simulation scenarios in LEVITATE context	The case of Vienna (modal share, mobility demand, penetration rate of automated vehicles of level x, …)

Vision characteristic	Definition: An indicator representing a policy goal that has to be achieved at a certain time. A single target within the vision in the level of first and second order impacts (which occur in the transport system, on a trip-by-trip basis / which involve system-wide changes in the transport system).	Number of accidental deaths, particulate pollution, noise, public green space.
Transformation Path	Definition: A postulated sequence or development of policy interventions / measures (and external events/measures/conditions) driving from a vision 'A' at time 'X' (which can be the current situation) to a vision 'B' at time 'Y'.	Situation now in Vienna (modal share, mobility demand, penetration rate of automated vehicles of level x, …), measures: campaign in 2020, funding for dedicated research in 2025, restricted access to freight in 2025, city toll in 2028; situation in 2030: (specified modal shift, expected mobility demand, penetration rate of automated vehicles of level x, …)