Backcasting City Dialogues: Feasible paths of interventions

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The impact of connected and automated transport systems (CATS) in several areas also has strong implications on a very central question of urban development: Given a certain vision based on a set of quantified policy goals for a city or a region, which supporting role take recommended policy interventions related to CATS to achieve that vision? This article provides a short overview of the *backcasting* approach applied in LEVITATE that addresses this question.

From a cities' perspective (refer e.g. to https://levitate-project.eu/2020/05/14/levitate-partner-in-the-spotlight-2/) the advent of connected and automated vehicles (CAVs) is not a strategic goal by itself. Rather, they are welcome if they are able to contribute to the defined smart city goals and have to support a livable city. Improvements in road safety or reductions in the demand for public parking space are promising candidates for such supported goals, with quantitative investigation of impacts currently ongoing in the project. But there are some other impact areas where an increasing market penetration of CAVs (without specific regulations) might be in conflict with the strategic goals of a city: empty AVs avoiding parking fees might increase congestion; the attractiveness of AVs might lead to adverse changes in modal split; acceptance of longer driving distances (due to increased comfort and use of travel time for working) might further increase road traffic and promote urban sprawl.

It is therefore essential for cities to integrate the full spectrum of related policy interventions into their considerations to prepare for the era of CATS – right from the start. Some positive impacts might be reinforced and accelerated by the appropriate policies, other desired impacts might occur only if a specific combination of policy interventions is applied – with the appropriate timing – and finally, some unwanted negative impacts might be mitigated by corresponding interventions. These causal relationships, however, are not always as simple and intuitive as it might appear at first sight. A lot of interdependencies – as in every complex system extending over different domains – makes it a necessity to apply a formal approach and consider a set of different methodologies that can support cities in their strategic decisions.

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 is a central part of the process, as it highlights feasible paths of interventions, steering into the desired direction. In the following, the steps in this process will be explained in more detail and exemplified for the City of Vienna.

The Vision

In the context of the LEVITATE project, the definition of feasible visions has been extended beyond the simple approach of specifying only certain mobility related targets, by also considering a wider range of indicators across four dimensions (safety, society, environment and economy). An overview of proposed goals and indicators [1] is given in Table 1, which has been developed in close collaboration with the city administration of Vienna to realistically reflect city priorities and data sources. The list is organised along the four chosen dimensions which provide a high-level structure (with certain goals even assigned to more than one dimension).

Table 1: Consolidated proposed goals and indicators for the four dimensions considered in 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: SO2, PM2,5, PM10, NO2, NO, NOx, CO, O3
	Efficient Settlement Structures	Building volume per square kilometre (total and per built-up area)
		Population density
	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

The next step was to use this indicator framework to perform a detailed statistical analysis of available data, in particular considering multiple European countries and cities, and based on that propose a quantitative approach to define desirable visions as regions in the abstract multi-dimensionl indicator space [2].

Challenging questions in this process were:

- How to prioritise different goals across these four dimensions?
- How are the different goals interrelated? Are they supporting each other (correlated) or are they conflicting (anti-correlated)?

A focused survey of literature regarding relationships and correlations among policy goals and indicators considered in LEVITATE showed that even on a high level, quite complex relationships are revealed, forming a "network" of interactions. A good amount of the correlations between goals is positive - this means goals are supporting each other, consider for example space for (and staisfaction with) walking and cycling infrastructure compared to "clean air" indicators . For some relationships, however, such a simple relation cannot be determined because there might be several contradicting causal relations, with varying dominance. And finally, some goals are obviously conflicting to a certain extent – this was found mainly for prosperity (and related economic indicators) opposed to environmental indicators.

From the statistical perspective, the challenges for the analysis of available data lie primarily in the high dimensionality (of indicators considered) and high sparsity in the data set; of all combinations of indicators with city (geo-entity) and year (time), only a small percentage is available. This situation led to the selection of two approaches to be applied:

principal component analysis (PCA) with data imputation combined with "collaborative filtering" based on machine learning techniques. Mainly data from two open data sources have been considered: European Statistical Office (Eurostat) and World Development Indicators (WDI). These data were organized along LEVITATE dimensions & goals, geographic levels (country / region / city) and time.

The goals of these statistical evaluations were the following: analysing how "close" several indicators are to each other (similarity of indicators), analysing the similarity for geo-entities (which cities show similar characteristics) and investigating the dynamics of indicators over time. Clustering of geo-entities was found to be quite strong: cities in the same (European) region (in the same decade) show very similar characteristics (which means the points representing them are near to each other).

In this abstract indicator space, movements of geographic entities over time can be illustrated in an easily interpretable way by reducing the multidimensional space to 2D, defined by the first two components after a principal component analysis (PCA). 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 remains the same).

Furthermore, vision "points" based on specific targets for some indicators (e.g., Vienna 2030, Vienna 2050) can also be mapped in this space; illustrating not only the gap between the 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 simple physical analogy of a moving missile 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 1.

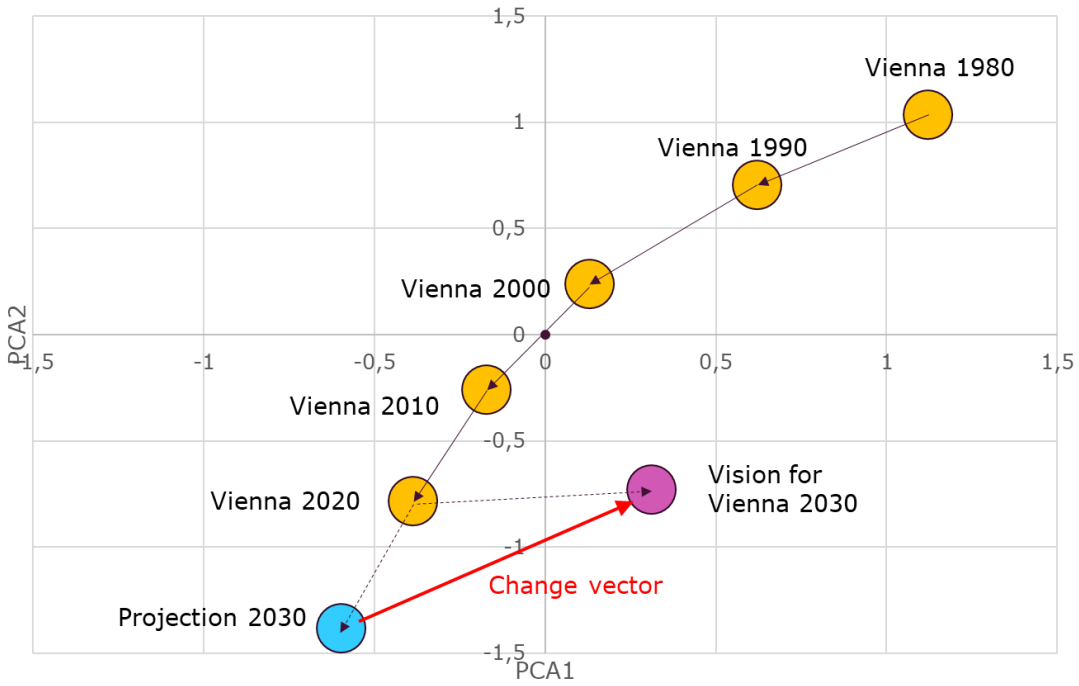

Figure 1: Gap between projected future and vision for a city, and resulting change vector (schematic, based on evaluated data for Vienna, the axes are the first and second principal components in embedding space)

Backcasting approach and City Dialogues

The specification of "desirable visions" is important to disclose conflicting goals and to allow a city to become aware about which goals should be prioritised in this respect, e.g. should economic goals be prioritised over societal goals. This enables cities to develop a clearer definition of its desired future and a more realisitc assessment of the feasibility of reaching multiple goals. Such a vision can then form the starting point for a backcasting exercise marking out a transformation pathway including appropriate policy interventions steering the development.

The flow chart in Figure 2 gives an overview on the steps in the backcasting process, the used inputs and the expected outputs [3] as performed in LEVITATE. The cornerstones of this process were repeated interactive sessions with City representatives, refered to as *City Dialogues*.

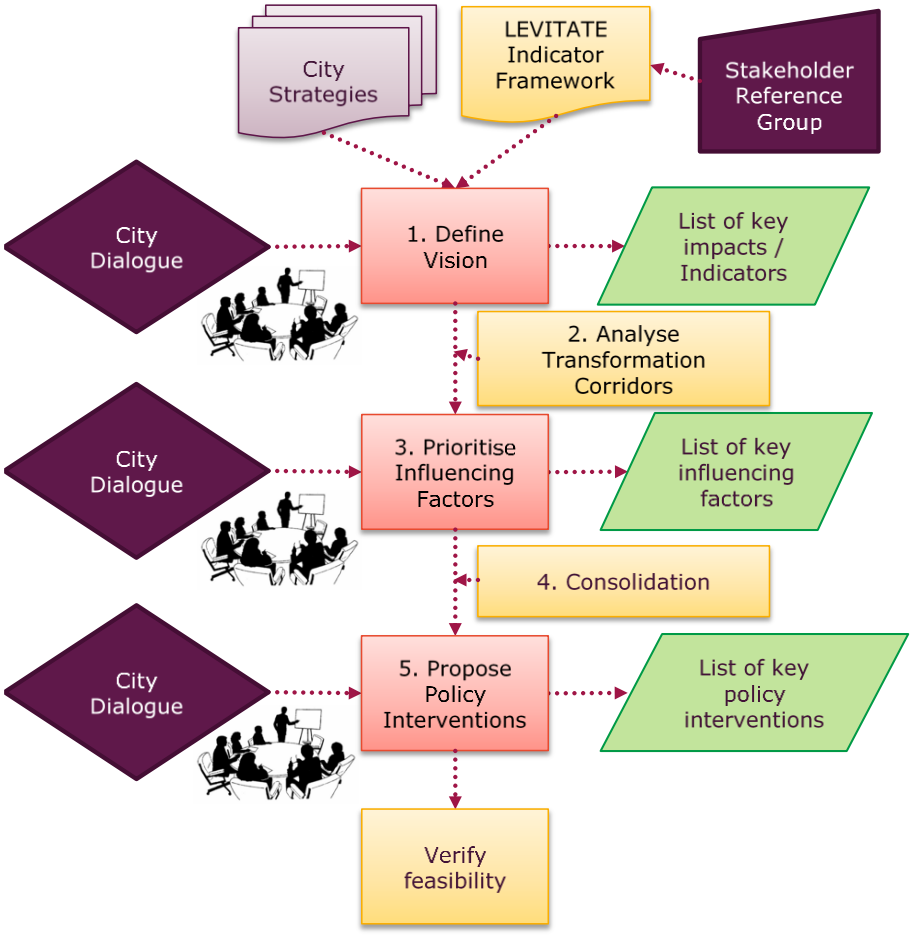

Figure 2: Flow chart for the steps of backcasting process in LEVITATE

Figure 3 further illustrates the steps detailing the relationship between vision, influencing factors and policy interventions. 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 – most important goals are specified by selecting and prioritizing a subset of LEVITATE indicators. For these indicators, specific target values and target dates should be assigned, and historic data up to the present time should be available.
2. These visions are consolidated and cross-checked for consistency, based on previous data modelling work and mapping of visions. Constraints for feasible transformation corridors can be indicated, based on the time-based development in the past and the "direction" (in the indicator space) towards the desired vision.
3. Influencing factors are selected and prioritized. 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, where the sub use cases to be considered have been defined.

5. Finally, the most promising policy interventions are selected and prioritized, again working backwards from the desired changes in the influencing factors.

Note that the CATS use cases, applications and interventions that are analysed in LEVITATE cover both the medium and the left pillar (influencing factors and policy interventions). It has also turned out during the city dialogues that a strict distinction between these two is not always possible or useful.

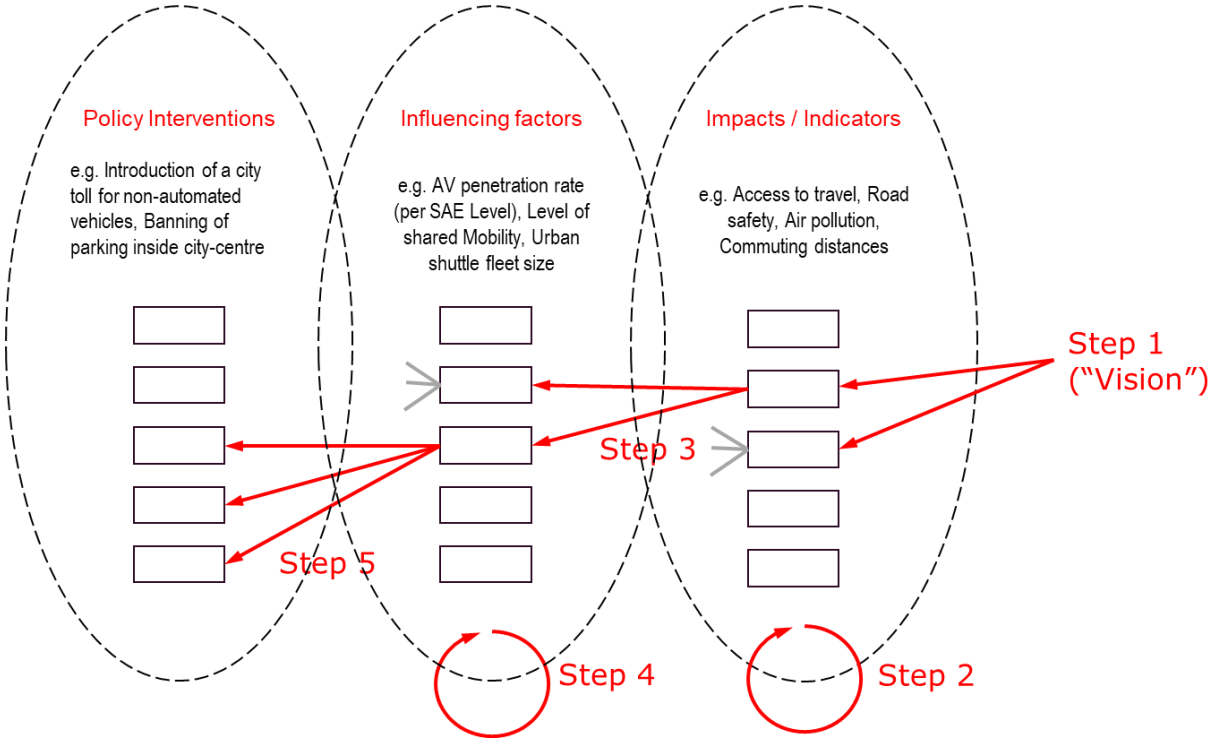

Figure 3: LEVITATE backcasting steps – three pillars view

A typical challenge for the selection of influencing factors and policy interventions is the question how far the considered interventions are specific to CATS (and therefore within scope of LEVITATE). Since the expected impact areas of CATS have 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) relation to CATS (in particular if we can expect only a very limited contribution of CATS towards that goal). 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" dependent on CATS itself (compared to all other influencing factors for those goals) – 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.

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

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

Example: City of Vienna

The interactive backcasting approach (implemented as city dialogue) as described in the last section has been performed for three cities in LEVITATE: Vienna, Greater Manchester and Amsterdam. At this point, the results for Vienna are briefly summarized.

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 related to LEVITATE are [4]:

1. Per capita CO2 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 trips 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 (although this target if no further specified).
6. The share of green spaces in Vienna is maintained at over 50% until 2050.
7. The volume of traffic crossing the municipal boundaries falls by 10% until 2030.

Starting form these highest priority targets, related influencing factors and policy interventions were discussed. The results are shown in the overview diagram in Figure 4. This illustration is again based on the three pillars view, where the process starts from the right hand side (vision identified by means of impacts and indicators), then defines related influencing factors and finally leads to a specification of most promising policy interventions (at the left).

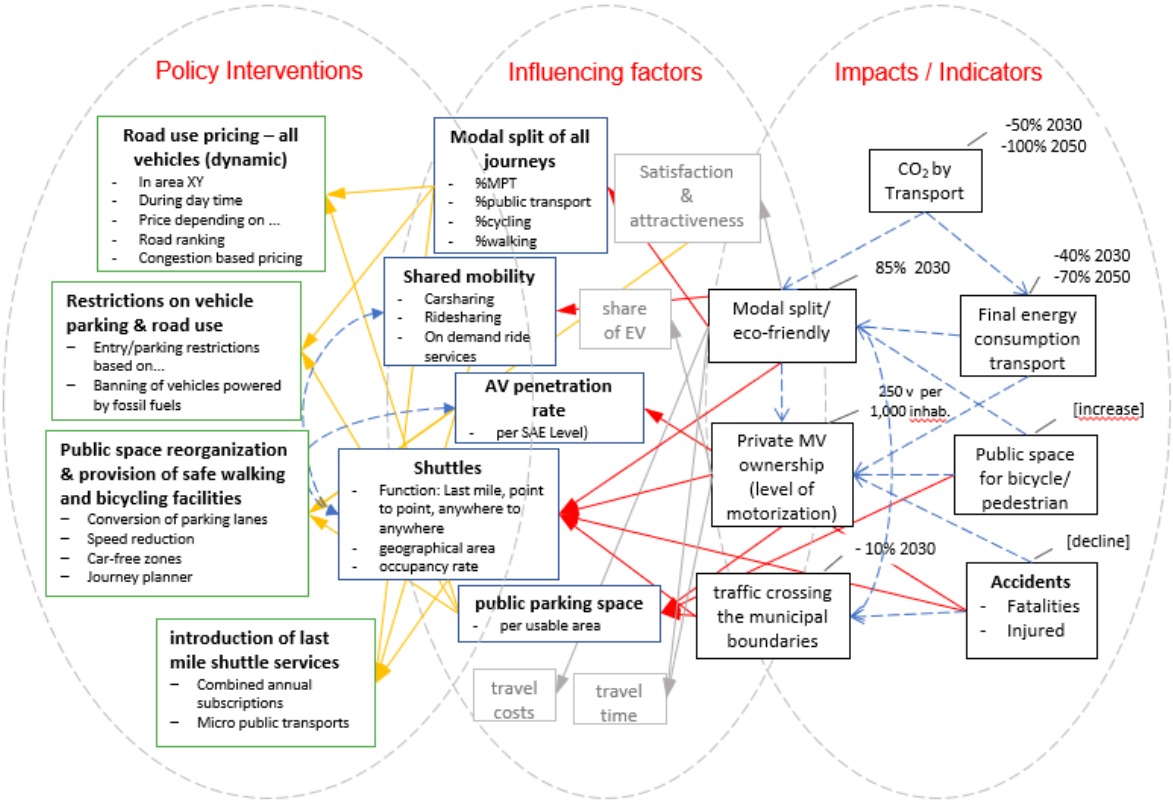

Figure 4: Backcasting for Vienna – Overview of results

For Vienna, the following areas of policy interventions were proposed and discussed in more detail; depending on the intervention and impact types these proposals are now being further assessed by several methods in the LEVITATE project (for example, micro-simulations, mesoscopic simulations and system dynamics):

- *Road use pricing (dynamic) for all vehicles*: This measure could be linked with several influencing factors such as shuttles, modal split of all journeys and AV penetration rate. From an expert´s point of view 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. Road use pricing 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 effective. It could be conceivable in areas such as the city centre, in a certain residential area or in a certain district. Regarding road ranking, "30 zones" (residential zones with speed limit of 30 km/h) might have the highest price in order to prevent misuse of residential areas for transit.
- *Restrictions on vehicle parking & 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 city centre, the problem is even bigger due to scarce space. A restriction on road use and parking could be considered as a more drastic step compared to the measure of road use and parking pricing.

- *Public space reorganization & provision of safe walking and bicycling facilities*: In order to distribute the public space fairly and increase the attractiveness for active modes of transport, several measures for reorganization of space were discussed: conversion of parking lanes into areas for walking, cycling or "flexible zones" (conversion into driving lanes was not seen as an option to follow as it would counteract the goals); speed reduction in residential areas; car-free zones with restrictions; rezoning (changes in intended land use). This policy intervention impacts several influencing factors, such as: satisfaction & attractiveness, public parking space and modal split of all journeys.
- *Introduction of last mile shuttle services*: The final measure discussed was the provision of faster, more cost-effective and convenient public transportation. The influencing factors associated with this measure are: AV shuttles, AV penetration rate and modal split of all journeys. This policy intervention focusses on the following sub-measures: (public) last-mile shuttles, e.g. areas around northern stations of the metro line U1; AV service instead of so called "B busses" (lower priority bus lines with longer intervals); combined annual subscriptions and multimodal public transportation packages; better coordination between different modes of transportation; micro public transport (covered by last-mile shuttles).

Besides the (simplified) diagram of expected relationships as illustrated above, the city dialogue brought several other valuable inputs for LEVITATE, such as:

Several *specific* policy interventions have been proposed, for example specific target areas for the introduction of automated last-mile shuttles. LEVITATE followed these proposals and will further investigate them in dedicated case studies, utilizing the variety of quantitative impact analysis results from different methods.

The importance of considering a *multi-dimensional optimization* for backcasting has been demonstrated: When only taking into account the goals of one dimension (for example environment), we might end up with clear proposals for policy interventions like total restriction of individual motorised traffic and public parking space, but such interventions clearly would not be feasible since they are in conflict with other dimensions (economy, society). The integrated, multi-dimensional perspective enables cities to comprehensively consider interrelations and specify reasoning for selecting or avoiding specific measures to achieve better transparency of their decisions and thus higher acceptance.

References:

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[2] M. Zach, C. Rudloff and M. Sawas, „Definition of Desirable Scenarios. Deliverable D4.2 of the H2020 project LEVITATE" 2019.

[3] M. Zach, M. Sawas, H. Boghani and R. de Zwart, „Feasible paths of interventions. Deliverable D4.3 of the H2020 project LEVITATE" 2019.

[4] Smart City Wien Framework Strategy, 2019 (validated 06/2019). [Online]. Available: https://smartcity.wien.gv.at/wp-content/uploads/sites/3/2020/05/SCWFS_objectives_overview.pdf.