Traffic Simulation for Mobility Policy Analysis

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ABSTRACT

Recently urban mobility has been changing quickly due to the growth of cities and novel mobility methods' introduction. These changes are causing ever greater traffic congestion and urban pollution problems. To deal with the growing complexity of urban mobility and traffic systems we are developing a system to support the decision makers in the URBANITE H2020 project. An integral part of the system is a system for simulation of mobility policy proposals based on traffic simulation. The simulations are used for evaluation of policy proposals. We developed a system for automatic simulation creation and an algorithm for population synthesis based on open data available for multiple cities.

KEYWORDS

smart city, traffic simulation, mobility policy

1 INTRODUCTION

As cities are becoming more populous, traffic congestions, pollution and other problems are becoming harder to handle. Such complex and interconnected issues, also called wicked problems, are hard to deal with and any policy targeting these issues may be seen as undesirable from certain stakeholders' point of view or may have unforeseen side effects. An example of a wicked issues is moving the residents from using cars to driving bicycles or using public transit [6].

This paper presents a method for using traffic simulations among other analysis tools to analyse and evaluate mobility policies. The developed method aims to contribute to solving such problems in the urban mobility domain by simulation of the changes and calculation of key performance indicators (KPIs) [7], co-designed with the city stakeholders.

The method was developed with two goals in mind. The first is to empower the administration to easily run new simulations with less involvement of technical experts and thus shorten the feedback time from idea to the results of the simulations. The second goal is to enable the automatic creation of multiple simulations by variation of specific parameters within given constraints to algorithmically produce candidate solutions for specific problems.

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The rest of the paper is organized as follows. Section 2 covers mobility policy simulations and overviews the selected traffic simulation tool. Section 3 describes the high-level view of the support system for mobility policy design and the role of the mobility policy simulation in the system. Section 4 overviews the process of partially automated simulation creation including the descriptions of data preparation processes, the design of the underlying relational database and the algorithms developed for each step of the simulation creation. The paper concludes with Section 5, which summarizes the paper and presents ideas for future work.

2 OVERVIEW OF THE SYSTEM FOR MOBILITY POLICY DESIGN

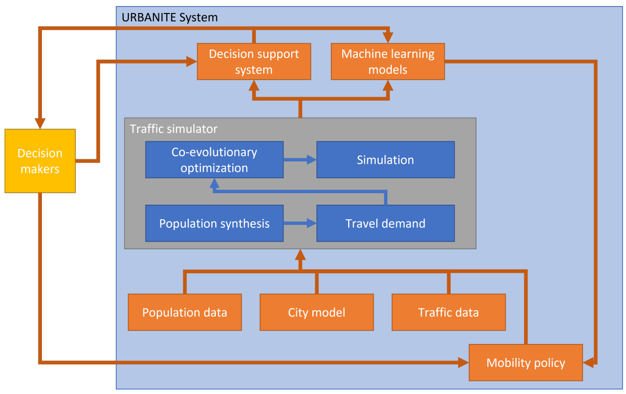

Figure 1: Architecture of the URBANITE system.

The URBANITE system consists of several components, including a data platform, AI-based tools including the mobility policy simulation, and tools for stakeholder engagement, including a forum and a social policy laboratory [11]. In this paper we focus on the architecture of the mobility policy simulation shown in Figure 1.

The decision makers work with the system in an interactive mode by evaluating and improving policy proposals in an iterative fashion, i.e., by defining the mobility policy proposals, which are simulated and evaluated by the system. In each iteration, they use the insight gained to modify the policy proposals. However, the system is also able to search for mobility policy proposals within user provided constraints. These proposals are automatically simulated and evaluated, and the decision makers are presented with a selection of the best ones according to the selected KPIs.

The main inputs to the mobility policy simulation system are the proposed mobility policy and the data required for the simulation: the population data, the city model and the traffic data. Examples of mobility policies are described in Section 3.

The mobility policy simulation module executes the following steps to create and run the simulation:

- Population synthesis is the process of using the population data to create the artificial agents.
- Travel demand generation takes the generated agents and their activities, and generates the trips that the agent will take to arrive to the locations of their activities.
- Finally, before the simulation is run the trips are optimized to fit them to the known traffic data.
- The simulation run is performed and the simulation recorded for further analysis and visualization, and to provide data for the machine learning models.

The simulation results are used by the decision support system to calculate the KPIs, evaluate the mobility policy proposals and provide multi-attribute decision analysis, as well as by the machine learning models used for policy proposal.

3 MOBILITY POLICY SIMULATION

Historically, modeling of mobility started with analytical modelling, mostly based on economic models combined with numerical methods for traffic estimation [3]. At the same time, simulation models were also developed [12]. A significant improvement came with the introduction of agent-based simulations, which are used for simulation of complex self-organizing systems.

3.1 Traffic Simulations

The URBANITE mobility policy simulations are based on traffic simulations provided by the open source package MATSim [4], a Java framework for traffic simulations. The selected traffic simulation framework is a state-of-the-art microscopic multi-agent traffic simulation package that allows the creation of traffic simulations with features such as multi-modal trips, support for bicycles and micro-mobility, public transit support, and emissions estimation.

Some drawbacks of the MATSim framework are high computational complexity, demand for high quality input data[1] and highly complex process for creating high quality simulations. The selection of MATSim among the available microscopic traffic simulation software options is based mostly on its extensibility and flexibility.

3.2 Representation of Mobility Policies

Mobility policy is a very wide category and general policy representation is out of the scope of this work. Instead we focus on specific policies. Besides the policy representation, appropriate KPIs are also required. This section focuses of four distinct types of policies that are considered by the pilot cities within the URBANITE project and the KPIs selected to evaluate them.

3.2.1 Closing a Major Square for Private Car Traffic. Bilbao is a city near the northern shore of Spain and the largest city of the Basque Country with nearly 350,000 residents. The policy proposed for simulation is closure of the Moyua square in the city for all private car traffic. Main goals of the proposal are to improve the air quality at the square and to relieve traffic trough the square.

From the simulation point of view, this is a relatively simple change of the city's road network. The change is implemented by changing the properties of affected road segments in the network to disallow private car traffic. Public transport and emergency vehicles are not affected by this change as well as pedestrian and bicycle traffic.

KPIs are selected in accordance with the goals of the policy. To estimate the effects on the air quality in the area, the daily amounts of different air pollutants emitted at the square and in the nearby areas are recorded. We expect that there will be less pollutants emitted in the square and some increase in the surrounding areas as the traffic will be redirected to them.

3.2.2 Changing a Major Road to a Bicycle Highway. Amsterdam is the capital city of the Netherlands as well as its largest city with over 1.5 million residents in the urban area. It has a highly developed bicycling culture to the point where bicycle traffic jams often form at the peak traffic times. The policy proposed is to close one of the major roads into the center, the Oranje Lopper, for motorized traffic. While similar to policy proposed in Bilbao, the goals of Amsterdam are mainly to alleviate the bicycle traffic by introducing a new bike highway into the city center.

To represent the policy for the simulation, we change the properties of the road segments that make up the Oranje Lopper to disallow private car traffic and instead introduce a number of new bicycle lanes.

KPIs selected are the number of bicycles using the new bike highway and more importantly, average bicycle travel times between the city parts connected by the Oranje Lopper.

3.2.3 Alleviation of Ferry Traffic via Building of a new Tunnel. Helsinki is the capital city of Finland. The Helsinki port is also the busiest passenger port in the world, which causes regular traffic jams in the Jätkäsaari area where the traffic from the port to the mainland is forced to use a single road. The policy proposal in Helsinki includes building a tunnel connecting the port directly to the motorway with the goal of alleviating the traffic jams that form periodically when ferries arrive to the port.

This policy is represented by the addition of new links to the road network representing the tunnel. To test this proposal, the ferry arrivals are modelled as seafaring public transport with forced high loads of vehicles arriving as scheduled.

The main KPI for this policy is the traffic flow at the existing point of crossing to the mainland. Another significant factor for the evaluation of this policy is the amounts of air pollutants emitted in the Jätkäsaari area.

3.2.4 Addition of new Bus Lines to Under-Connected Areas. The last policy we consider is the addition of public transport lines to under-connected areas of the Messina municipality in Sicily, Italy. Generally the city is well connected by public transport, however as the city is caught between the sea shore and a mountain area, some of the more remote parts lack connectivity and are only accessible by private vehicles. These areas are also generally too remote to access the city by foot and too mountainous for everyone to use bicycles.

To simulate this policy, we add new bus lines by creating the GTFS data compatible with existing public traffic and including it in the simulation.

[1]In the context of URBANITE project, which this work is a part of, data gathering and quality assurance are parts of the project.

4 CREATING SIMULATIONS

To create a traffic simulation using MATSim, a set of input data needs to be defined, and the simulator's configuration must be specified. The simulation is run in two consecutive steps: first, the agents' actions are optimized using a co-evolutionary algorithm; second, the final run of the simulation is stored and analysed.

4.1 MATSim Input Data

In this section we describe the input data necessary to run the simulation, and the process for creating these files. For each of the files we also describe the data model and explain how the data is used.

4.1.1 Road Network. The road network represents the traffic infrastructure and its properties such as lane capacity and max speed. Currently, we rely on Open Street Maps [10], a crowd-sourced publicly accessible map database. It is a very valuable resource, however due to its nature it is not complete and there may be some inaccuracies in the data.

The resulting network is a collection of nodes and link. Each link represents a straight part of a single lane and connects two nodes. The link also contains other relevant information such road type, speed limit, road or street name, etc. The nodes represent the location via coordinates. This means that a single road or street is made of multiple links that may have different properties.

4.1.2 Facilities. To get the data about specific places in the city, such as hospitals, schools, parks and workplaces among others, we provide the simulator with a list of facilities. These are gathered from OSM along with the network itself and attributes are added from the city datasets. The attributes of interest include number of employees, average number of daily visitors, number of employee and visitor parking spots, etc. Before running the simulation, the facilities and the network are pre-processed together to match the coordinates and other attributes between the files.

4.1.3 Agent Plans. Agent plans are the daily plans of each of the agents that represent the population. These are described as a list of activities and a list of trips that allow the agent to engage in the activities. The agent plans are the results of the population synthesis and travel demand modelling, described in Section 4.4. There are multiple algorithms for population synthesis that are developed for working with different sets of available input data [2].

The trips for each agent are used for the final simulation run. The data contains a collection of trips, each made up of multiple trip legs that may use different transportation modes (e.g., an agent may take a bus to go to work but walk back home).

4.1.4 Vehicles. When interested in vehicle-related data, such as amounts of certain pollutants emitted, data about the vehicles in the city are necessary. Multiple types of vehicles can be defined with attributes such as vehicle type, engine technology, cylinder displacement and latest EURO emission standard it supports. A simulation using this data can be analysed for amounts of pollutants emitted per link for each vehicle by using the HBEFA [9] emission factors.

To use the defined vehicles, the agent population has to be split up into multiple subpopulations. Each subpopulation may link a specific vehicle fleet (a set of vehicles) that the agents can use.

4.2 Automating Simulation Creation

To automate the creation of mobility policy simulations, the following steps were taken:

- The entities representing input data are connected via appropriate relations and a relational database is designed. The input data is related to a simulation instance.
- Processes and algorithms for creating the input data are developed and implemented.
- Simulation results are stored and exported for visualization and further analysis.

We defined a database that allows the simulations to be automatically created and compared using a multi-attribute decision analysis methodology. To allow the user easy comparison of different simulation outcomes, the table `Scenario` includes multiple simulations. Each `Scenario` links to a `Decision Model`, that is designed and evaluated using the multi-attribute decision analysis tool DEXi [1]. This setup of entities `Scenario`, `Simulation` and `Decision Model` allows for a common and automated evaluation and comparison of different simulation results.

At the same time, the `Simulation` entity is linked to entities `Network`, `Agent Plans` and `Vehicles`. These include all the data that is needed to run the simulations.

4.3 Road Network Preparation

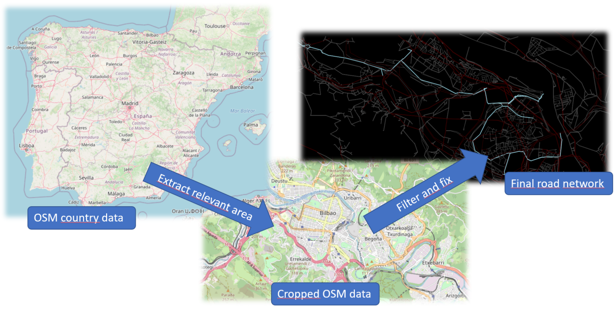

Figure 2: (1) The country wide map is retrieved from OSM. (2) The relevant area is extracted. (3) The map data is filtered and the minimal road network is stored.

OSM is limited by the area size it can export using the API. Instead, we download the binary map data for the entire country from the map catalogue. We use an open source tool Osmosis to extract the relevant area and filter out all the unneeded data in order to keep performance of the simulations to a minimum. Next, we remove any broken links, unconnected links and parts of network that are isolated from the greater connected network, usually artifacts of extracting the selected area.

4.4 Population Synthesis Algorithm

The selection of the algorithm is limited by the data available in the four pilot cities. Another important goal of the algorithm selection is to use mainly open data. Often the studies in this field are not reproducible due to use of proprietary data or data that is not publicly available, as well as the use of proprietary software. The common population model used for population synthesis is shown in Figure 3. The city is split into existing statistical districts and each district is modeled separately. Each district has a population model and a corresponding vehicle fleet used for estimation of air pollutants emitted.

We adapted an algorithm developed for population synthesis using publicly available data in Paris [5], in order to process the data available in the pilot cities. It consists of the following steps:

(1) Sample the marginal distributions of the socio-economic data. Each household is assigned a home location and agents are generated for the household by sampling the marginal distributions of the population attributes.
(2) Iterative Proportional Fitting [8] is used to improve the matching of the agents' attributes by fitting to a small sample of the census data.
(3) Households are assigned income levels sampled from the income level marginal distribution.
(4) Activities are generated and activity chains are assigned to each agent. First, the primary (work and education) activities are considered, then secondary (shopping and leisure) activities are added, based on the travel surveys and facility data.

The lists of households, persons, activities and trips generated need to be optimized to match the traffic data before the final simulation. The initial version of the algorithm was already developed and is based on the open-source implementation of the algorithm described in [5], while the final version is under development.

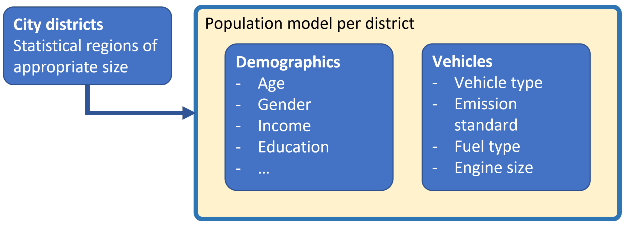

Figure 3: Each district has a separate population model and vehicle fleet.

5 CONCLUSION

We are developing a mobility policy simulation module as a part of the URBANITE system for mobility policy design support. The designed module consists of an open source multi-agent traffic simulation system, population synthesis algorithm including travel demand modelling and the co-evolutionary optimization algorithm for fitting the simulations to existing traffic data.

The system enables mobility policy simulation by implementing the processes for creating the simulations using open data and with no proprietary software required. Using open data allows the users to develop algorithms applicable to multiple cities and ensures the reproducibility of results.

The algorithm for population synthesis and travel demand modelling was selected and adapted to the data available and pilot cities' needs, and preliminary simulation were developed.

The research on this topic is far from concluded. Some of the future work include development of the co-evolutionary simulation fitting algorithm and the final implementation of the population synthesis algorithm.

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