URBANITE

Supporting the decision-making in urban transformation with the use of disruptive technologies

Deliverable D4.5

Recommendation system for policy design

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Abstract:	This document provides functional specifications for the recommendation system to be developed and integrated into URBANITE. This document comprises algorithms and mechanism and the empirical evaluation of the methods used. The deliverable is the result of task 4.2 and 4.3.
Keyword List:	Recommender system, Decision support, Mobility policy, Traffic simulation, Advanced visualisations
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v1.0	06/04/2021	Ready for submission	TEC

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Terms and abbreviations

API	Application Programming Interface
CO2	Carbon dioxide
dBA	deciBels A
EC	European Commission
GTFS	General transit feed specification
KPI	Key performance indicator
MCDA	Multi-criteria decision analysis
NOx	Nitrogen Oxides
O/D	Origin/Destination
PMx	Particle of metal of size x
PT	Public transport
SUMP	Sustainable urban mobility plan
UI	User interface
vkm	vehicle kilometer

Executive Summary

This deliverable describes the recommendation system for policy design that will be implemented as part of the URBANITE solution. The document covers the objectives, context, and functional description of the system, followed by detailed descriptions of subsystems and their functional requirements.

This deliverable is the main result of task T4.2, in coordination with T4.3, in the work package WP4, building on and referring to the deliverable D4.1, Strategies and algorithms for data modelling and visualisations. It describes the recommendation engine module and it's relation to the mobility simulation module and URBANITE UI module. Some parts of this system will also be used in the Policy validation and evaluation module, specifically the Multi-criteria decision analysis (MCDA) and common evaluation framework for the policy comparison.

The main sections of the document describe the recommendation system in the context of mobility policy design, which covers the challenges and opportunities for developing such a system; the functional requirements, which cover the description of specific subsystems and main capacities expected for them; and the underlying methods and tools for the implementation of the systems.

A result of the deliverable is the definition of the policy encoding wizard, which will ease the creation of simulations and enable the creation of a common evaluation framework, the definition of the MCDA approach and how it supports the iterative policy design process and the discussion of an advanced visualisation for comparison and evaluation of specific mobility policy proposals.

This deliverable presents the basis for the implementation of the recommendation engine for mobility policy design. Future deliverables, D4.3 URBANITE policy decision model and D4.6 Final implementation of the recommendation system for policy design will be guided by this deliverable. Future work includes tailoring visualisations for use in the domain of mobility policy design, detailed definitions of some of the KPI calculations, and implementation of the system.

1 Introduction

1.1 About this deliverable

This deliverable described the objectives, methods and tools and functional requirements of the decision support system. Specific subsystems are described, and also the rationale for design choices are presented. This deliverable is the result of tasks T4.2 and partially T4.3.

1.2 Document structure

This document is organised into different chapters:

- This introductory chapter explains the rationale of this document and its structure in more detail.
- The second chapter, devoted to the Recommendation system in the context of mobility policy, describes the objectives, context and description of the system.
- The third details the functional requirements as currently proposed for specific subcomponents of the system:
    - Policy encoding wizard describes the subsystem for encoding the policy into an evaluation scenario, including variations.
    - Simulation of proposals and variants covers the subsystem for simulation of the evaluation scenarios with variants.
    - KPI calculation covers the methods of evaluating the KPIs based on the results of the simulations.
    - Multi-criteria decision support describes the requirements of the subsystem for multi-criteria decision analysis.
    - Visualisations methods previously discussed in the deliverable D4.1 for mobility policy design and specifical visualisations of the decision analysis results.
- The fourth, Methods and tools, cover in more details the tools and methods that will be used to implement the system for each of the subcomponents.
- The conclusions conclude the document and present the main points.
- Finally, the references contain the bibliography used.

2 Recommendation system in the context of mobility policy

The recommendation system will provide recommendations during- and generally support- the process of creating the traffic and mobility simulation scenarios and evaluation framework. In order to support the creation of mobility policy, the recommendation system will enable a robust evaluation and comparison among them by using a common evaluation framework, and also propose improvements for the selected policies.

While commonly recommendation systems work using collaborative filtering or similar methods that harvest the preferences of many users, in the context of mobility policy development support, such methods cannot be used. [1] [2] Therefore, we will provide recommendations based on multi-criteria decision analysis (MCDA) in order to identify the best proposal as well as during the process of traffic simulation scenario creation with regards to possibilities of optimization of proposals and best practices of simulation preparation. The recommendation will be provided in three ways:

- Recommendations during the process of traffic simulation scenario on how to set the scenario up, based on expert knowledge,
- Recommendations during the process of traffic simulation scenario on what can be optimised, based on functionalities of other subsystems, and
- Recommendations after the simulations are performed, based on MCDA and simulation results.

2.1 Objectives

The main objectives of the Recommendation system for policy design are:

- Support the generation of the evaluation scenarios for the simulator and recommend variations for higher robustness of the simulation results.
- Enable a multi-criteria analysis of multiple proposals. Specifically, enable the decomposition of the decision problem into less complex sub-problems, specify the attributes, evaluate the ranges of attributes' values and define the decision rules.
- Suggest optimisations when applicable. Some proposals can be adjusted by using standard single- or multi-objective optimisation methods. For example, public traffic schedules, locations of public car parking location and similar problems can be evaluated using evolutionary algorithms.
- Support a data-driven decision making. The recommendation system will provide support during the length of the decision-making process and simplify the use of gathered data.
- Enable robust KPI estimation by providing the recommendations of variant evaluation scenarios, such as sunny, rainy and snowy weather variants; or workday and weekend traffic demand variants.

2.2 Context

To support the policy design process, we are considering an iterative design process [3]. The process consists of identifying a problem, analysing the available related data, proposing multiple iterations of writing a policy proposal, creating the simulation scenario and finally, evaluating the proposed plans. Each iteration should improve on the previous, based on discovered attributes and MCDA.

The following figure shows the global functional overview of the WP4, where blue lines indicate the workflow: (i) Exploratory data analysis and preparation, (ii) Based on the policy proposal, an evaluation scenario is prepared, (iii) Evaluation scenario is simulated and (iv) Results are presented, using the Advanced Visualisation module, then analysed using machine learning or used for additional analysis.

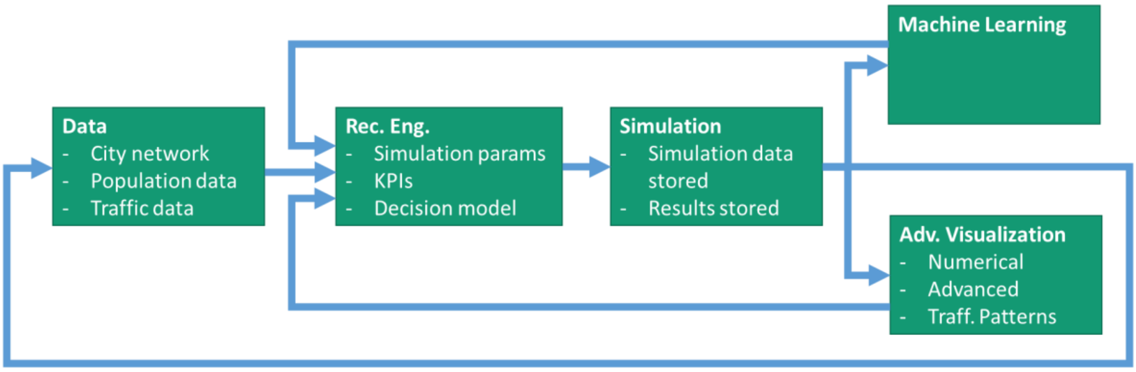

Figure 1: Global functional overview of the WP4.

To support this process, each policy will be associated with one or more simulation scenarios. The simulation scenarios will also include a framework for evaluation and comparison with different approaches.

The evaluation framework consists of selected or customized KPIs and a common decision model. Each KPI must be associated with relevant data attributes and relevant simulation result attributes in order to ensure that the common decision model can be used to perform evaluations. The MCDA process will be based on selected KPIs, which will act as the criteria for comparison.

Due to the high-probability of competing metrics (e.g. lower traffic noise and raise traffic volume), a multi-criteria decision analysis methodology was adopted. Thus, we will enable the inclusion of all KPIs and metrics while allowing a human to finalized the decision between different, dominating KPIs.

2.3 Description

The recommendation system will support the policy design process and the final decision on selecting the best proposal to implement. Based on the initial mobility policy proposal, the policy encoding wizard will support the initial simulation scenario creation, decision model definition, custom KPI definition and common evaluation framework setup.

The policy encoding wizard will guide the user through the steps of scenario creation, described in more detail below. The final scenario will include one or more proposal simulations with accompanying variations (zero or more for each simulation). Results of variations of the same simulation will be aggregated to ensure the robustness of the simulations. [4]

The process will continue with the definition of the custom KPIs. Custom KPIs will be limited to use available data attributes and results of the simulation runs and certain predefined calculation formulas (such as the sum of attributes, linear combination of attributes, etc.). The user will be presented with possible attributes and calculation formulas. While this approach will limit the scope of possible KPIs, it enables the customization of predefined KPIs as well as creating completely new ones.

The process will continue with the definition of the common evaluation framework. This includes the definition of the decision attributes, the attribute hierarchy, attribute scales and finally, the decision rules. The framework will also include all relevant KPIs.

Once these are defined, the simulation will be executed, the results of those simulations will be aggregated and the MCDA will be run. The results will be presented both textually and visually. The visualisation description of the MCDA results is further described in section 254.5.

Figure 2: Relations between data types, shows how one mobility policy proposal is represented by one or more simulation scenarios, each of them containing the data required and scenario variations. Each scenario variation specifies an attribute of the simulation scenario to vary and the range of values it can take.

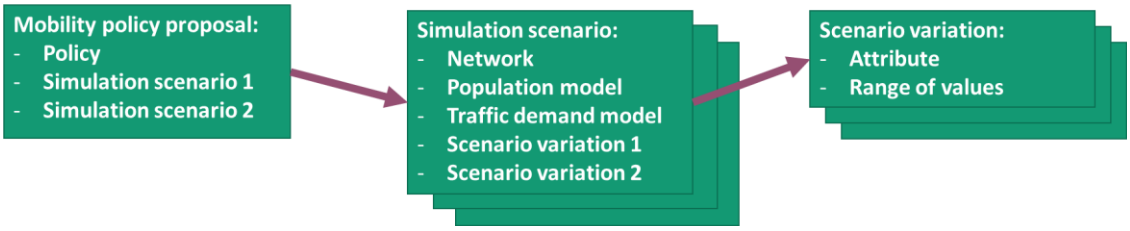

Figure 2: Relations between data types

3 Functional requirements

This chapter describes the subsystems in greater detail and specifies the functional requirements for each one.

3.1 Policy encoding wizard

A policy encoding wizard is a tool that guides the user through defining the mobility policy proposal and encodes its effects as a simulation scenario, define the process of evaluating the proposed policy and the decision support model that will be used to compare different proposed policies. During the process, the tool interactively suggests possibilities of generating variant scenarios and optimising certain types of policy proposal scenarios. The final stage of the policy encoding wizard is to trigger the start of computing.

Policy encoding wizard will enable the simulation of [5]:

- Infrastructure modifications:
  - Roads (new infrastructure, changed infrastructure).
  - One-way streets (analysis of changing streets to one-way, possibility of optimization described below).
  - Bike lanes (possibility of optimisation described below).
  - Parking locations (including pricing, capacity).
- Public transport (line changes/additions, schedule changes, possibility of optimizations described below).
- Public transport vehicle pool (removal of old vehicles, introduction of e-vehicles and eco-friendly vehicles, vehicles with different capacities).

The wizard guides the user through several steps of creating a simulation scenario that will be used to evaluate KPIs and building a decision model [6]:

- Prepare relevant network subset and boundaries.

- Import needed infrastructure data.
- Import public transport data.
- Import vehicle data.
- Generate population using census data.
- Prepare a demand model using population sampling and available traffic count data.
- Select KPIs from the list of those available.

The following tables present an overview of pilot specific requirements for the policy encoding wizard:

Table 1: Functional requirements for Amsterdam pilot.

Functional requirement (Amsterdam)	Description
Enable modelling of proposed policies' outcomes	The policy encoding wizard will support the creation of a model of a specific policy and simulate the results of such policy.
Enable simulation of bicycle traffic	The policy encoding wizard will support using bicycle-related data in the simulations.

Table 2: Functional requirements for Bilbao pilot.

Functional requirement (Bilbao)	Description
Support for simulation parameters configuration	The policy encoding wizard will enable the setup of simulation configuration.
Calculate SUMP indicators	The policy encoding wizard will enable the selection of different SUMP indicators to calculate.
Compare performed simulations	The policy encoding wizard will enable the setup of a comparison framework that can be used to compare different simulations.
Enable setup of custom KPIs	The policy encoding wizard will enable the setup of custom KPIs by selecting known attributes and defining how to calculate them.

Table 3: Functional requirements for Helsinki pilot.

Functional requirement (Helsinki)	Description
Provide pre-packaged simulations	Particular simulations (e.g. impact of urban planning on the traffic) will be available for running. These predefined simulation scenarios will be easy to adapt to specific data (e.g. a specific urban plan can be loaded into the predefined scenario).
Provide some automatic analysis	The results of the simulation will be analysed, and the results of the analysis will be offered automatically.

Table 4: Functional requirements for Messina pilot.

Functional requirement (Messina)	Description
Simulate multi-modal paths of the citizens	The policy encoding wizard will enable multi-modal simulations and retrieving the paths of simulated citizens.
Simulation of public transport	The policy encoding wizard will support the inclusion of known public transport lines and schedules via a GTFS data stream.
Enable the optimisation of public transport lines	The policy encoding wizard will enable the optimization of public traffic lines using an evolutionary algorithm.

The table below describes the functional requirements common to all pilots.

Table 5: Common functional requirements for all pilots.

Functional requirement (Common)	Description
Support traffic simulation scenario creation	The policy encoding wizard will simplify the creation of traffic simulation scenarios.
Check scenario for errors	Each step of the wizard will check the scenario for any errors and ensure that the scenario is well-formed.
Execute the simulation	The created traffic simulation scenario can be executed (simulated) and results retrieved.
Support integration of data from different sources	Different data sources can be used in the simulations. This functionality is provided by default using the data management platform.
Export the network for editing	The network file will be editable using external editor.
Import edited network	The network, edited using an external editor, can be imported into the simulation, stored and used for simulation.

3.2 Simulation of proposals and variants

Simulations will be prepared and run for each of the proposals. Certain variants of the simulation will be generated in order to ensure the robustness of the process [4]. These include:

- Weather.
- Random seed.
- Urban planning.

Table 6: Simulation variations.

Attribute	Possible values

Weather	- Dry (normal road conditions) - Rainy (worse brake performance, less acceleration) - Snowy (worst brake performance, slight acceleration)
Random seed	The random seed will be stored with each performed simulation. Each simulation will be performed multiple times with different seeds in order to minimise the impact of randomness on the simulation results.
Urban planning	When applicable, the simulations will be performed by using different urban planning proposals.

Some proposals may be possible to optimize [7], [8], [9], [10], [11]:

- Directions of one-way lanes.
- Positions of parking locations.
- Public transport lines routes.
- Public transport schedules.
- Locations of missing bicycle lines.

Table 7: Possible optimisations of proposals.

Optimisation	Description
One-lay lane directions	A selection of connected streets can be selected, and different configurations of one-way direction can be tested and evaluated. By using an evolutionary algorithm, many possible configurations can be generated and evaluated. Best options will be presented to the user and stored.
Positions of parking locations	Several possible locations for parking houses or car parks can be proposed. Here, by using evolutionary algorithms, different combinations of parking locations and capacities can be generated and evaluated. Best options will be presented to the user and stored.
Public transport line routes	New and existing PT line routes can be optimized by using evolutionary algorithms to achieve better coverage and PT vehicles capacity.
Public transport schedules	New and existing PT line schedules can be optimised using evolutionary algorithms to achieve shorted traffic delays and PT vehicles capacity.
Locations of missing bicycle lines	After identifying unconnected parts of the bicycle lane networks, an evolutionary algorithm will provide the best routes for bridging the unconnected networks while optimising for a minimal length of new bike-lane segments, price of development or other metrics.

To perform the optimizations, many simulation runs are needed to evaluate different solutions. The number of required simulation is the number of simulations for a proposal × number of variations × number of values per attribute. This process may take a long time and optimizations of the relevant optimization scenarios are necessary. The scenario creation wizard will recommend performance optimizations for a specific type of optimization, including:

- Proposal of minimal needed subnetwork (only including the streets relevant and directly connected main roads).
- Proposal of elimination of certain vehicle types that may not have a major impact of the simulation results (e.g. elimination of heavy traffic from a scenario for optimization of one-way lane directions in residential zones).

3.3 KPI calculation

The following tables identify some of the candidate KPIs from the different use cases:

Table 8: KPIs for Amsterdam pilot.

KPI (Amsterdam)	Description
Number of cyclists	Number of cyclists passing at a set of reference points in an area during specific hours a day or during the whole day.
Opportunity for cycling	Percentage of the roads equipped by bike lanes (excluding motorways)
Occupancy of bike stand for cyclists	Occupancy of bike stand for cyclists: Average number of bikes per bike stand in the hours of the day
Green bike tracks	Tracks dedicated to bikes crossing avoiding high emission zones
Waiting time in front of traffic lights (comfort)	Time spent by people waiting for traffic lights
Bike safety	Number of accidents involving bikes per road, the status of the roads, availability of dedicated bike lanes separated from car traffic, etc.
Air pollution (CO2 emission)	Level of CO2
Bike congestion points	Identify congestion points of bikes (Covid-19 scenario)

Table 9: KPIs for Bilbao pilot.

KPI (Bilbao)	Description
Proportion of internal travel by mode of transport.	Modal share between the different urban transport modes
Acoustic pollution level	Reduction by 2 dB(A) compared to the current noise map.

Table 10: KPIs for Helsinki pilot.

KPI (Helsinki)	Description
Traffic load and average vehicle speed	Traffic speeds

Table 11: KPIs for Messina pilot.

KPI (Messina)	Description
Public Transportation usage (peak/offpeak)	Number of users that use bus and tram
Use of shared mobility in the week (peak/offpeak)	Number of users that use the bike
Use of private vehicles in the week (peak/offpeak)	Number of vehicles used
	Number of vehicles used for type: normal, hybrid, electric
Traffic indicator	Average speed
On-demand services for elder/fragile people	Number of people who use the service (linked to COVID-19 issue)
Environmental indices 1	Level of PM2.5 for a geographical area
	Level of PM10 for a geographical area
Environmental indices 2	Level of acoustic noise for a geographical area
Environmental indices 3	Level of electromagnetic noise for a geographical area
Vehicles accidents	Number of accidents (night/day)

Table 12: Considered potential KPIs categorised by impact.

3.4 Multi-criteria decision analysis

The multi-criteria decision analysis (MCDA) is a methodology for both, analysing the decisions and data-driven decision making. The method approaches decision-making using a divide and conquer approach. The decision is deconstructed into a hierarchy of simpler sub-decisions and rules for evaluating each decision based on the sub-decisions. This is repeated until only the base attributes remain, from which the final decision is derived by evaluating each sub decision from the attributes up to the root decision.

- The main concepts of the methodology are:
    - **attributes**, variables that represent the basic features of considered alternatives;
    - **scales** of attributes represent are sets of words that represent the qualitative assessment of the attributes' values, usually ordered preferentially;
    - **hierarchy** of attributes represents the decomposition of the base problem and relations between attributes – higher-level attributes are an agglomeration of the lower-level attributes; and

    - **decision rules**, a mapping between lower-level attributes and corresponding higher-level attributes. Decision rules should specify the values of the higher-level attribute for all possible combinations of lower-level attributes.
- The user describes the decision model by specifying the attributes, scales, hierarchy and decision rules, thus specifying the multi-criteria decision model.
- The decision model is evaluated and its results presented to the user
- Based on the calculated potentially contradicting KPIs, we can analyse which proposals and their variants have specific advantages and disadvantages compared to others. Non-dominating proposals will not be presented to the user because dominating proposals will be better by any metric and may therefore be dropped

The multi-criteria decision analysis methodology will enable the users to use the common policy evaluation framework. Based on the defined decision model, including the attributes, scales, hierarchy and decision rules, the users will be empowered to compare different proposals and to identify specific weaknesses and strengths of a specific proposal. [12], [6]

MCDA will be run automatically when the simulations are finished. The results of the MCDA will be presented visually to the user as described in chapter 4.4; being the visualisations implemented, interactive. The user will be able to expand the hierarchical model of attributes to analyse the contributions of specific data attributes to the final evaluation of the proposal. [13]

The results will be stored for further analysis.

3.5 Visualisation

This chapter describes the visualisation capabilities, selected for presenting the MCDA results and the proposed policy representation (simulation scenarios showing a policy proposal). Parts of the UI are also described.

The next step for the advanced visualisation development is the tailoring of the methods described here to the needs of the URBANITE project. The provided examples are representative of different domains and will be changed to fit the domain of mobility policy.

Visualisation methods covered are split into MCDA presentation that visually explain the decision analysis results and mobility proposal visualisations, representing modifications implemented in the simulation scenario.

3.5.1 Visualisations of the multi-criteria decision analysis

For the visualisations of the analysis (MCDA) there are multiple requirements:

- The decision model must be visualised.
    - The hierarchy of the attributes and compound attributes will be visualised using a tree of nodes. Each leaf node will represent a base attribute, and each internal node will represent a compound attribute.
    - The decision rules will be presented using a decision tree [14] or a mesh plot.
- The KPIs for a specific policy must be visualised.
- The comparison of different proposed policies must be visualised.

3.5.1.1 Decision rules visualised using a decision tree.

A decision tree is a tree graph that shows decision points as internal nodes and the resulting decision value as tree leaves. The value of the compound decision is illustrated with colour and described for each leaf node.

The example below is from a medical domain and shows the rules for a compound attribute named *saDDD* with binary numerical scales (0, 1). The base attributes are *p2_sss* with scales (0, 1, 3) and *p2_migotanieprzed* with scales (0, 1, 2, 3). The value of the compound attribute is then described and represented with colour in each of the leaf nodes.

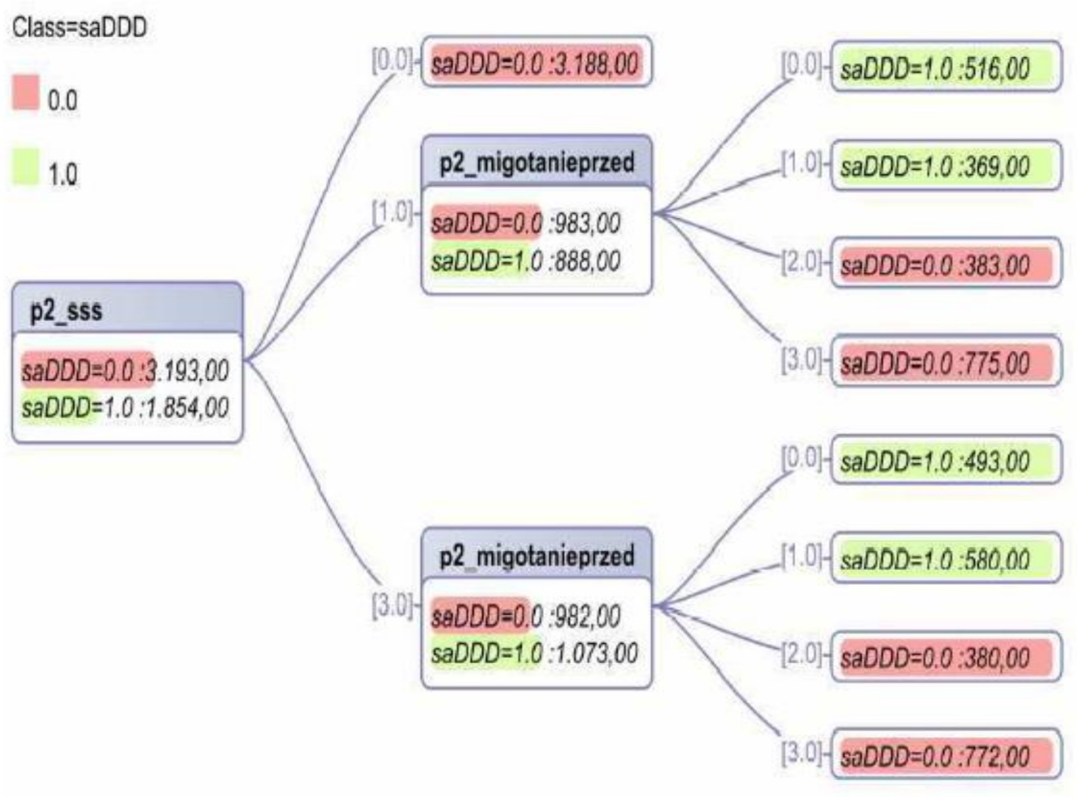

Figure 3: A decision tree visualisation of a decision rule in the domain of cardiology.

3.5.1.2 Decision rules visualised using a mesh plot [13]

A mesh plot is a 3-dimensional visualisation of a surface. Each point on the horizontal plane represents a specific combination of two selected decision attributes. The value of the compound attribute for each point is represented using the height (z value) as well as color.

The example below is from a decision model of buying a car. The compound attribute presented is *COMFORT*, a measure of car's comfort. The comfort of a car is based on two attributes, maximum number of passengers *(#PERS*) and number of doors (*#DOORS*). The scales for attribute *#PERS* are (<2, 3-4, >4) and the scales for attribute *#DOORS* are (2, 3, 4, >4). The scales for the compound attribute COMFORT are descriptive and sorted: (small, medium, high). The following image shows an example of visualisation of the two attributes and their value for a car, and the values on the vertical axis shows the value.

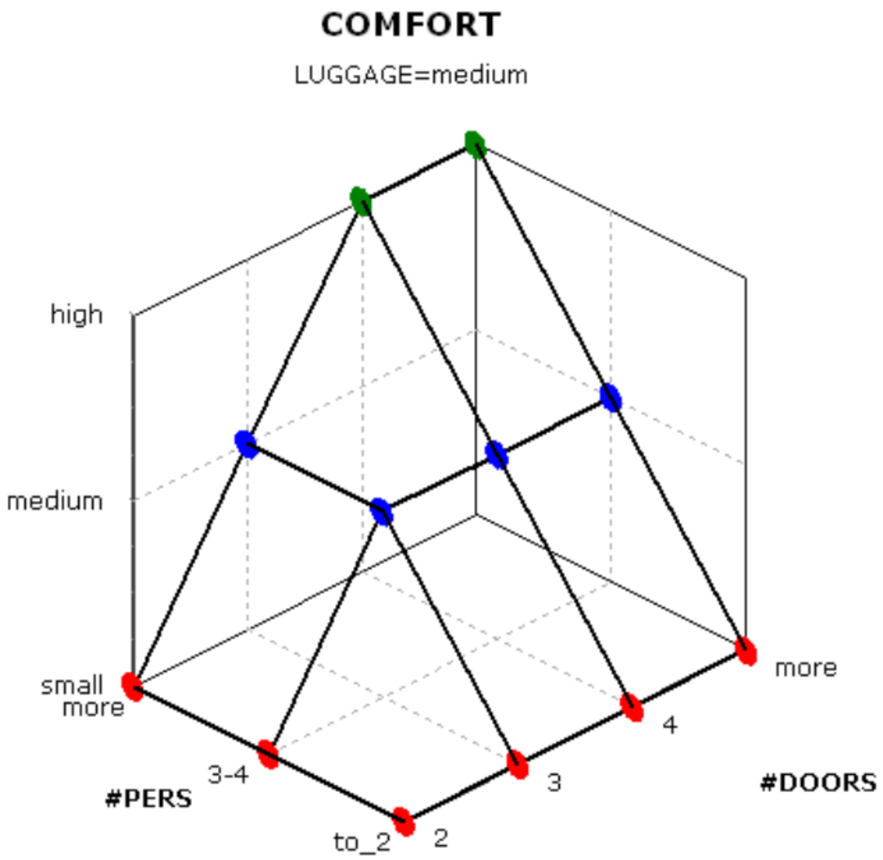

Figure 4: Example of visualisation of two attributes and their value for a car

Similar more advanced visualisation will be used to compare different proposals and up to 5 different attributes, as shown below. These visualisations were developed for visualisations of COVID-19 countermeasure plans effectiveness. Due to the nature of the problem, it can also be used to visualize multiple KPIs for mobility policy proposals. [14]

The next image shows 10 different counter-measure plans (each colored line one), average plan stringency and date on the horizontal plane and average projected number of infections per day on the vertical axis.

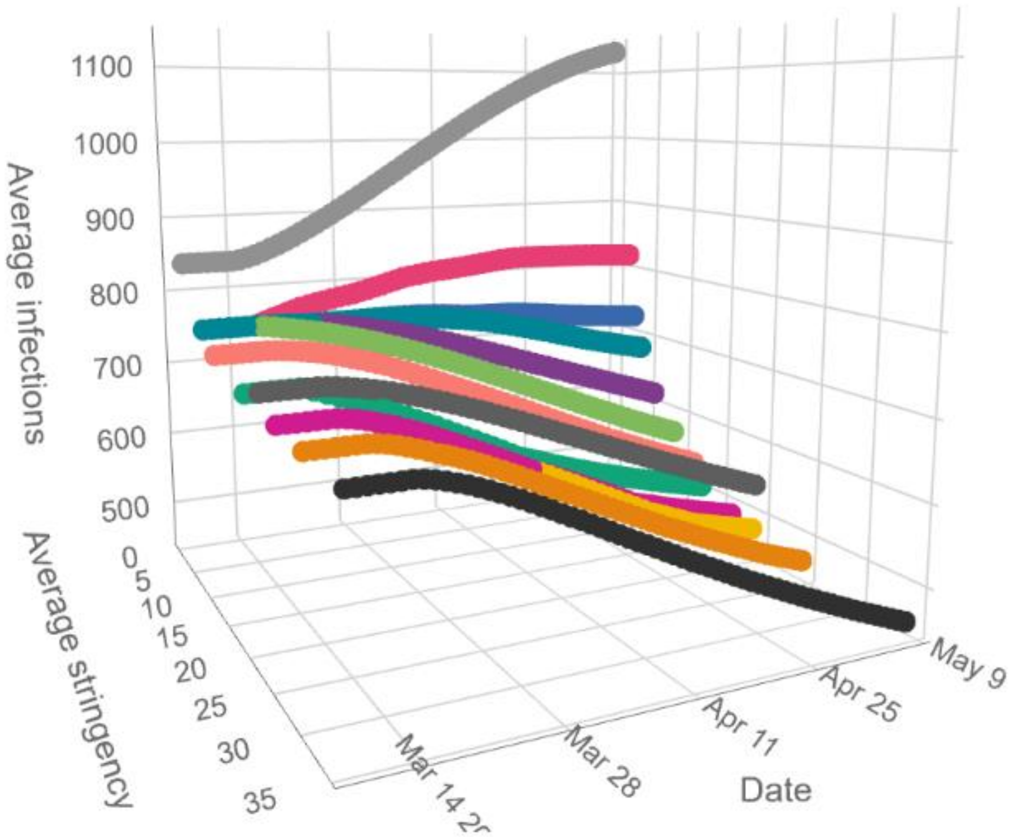

Figure 5: Different counter-measure plans, average plan stringency and dates

3.5.1.3 Proposal comparison over multiple KPIs [12]

Using a radar chart, we can visualize multiple proposal and the values of multiple selected KPIs. The following image shows an example of a multi-criteria evaluation of three different mobile phones. We can see that each of the items of analysis is best at some KPI. This is an example of an MCDA result where a human needs to make the final decision between three different dominating items. In the context of a mobility policy proposal, items of comparison are different mobility policy propositions, and metrics are relevant KPIs. The following figure presents a sample radar chart showing values of 8 metrics for 3 compared items, an example where none of the items dominates others – each compared item is best according to one or more metrics.

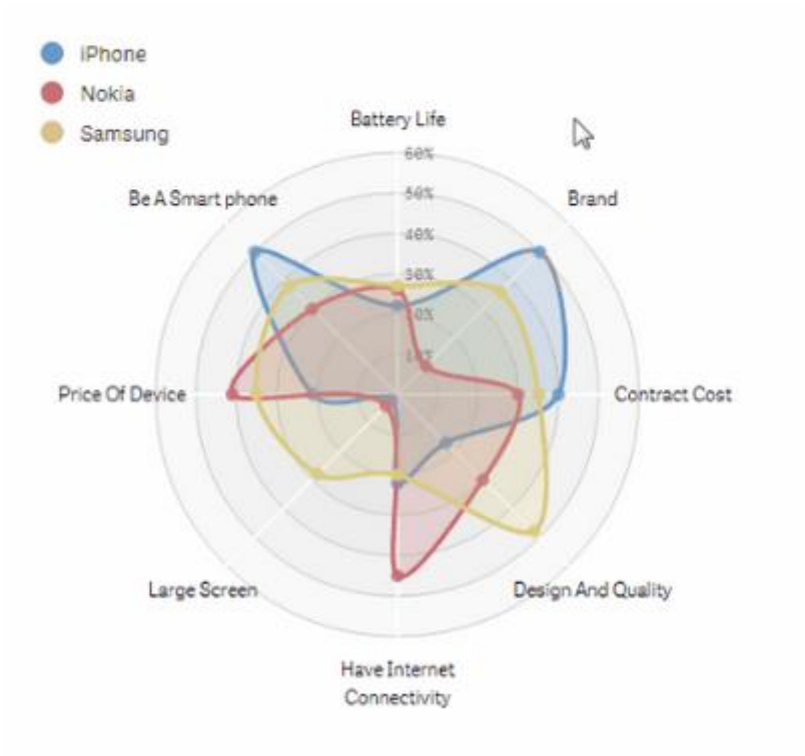

Figure 6: A radar chart showing values of 8 metrics for 3 compared items

3.5.2 Visualisations of the mobility proposal representation

The visualisations of the mobility policy proposals will present the methods already used for representing related data types. Following is a short overview of methods for considered policy options:

- Infrastructure modifications will be shown using a map with included proposed modifications. These include changes to road infrastructure, new roads and removal of roads. Modifications will be highlighted using an appropriate visual cue.
    - More specifically, one-way streets will be shown using arrows describing the travel direction.
    - Bike lanes will be shown in a specific colour.
    - Parking locations will be shown using a dot, with size defined by the parking location capacity and coloured according to the pricing.
- Public transport lines will be shown using a specific colour. Modifications will be shown in a different colour from existing PT lines.
- Public transport schedules will be dynamically visualised using animated dots, representing locations of vehicles at specific times.
- Urban plans will be shown using shapes with colour based on zone type (residential, commercial, etc.). Attributes of specific zones will be shown when needed.

These visualisations will be based on the map of the city. Some aspects of mobility will be visualised common charting methods (e.g. pie chart for the composition of vehicle pools).

3.5.3 Elements of the policy encoding wizard UI

In order to support the simulation scenario creation and common evaluation framework setup, we will provide the policy encoding wizard. This chapter overviews the elements of the user interface and describes the interactions.

The UI elements will be based on the common URBANITE UI template, ensuring visual integration and a common look and feel.

3.5.3.1 Population model setup

This part of the policy encoding wizard enables the creation and fine-tuning of the population model. Following is a list of UI elements and their functionality.

- List of relevant datasets. The list of datasets allows the user to select datasets that will be used for population model generation. The relevant datasets include city district shapes, population per district with related census data, traffic counts, public transport O/D matrices, and urban planning data (residential zones, commercial zones, specific facilities).
- Attribute selection form. This form allows users to select the data attributes and link them with specific population attributes.
- Population variations setup form. To add a variation, the user must select an attribute and select a set of values. A simulation will be run with a population generated for each value in the set.
- Vehicle pool setup. Enables the user to define the vehicle pools based on statistical data. Vehicle types can be defined, including the emissions according to EURO standards, vehicle estimated price, and the driving characteristics such as maximum acceleration and deceleration.

3.5.3.2 Custom KPI setup

This part of the policy encoding wizard will enable the creation of custom KPIs. The UI elements needed are described below:

- Predefined formula selection. The user selects one of the possible base formulas (e.g. linear combination, sum, product).
- Attribute selection form. This form allows the user to select attributes of the input data or the simulation results.
- KPI definition form enables the user to link the selected attributes with placeholders in the predefined formula.

3.5.3.3 Decision model setup

Selection of the underlying decision model.

3.5.3.4 Simulation scenario setup

This part of the policy encoding wizard will let the user define the simulation scenario by selecting and combining the population model, KPIs and custom KPIs, and the common evaluation framework. Following is a list of UI elements with descriptions.

- Network refinement layer. This is a map layer that allows the selection of network boundaries and network-level of detail. The user may change the network boundaries to select a region of interest. The level of detail is shown as a set of radio buttons.
- Public transport setup form. The form allows the user to select the datasets to use for generating public transport. Supported GTFS datasets are presented.
- Evaluation framework setup form. Enables the user to select a decision model, including KPIs.

After the simulation scenario is created, it will be evaluated and the simulations added to the simulator queue.

4 Methods and tools

The recommendation system is based on a similar module from project CONDUITS [15]. Here, we overview the original design and our improvements and needed changes to adapt the methodology to the URBANITE Solution.

Overview of the CONDUITS solution:

- Propose a performance evaluation framework for traffic management and Intelligent Transport Systems.
- The framework consists of a set of KPIs for the strategic themes of traffic efficiency, safety, pollution reduction and social inclusion.
- Present multi-criteria decision support tool through the inclusion of the KPI on traffic efficiency, based on micro-simulation modelling outputs; specifically, the SUMO microscopic traffic simulation package is used.
- The system is adapted to suit the requirements of the URBANITE Solution.
- The system is modified to focus on long-term policy proposals instead of real-time decision support, as it is used in CONDUITS.

The methods and tools used for implementing the proposed functionalities:

MATSim [5] is a tool used for microscopic modelling of traffic flows and the congestion they produce. The tool is an activity-based, extendable, multi-agent simulation framework implemented in Java. It is open-source and is designed for large-scale scenarios, meaning that all models' features are stripped down to efficiently handle the target functionality. MATSim is intended to model a single day, which is a common unit of analysis for activity-based models. Extending this tool, the following capabilities are going to be implemented:

- Generation of **multi-modal network** downloaded from OpenStreetMap, that supports different kind of vehicles: car, bicycle, public transport etc.
- Simulation of **traffic flow** for a given network and population demand. The tool allows customisations to be made on the virtual road network such as lane(s) closure/opening, traffic light signal alteration, etc., which can offer the possibility of performing detailed analyses on the traffic network state.
- **Noise** and **air pollution** estimation.

DEXi [13] is a tool that aims to perform interactive development of qualitative multi-attribute decision models and the evaluation of options. It will be used to support the decision-making task, where there is a need to select a particular option/policy from a set of possible ones to satisfy a goal.

Due to ease of integration and implementation, we will use the **jDEX** Java library, which provides very similar functionality to the DEXi tool. While some high-level functionality is missing from the jDEX library, we will implement those capabilities partly in the policy encoding wizard and partly in the advanced visualisation module.

4.1 Policy encoding wizard

The policy encoding wizard will be implemented on the front-end using the Angular framework. Specific parts of the encoding process will be implemented using distinct components in order to enable partial scenario creation, only defining custom KPIs, or only setting up the evaluation framework.

While the scenarios, simulations, variations, KPIs and the evaluation framework are connected, they can be created independently. These objects will be stored on the traffic simulation server back-end. Thus, they will be available for future simulation scenarios and evaluation of multiple proposals.

4.2 Simulation of proposals and variants

The traffic simulation module will perform all the necessary simulations to evaluate the proposal. To cut down the required computation time, the simulation module will perform one simulation on each available processing core. As the simulations are not parallelisable yet, this will offer linear or pseudo-linear speed up relative to the number of available processing cores. This is necessary because each of the proposals may include more simulations and each simulation may consist of multiple variations.

The following table covers the specifics of how different variations will be generated.

Table 13: Simulation variants implementation methods.

Attribute	Value	Implemetation method
Weather	Dry	Dry weather is the default weather condition.
	Rainy	Rainy weather will lower the maximum braking deceleration, maximum acceleration and maximum speed when turning. The traffic demand model will be prioritised
	Snowy	Snowy weather will further lower the maximum braking deceleration, maximum acceleration and maximum speed when turning.
Random seed	Integer	This attribute sets the random seed used for simulation. It will be stored with the variation to ensure replicability of the simulations.
Urban planning	Residential zoning plans	Residential zoning plans will be used for the generation of the population modelling. Residential zones provide information on the number of people living in specified zones.
	Commercial zoning plans	Commercial zoning plans will be used for traffic demand modelling. Commercial zones provide information for the number of people working and spending some of their leisure time in specified zones.
	Facilities plans	These include public facilities such as hospitals and schools. These include information about the number of people working there and the number of people with the need to access them. These will be used to generate traffic demand modelling.

4.3 KPI calculation

KPIs will be based on available mobility data and the results of simulations. The predefined KPIs as those identified by the pilot cities will be implemented on the server-side, some as MATSim contributions and some as Python functions. Custom KPIs will be defined as one of the predefined functions (e.g. linear combination) of data attributes and simulation results.

In order to calculate the KPIs robustly, the simulations will include multiple variations of specific attributes (as described above). Those will need to be aggregated to minimise the effect of randomness on the results.

KPIs will be calculated for each variation of the simulations and aggregated in a meaningful way, e.g. variations differing only by random seed will be averaged. At the same time, variations based on weather and other attributes will be available unaggregated while also considering the maximum and minimum values of the KPIs for further analysis.

MATSim provides packages that will be used to estimate some of the KPIs [16]:

- **Bicycles** - analyzing bicycle traffic and its interaction with motorized traffic. The network generation considers attributes that are relevant for cyclists (e.g. road surfaces, slopes). The travel speed computations, the plan scoring method and the routing take into account these infrastructure attributes. The scoring, i.e. the evaluation of simulated daily travel plans, is furthermore enhanced to account for traffic events that emerge in the simulation (e.g. car traffic density), which have an additional impact on cyclists' decisions.
- **Estimation of air pollution –** two types of emissions are considered: cold and warm emissions. The former emissions occur during the warm-up phase and depend on the engine's temperature when the vehicle is started; the latter are emitted while driving and are independent of the engine's temperature. The calculation of warm emission takes into account the kinematic characteristics from the simulation and combining this information with the vehicle characteristics extracts information from the HBEFA (Handbook on Emission Factors for Road Transport) database.

4.4 Multi-criteria decision analysis

4.5 Visualisations

The visualisations will be developed on the front-end as common Angular components. For the implementation of the plots, JavaScript libraries will be used, specifically plot.ly for charts and leaflet.js for maps and map layers (such as the proposal visualisations and geographically specific metrics, e.g. air pollution). For more information on the tools used for these capabilities, refer to the deliverable D4.1.

5 Conclusions

This deliverable overviews the objectives, rationale and methods used in the decision support system. In the context of mobility policy design, we cannot use common methods for generating recommendations, such as collaborative filtering. Instead, we propose a specific solution that helps the users to define the policy proposal evaluation scenario and a common evaluation framework used to compare different proposals.

Recommendations are generated during the process of simulation scenario creation, decision model definition, custom KPI definition and finally, during the review of the evaluated policies.

The first part of the recommendation system will be implemented as a policy-encoding wizard on the front end, while the second part of the recommendation system will provide multi-criteria decision analysis support and help in the identification of the negative aspects of the proposal, thus supporting the iterative process of mobility policy design.

The next steps will be focused on the parametrisation of different policy recommendations, based on simulation of potential scenarios, the tailoring of visualisations for use in the domain of mobility policy design, a more detailed definition of the calculation of some of the relevant KPI and the implementation of the system.

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7 Annex I: Potential KPIs

The following table lists different considered potential KPIs, categorised by impact type. Categories are further split by sub-category and aspect the KPI considers.

Table 14: Considered potential KPIs categorised by impact.

IMPACT CATEGORY	IMPACT SUB-CATEGORY	ASPECT	KPI		Description
Transport System	General	Modal split persons	Main	Average modal split in the number of trips	Percentage of trips using each mode for a specific target group during a day (weekday, week-end day) or per hour (peak hour, off-peak hour, …). For an area, the model split of both the trips of the residents and the outgoing people are analysed
	Safety	Transport safety	Main	Number of people killed and seriously injured (KSI) caused by transport accidents	The number of recorded transport injury accidents and the resulting number of fatalities and casualties caused by any means of transport. A fatality is a death within 30 days after the traffic accident as a corollary of the event.
				Bike safety	The number of accidents involving bikes per road, status of the roads, availability of dedicated bike lines separated from car traffic, etc.
	Walking	Opportunity for walking	Main	Quality of pedestrian infrastructure	Percentage of the total distance of the city's streets (including squares: the "distance" of a square is the sum of the length of its sides) with good quality for walking on the total length of the city road network (excluding motorways)
		Number of pedestrians	Intermediate	Number of pedestrians	Number of pedestrians passing a set of reference points in an area during specific hours a day or during the whole day.
	Cycling	Opportunity for cycling	Main	Quality of cycling infrastructure	Percentage of the total distance of the city's streets (including squares) with a good quality for cycling on the total length of the city road network (excluding motorways)
				Quality of bicycle paths	Calculation of the bikeability index of all streets in an area describing in detail all aspects of quality for a sidewalk
		Number of cyclists		Number ofc yclists	The number of cyclists passing at a set of reference points in an area during specific hours a day or during the whole day.

		Opportunity for cycling		Opportunity for cycling	Occupancy of bike stand for cyclists: Average number of bikes per bike stand in the hours of the day
		Cycling perception		The image on the cycling conditions (subjective)	Attitude towards cycling conditions based on the answers of a survey among citizens and visitors or cyclists on the street.
		Green bike tracks		Green bike tracks	Tracks dedicated to bikes crossing avoiding high emission zones
		Wasted time		Waiting time in front of traffic lights	Time spent by people waiting for traffic lights
		Congestion Levels		Bike congestion points	Congestion points of bikes (Covid-19 scenario)
	Car	Average speed	Average speed	Average speed	The average speed for cars by date, hour, etc.
		Traffic Flows	Intermedi ate indicator	Traffic flow by vehicle type (peak/offpeak)	The average daily vehicle flow during the peak and off-peak hours.
		Congestion Levels	Main	Average vehicle speed (peak/offpeak)	The average network or route speed by vehicle type during the peak and off-peak
	On-demand	System usage		System usage	Number of people who use the service (linked to COVID-19 issue)
Econo my	Costs	Investment costs		Capital investment costs	The total capital costs for the purchase of infrastructure, equipment and vehicles. It can also include the total costs expended in setting up the measure and cover a period from the initiative of the measure preparation until the start of the measure implementation.
		Operating costs		Average operating costs	Operating costs including, for example, the personnel costs, fuel, electricity and maintenance costs for the vehicle(s) involved
Environ ment	Pollution	Emissions	Main	CO2 emissions	The average CO2 emissions per vehicle-km by vehicle and fuel types or by city resident/system user.
			Additional	CO2 emissions	The annual average CO emission per vehicle-km by vehicle and fuel type or by city resident/system user
			Additional	NOx emissions	NOx per vkm per vehicle-km by vehicle and fuel type or by city residents/system users
	Nuisance	Noise	Main	Noise level	Noise level (dB(A)) measured on-site in the area or corridor under study.

		Electromagnetic	Main	Electromagnetic level	Level of electromagnetic noise for a geographical area
Governance	Planning	Planning process	Main	Quality of the Sustainable Urban Mobility Plan	Qualitative check of the content and process of the Urban Mobility Plan verifying to which extent the content of the plan and the process of developing it corresponds with the EU guidelines on Sustainable Urban Mobility Plans.
			Additional	Quality of policies, plans, and programs	Qualitative description of the change in the process to develop policies, plans, and programs (including SUMPs).