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Future Mobility Scenarios for Hamburg, Germany

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Abstract This contribution describes the set-up for performing a simulation-based assessment of four future scenarios for the mobility in the Greater Hamburg area, Germany. It is based on work done within the project "Real-Lab Hamburg", which is presented elsewhere in this ITS World Congress. The approach performed in this project mixes different approaches for such a future mobility system so that they may reinforce each other. It also presents a combination of more conventional, and more speculative approaches like automated driving.

Currently, few results are available, but at the time of the conference, the scenarios will have been simulated and analyzed.

Keywords: Future mobility · agent-based simulation · assessment

Introduction

The future of mobility may look very different from today, two of the more important threads are the Mobility as a Service (MaaS) and autonomous vehicles and autonomous transport. Especially regarding the latter, there is a lot of excitement, and a huge flow of scientific papers that deal with the prospects and ramifications of autonomous transport [1–3].

Here, a more modest approach is taken (with one exception) where we rely in most of the cases on methods that are currently in the field, although in a more conceptional phase.

The exception is the scenario described in more detail below, where we assume that most of the private transport will be substituted by a fleet of shared vehicles (sometimes named DRT = demand-responsive transit) that also offers shared and non-shared trips where the transport vessels may have different sizes.

It is clear, that mobility systems needs to become CO_2-neutral in a very short amount of time. Currently, they are far from it, for Germany it is known that for 2030, the transport sector should emit about 31% of CO_2 less compared to 1990, this amount to 67 million tons CO_2 to be saved annually.

Real-Lab Hamburg

This work is being done within the German project Real-Lab Hamburg. It consists of 11 sub-projects, the ones important for the simulation scenarios will very shortly characterized below. They are picked for their technology readiness, since they are going to presented separately at this ITS World Congress. Of course, they are not meant to be a complete set of examples of future mobility, neither is this description a complete one.

Communication

This will not be part of the scenarios, but we think it is important as well: The project has invested in research toward an advanced participation procedure in order to take into account citizens' and end users' needs as well as their ideas for future mobility. Moreover, a comprehensive communication strategy is being developed to win people over to the project goals of a sustainable and digital mobility. The details are described in a companion paper submitted to this conference [4]. Here, it is sufficient to know that this sub-project sports what is known as a mobility lab in which the project team enables groups of citizens to develop ideas for the future mobility of Hamburg. The results will then be analyzed and communicated to different relevant stakeholder groups (e. g. public administration, industry, mobility services, and science). The insights gained via participation are expected to yield additional information that may shape the scenarios below, and they may provide input what people like and what they do not like.

The scenarios

Four different future scenarios, together with the base scenario, have been defined. Note, that the demand is the same in all of the five scenarios, it is the demand from 2019.

Base2019 The base scenario, it defines the status before the Corona pandemic. The modal share of motorized private transport (car and ride mode) in Hamburg is 36%, that of public transport 22% of the trips (MiD 2017).

RealLab2030 In this scenario, the extensions of the technologies presented in the next section, and discussed in detail below, are extended to the entire city. This then maps what is achievable with these technologies in terms of transport efficiency overall, and to CO_2 emissions in particular.

RealLab2030plus This is the same scenario as the previous RealLab2030, but with the addition of Hamburg's planned Hamburgtakt by 2030. The Hamburgtakt represents a significant expansion of the current public transport system, with halved cycle times and some extensions and densification of the existing (2020) network. The city has started with the implementation, but it will not finish before 2025.

ProClimate2030 In addition to RealLab2030, measures are taken to reduce the attractiveness of private transport and to increase the attractiveness of other modes of transport. The main tool for this is a congestion charge, which is complemented by a range of other measures. (New partitioning of road space, additional cycle lanes, parking space management, increasing road safety, improve the quality of stay in urban spaces).

DRT2030 This is the scenario with the strongest conceivable digitalization: a DRT service (DRT = demand-responsive transit) with differently sized automatically driving vehicles is set up parallel to the motorized individual traffic. As in ProClimate2030, a congestion charge is introduced to favour DRT and public transport in terms of costs. Normal public transport will remain in place. It will also be important to ensure that the remaining modes such as cycling and walking are not cannibalized.

The Tool-chain

The whole tool-chain consists of the usual steps: input, the simulation itself, and the assessment. In addition, five different scenarios are input as well, and all of this is described in this section.

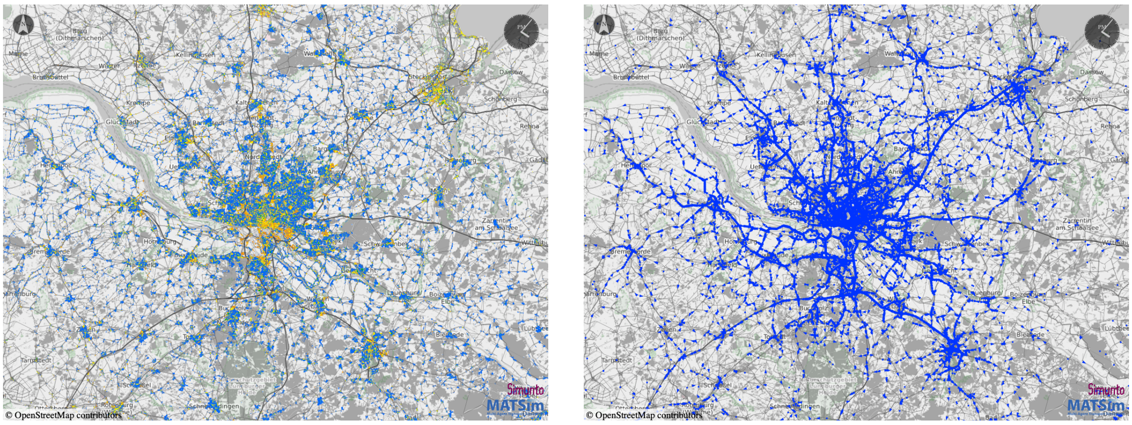
Input

The input consists essentially of the network and demand data in the Greater Hamburg area (see Figure 1 and 2). In addition, a certain amount of other input data is required, in particular to calibrate the simulation to the state of the real-world transportation system of the Greater Hamburg area.

The network is derived from OpenStreetMap (OSM) [5] and modified (mostly simplified) to be used as transport network. This network format used is made so that it can subsequently used without change in a more detailed microscopic simulation like SUMO [6]. This mechanism is described in another paper submitted to this conference [7].

Demand is a mixture from different sources, the most important of it is the data that stem from data from cell-phone readings that are being commercialized by a certain company.

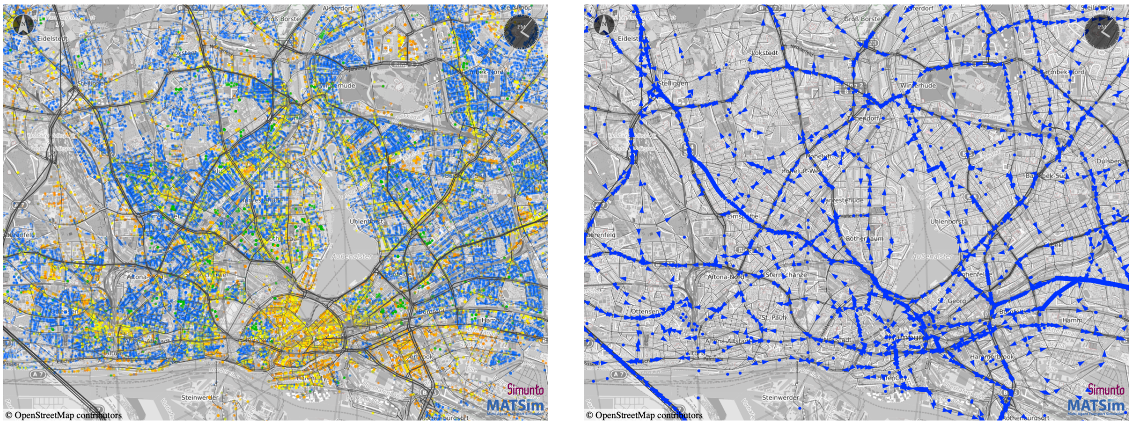
In addition to this, the following data have been used:



(a) Simulated activities: blue = home; orange = work; green = education; yellow = shopping, leisure, other

(b) Simulated vehicles (in blue): road users and public transit vehicles

Figure 1: Simulated activities and vehicles in the Greater Hamburg area (25% sample)



(a) Simulated activities: blue = home; orange = work; green = education; yellow = shopping, leisure, other

(b) Simulated vehicles (in blue): public transit vehicles and cars

Figure 2: Simulated activities and vehicles in the Hamburg city center area (25% sample)

- GTFS (General Transit Feed Specification) data of the PT provider in Hamburg, the Hamburger Hochbahn, both for 2019 and as a planning alternative for 2030.
- Demand for goods and commercial transport are provided by the BVM, which is Hamburg's authority for traffic and mobility (our translation), and from the commercial transport model of the DLR.
- Data of the recent Mobility in Germany survey [8] are used for calibration, as well as count data that stem from Hamburg's Urban Data Platform.
- Socio-demographic data.
- Data about the urban structure, and data about the locations where the agents can perform their activities.

Simulation

The simulation itself is performed by using the agent-based simulation framework MATSim (Multi-Agent Transport Simulation, see `www.matsim.org`) [9]. In MATSim, transport users are modeled as individual agents that each have a so-called daily travel plan (see Figure 3) which describes the intended travel behavior, including the activity-trip-chain, departure times, transport modes and routes. For each of the more than 3 million residents living in the study area or transport users traveling through or into the study area daily travel plans are created and then simulated in order to test whether the simultaneous

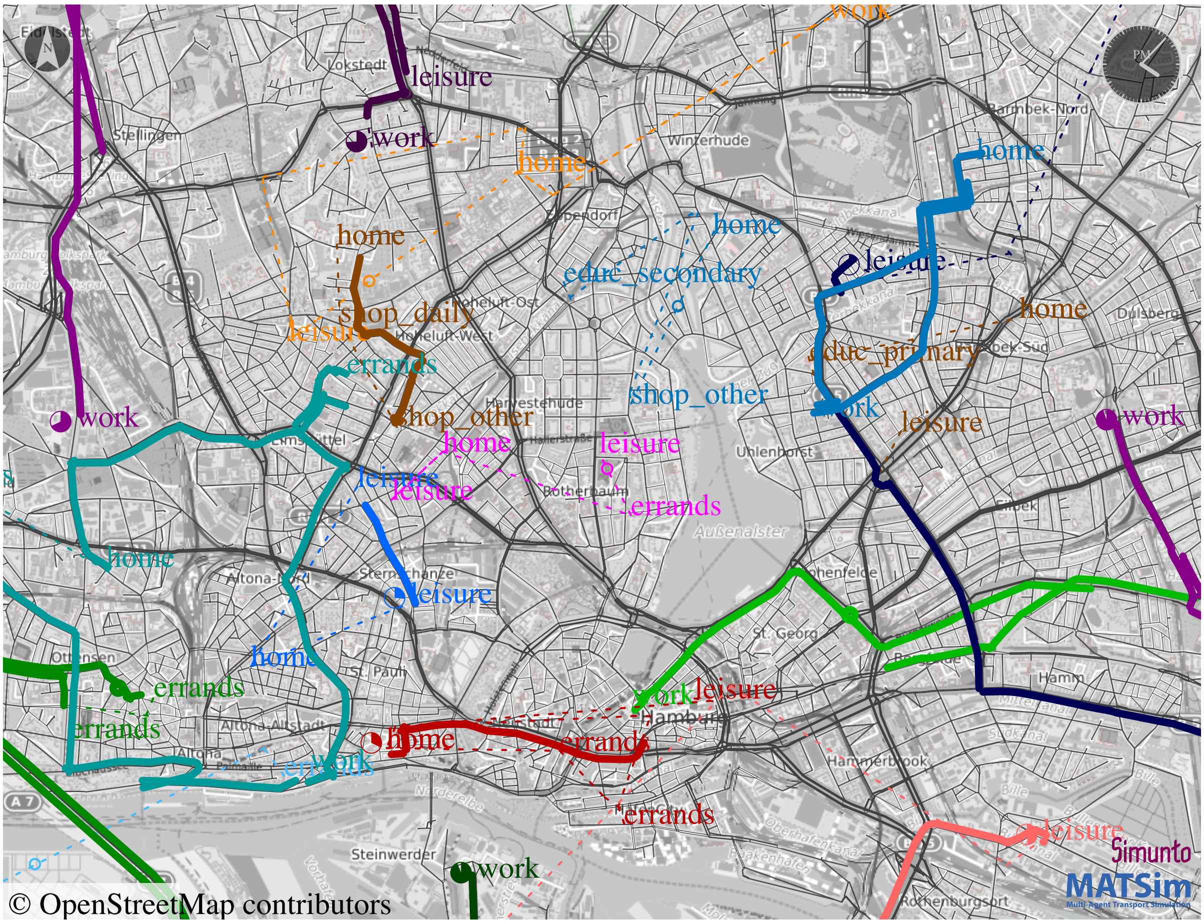


Figure 3: Simulated daily activity-trip-chains of some agents. Solid line: car or ride mode; Dashed line: public transit, bicycle or walk mode. Each color represents the activities and trips of the same person.

execution of all plans yields the correct traffic patterns observed in the Greater Hamburg area. To simulate the interaction of transport supply and travel demand, an evolutionary iterative approach is applied which involves the following three steps:

1. Travel plans are simultaneously executed and traffic flows are simulated applying a queue model with dynamic traffic congestion and spill-back.
2. Executed travel plans are evaluated based on predefined utility functions and behavioral parameters.
3. Agents are enabled to adjust their travel plans along predefined choice dimensions (in this study: transport mode, departure time and route).

This iterative cycle is repeated until the plausible travel plans are generated and an approximation of the stochastic user equilibrium is reached.

The link between the technologies described below, and the behaviour of the agents is made by a simplified discrete choice approach: In a first step, plausible choice sets are generated by mutating existing travel plans, e.g. agents try out a new mode of transportation or choose a new transport route. In a second step, during choice set selection, the agents choose among their acquired set of travel plans based on the (expected) utility applying multinomial logit model. The utility is computed as a function of features associated with a certain travel plan (daily monetary costs, trip travel-times, waiting times, distance-based costs, . . .), each of which weighted by individual factors that describe how strong they contribute to the (dis-)utility. If these factors, and their distributions in the population are known, they should describe the travel behavior of the agents to sufficient accuracy, and, even more important, the reaction of the agents to the scenarios defined above.

Assessment

Finally, not only the traffic patterns can be extracted from the simulation results, but also almost any other feature of interest to the analyst. All features are available in a high spatio-temporal resolution, where the spatial resolution is given by the underlying OSM network, and the temporal resolution can be as fine as one second. For all the links in the network, the load, the speed, the loss time, and the pollutants produced by the transport system can be computed out of the simulation. In addition, more aggregate information like the modal share are extracted from the simulation, and parameters describing the operation of various vehicle fleets. This latter information can be used to test for economic viability of the different services embedded in the simulation.

Relevant technologies within this project

These technologies are being deployed during the course of this project. Here, only those are regarded that could be expected to have an effect on future traffic, and that are translatable into parameters and procedures of the simulation tool. This essentially amounts to an entry in the cost-function described above.

Mobility platform

The mobility platform of the project is provided by the PT-provider of Hamburg, the Hochbahn. It features the possibility to choose between a set of different modes (PT only, PT plus feeder service, car-sharing) and to book each of them with ease and directly out of a smartphone app that is developed and distributed as well, and that fits within the already existing app of the Hochbahn. There is still room for improvement, but it can be regarded as a simplified MaaS, and as such it can be implemented into the MATSim simulation. In essence, it lowers somewhat the costs of using such a mode.

Long distance travel information and booking system

This is similar to the Mobility platform, but it approaches a different segment of travel, that is the long-distance travel that starts and ends in Hamburg. This once more is a MaaS system, however for a different brand of customers, whose spatio-temporal distribution in Hamburg can be identified and then used as input into the MATSim simulation.

Mobility budget

The mobility budget will be given to about 500 people in exchange for their company car. Of course, to be of interest for a future mobility system, this approach has to be generalized to a mobility budget given to a much wider range of people. The details of how this can be done are currently discussed in the group of these authors, in the final scenarios we will come up with a reasonable choice about the group of users enjoying such a mobility budget.

Autonomous shuttle service

At the light rail station Bergedorf, an autonomous shuttle service will be set up. It will run there for three months (and especially during the World Congress), and it will use three autonomous shuttles that pick people up near their home and transport them to the station, and vice versa. It is unlikely, that these three vehicles can handle the complete demand of such a station, therefore additional simulations are needed to determine the amount of vehicles needed.

This is then translated into the scenarios (and the simulation) as follows: for all the railway stations around Hamburg, such a feeder service is set-up with sufficient capacity to serve the corresponding demands. This is integrated into the simulation as a separate inter-modal mode of transport: before, people mostly walked to the station (walk + public transport (PT), now they have an additional mode at their disposal, feeder + PT. Of course, this new service has to have it own set of generalized costs and cost-functions, which are determined by polls and can in principle estimated from the running service.

Shuttle services in rural areas

In three rural areas in the orbit of Hamburg (Ahrenburg, Harburg, Stormarn), a feeder shuttle has started mid-December 2020. It consists of a small fleet of vehicles that could in principle transport six persons (which has been halved to three during the Corona pandemic). They pick people up close to their home and deliver them at the nearest rail-based public transport station, and vice-versa. No direct routes between two destinations in the area are serviced, even if they were possible, and it is made sure that they do not conflict with a regular bus service that runs at some places in parallel, but with a low frequency. Each person who rides such a feeder shuttle is charged with 1 Euro in addition to the regular fare, she or he needs to have a regular ticket as well.

Communication for VRU

Here, a communication will be established between motorized traffic and vulnerable road users such as bicyclists, pedestrians, or scooter drivers. It serves two goals: (i) a collision warning application has been created that samples the GNSS-data that are available from all the road-users subscribed to the service, and computes possible collision probabilities. Once such a probability gets too large, a warning is issued so that road-users can react to it. The second aim is to provide a kind of GLOSA (green-light optimized speed advice) for bicycle drivers, by using in addition data provided by the traffic signals in a certain test-field of Hamburg.

Of course, the idea is to improve the safety of the VRU, thereby increasing the motivation for citizens to use a bike or to take a walk to their destination. Again, this will be distributed over the whole city, so in the future scenario this in general will changed the cost function for these active modes of transport to become more attractive.

Results and Discussion

So far, this paper presents what will be done on the simulation side in order to better understand how future ITS-services may play together to improve the mobility of the people in Hamburg, while subsequently working toward the goal of decreasing CO_2.

At the time of writing, the project is still ongoing, so there are no results to be presented right now.

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