CONSTRUCTION OF A SIMULATION OF ON-DEMAND MOBILITY CONCEPTS IN SUMO

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1. ABSTRACT

The aim of the conference contribution is to discuss the parameters and scenarios of a simulation of demand-oriented mobility concepts. For this purpose, a model is built with the simulation tool SUMO ("Simulation of Urban Mobility") that illustrates an On-Demand operating concept in a certain examination area with regard to parameters like travel time and fleet size.
On-Demand Mobility, also known as Ridepooling or Demand-Responsive Transport (DRT), is a digital demand-oriented mobility concept, in which temporally and spatially corresponding trip requests of several passengers are bundled in real-time. The resulting route can be dynamically adapted to further trip requests. These mobility concepts are currently being tested in pilot operations in various large and medium-sized cities worldwide. To design a successful On-Demand concept, a complete understanding of the principles of On-Demand is necessary. In particular the inclusion of technological, organisational and operational requirements is one of the challenges of transport and mobility research.
For this purpose, the development of a traffic simulation with the simulation tool SUMO is described. SUMO is an open-source software for microscopic traffic simulation that allows the simulation of different modes of transport and mobility concepts and is constantly being further developed. Suggestions for the development of simulation scenarios are given. The setup of the simulation is illustrated using the example of Schwarzer Berg, a district of the city of Braunschweig in Lower-Saxony, Germany.

2. ON-DEMAND MOBILITY

The term On-Demand mobility, also known as Demand-Responsive Transport (DRT) or Ridepooling, describes digital demand-oriented mobility concepts in which temporally and spatially corresponding trip requests of several passengers are bundled in real-time in the sense of shared mobility (Viergutz 2019). The resulting dynamic route can be adapted during the journey to further trip requests made by other passengers.
In addition to these pooling characteristics, On-Demand mobility concepts are characterized by their demand-oriented operating concept, in which trips, in contrast to traditional supply-oriented regular services, only operate if there is a request to travel. The routes resulting from the pooling of several trip requests are created dynamically and are adjusted during the journey (Ronald et al. 2015). This means that On-Demand mobility concepts can be located operationally between individual and public transport systems (Laws et al. 2009) or between bus and taxi (Navidi et

al. 2018). A complete understanding of the system is neccessary for the design of successful On-Demand mobility concepts. A particular challenge is the identification of cause-effect relationships between several aspects of mobility concepts. A simulation can contribute to answering emerging questions regarding the optimal operating concept and support the examination of the operating conditions and the resulting effects.

3. PARAMETERS, SCENARIOS AND CHARACTERISTICS

A simulation can be useful in many ways and depending on the focus of the simulation, various questions can be pursued. In order to ensure that the results of the simulation can be evaluated for the respective research questions, a prior examination of the objectives of the investigation and the specific focus of the simulation is necessary. The essential elements here are the input and output parameters as well as the framework conditions and scenarios of the simulation.

Output parameters represent the quantified result of the simulation. For example, if a simulation is to provide information on the environmental influences of a mobility concept, the output parameters to be considered could be noise and pollutant emissions such as CO_2 or nitrogen oxides or energy consumption. If the aim is to investigate traffic and operational effects, possible output parameters could be, for example, travel time, travel speed, land consumption, number and capacity of vehicles used or traffic flow and volume. Another aspect is the intended reference value. Examples could be the considered period or the considered spatial aspects (consideration of an entire examination area or focus on selected lanes).

If the desired output parameters are defined, the necessary input parameters are determined to achieve this goal. These input parameters can be based on real data or generated by assumptions. A key input parameter is often demand or traffic volume. Here, the necessary granularity in which these data must be available is a basic prerequisite for the conception of a meaningful simulation environment. In order to represent a traffic volume in an investigation area, hourly data or a specific hourly traffic load curve is often sufficient. If it is to be investigated whether – as here in the example of On-Demand transport – trip requests can be combined with each other in terms of time and space, a fine-grained (minute-based) demand is required.

Parameters can often be either input parameters or results, depending on the research question. An example is the interaction between demand and the number of vehicles used. If the size of the fleet is given, the simulation can determine the maximum demand that can be covered. – Conversely, if the demand is fixed, the necessary number of vehicles can be determined (Armellini 2019).

In the simulation of demand-oriented mobility, different forms of operation can also be considered. The density and distribution of access and egress points, so-called pick-up-drop-off-spots (PUDOS), are of particular interest. These PUDOS can consist in predefined stops, just like the stops of a regular public transport service, or there can be completely flexible access points corresponding to a door-to-door operation.

For the structured creation and selection of suitable simulation scenarios different methodical approaches are conceivable. One approach is the implementation of a trend analysis according to Viergutz and Scheier (2019) in order to prioritize possible scenarios.

4. DEVELOPMENT OF A POOLING ALGORITHM FOR SUMO

The simulation described in this paper mainly involves the simulation tool Simulation of Urban Mobility (SUMO) and the Traffic Control Interface (TraCI).
SUMO is an open-source software for microscopic traffic simulation (Alvarez Lopez et al 2018), which has functionalities for the simulation of different transport modes and mobility concepts and is constantly being further developed. Currently, different pooling algorithms for the mapping of demand-oriented mobility concepts are being developed and tested. The findings from the simulation can be used to further develop a transport model.
TraCI is an interface that can be used to intervene in the SUMO simulation (DLR o.J.). Thus, an algorithm can be developed independently from the simulation environment and coupled to SUMO to influence the simulation process. In connection with the algorithm presented here, TraCI has the task of having the calculations of individual conditions carried out and of reporting the result back to the schedule.
In order for On-Demand mobility with bundled trips to be represented in the simulation, a pooling algorithm must be developed that calculates the optimal route of a vehicle based on the existing trip requests (Armellini 2019). The algorithm is based on a flowchart that defines the sequence of conditions that are used to decide whether a bundling ("grouping") of the respective trip requests is carried out. The conditions can be adapted to the respective goal of the investigation.
These condition for example can represent a minimum and maximum value Estimated Time of Departure (ETD) of the passengers. The ETD describes the time span between booking a trip and its start and can be interpreted approximately as the equivalent of the waiting time in timetable-based regular services (Viergutz and Scheier 2019). In order to avoid unreasonably long travel times for passengers, a detour factor should also be taken into account. This specifies the travel time ratio between the grouped trip and the corresponding exclusive trip. In order to create a sustainable, environmentally-friendly mobility service, a reduction in pollutant emissions and thus a reduction in transport performance makes sense. For this reason, the frame condition can be set that the total distance travelled on the grouped trips should not be greater than the total number of kilometres of exclusive trips were. This condition is also calculated using TraCI and fed back to the algorithm. Further frame conditions are conceivable.

5. SIMULATING AN ON-DEMAND SCENARIO IN BRAUNSCHWEIG, GERMANY

An example is given to illustrate the simulation of On-Demand Mobility in SUMO. We are using the example of Schwarzer Berg, a district of the city of Braunschweig in Lower-Saxony, Germany. It is a residential area with a spatial expansion of around 1.000 m x 600 m and a population of 4.482 inhabitants, which gives a population density of 7.000 inhabitants per km².
In the following, the individual steps performed when setting up the examination area in SUMO are described briefly. The first step is to create the net layout. This can be

facilitated e.g. by selecting inftastructure from a digital map (e.g. OpenStreetMap). The visual network editor SUMO Netedit allows the configuration and visualization of a selected map section. This is followed by the adjustment and revision of the area. This includes for example the number and direction of the lanes and intersections, the turn off relations and specifications like speed-limits.

In a next step, Traffic Assignment Zones (TAZ) are defined. Fig. 1 shows the defined TAZ in the examination area of Schwarzer Berg. In this example, four TAZ are defined (blue frames). As criteria for the definition of the TAZ, data on the population density of individual areas of the study area were used. The part of the area that is not covered by a TAZ is also not part of the examination area since there are uninhabited areas such as allotment garden associations.

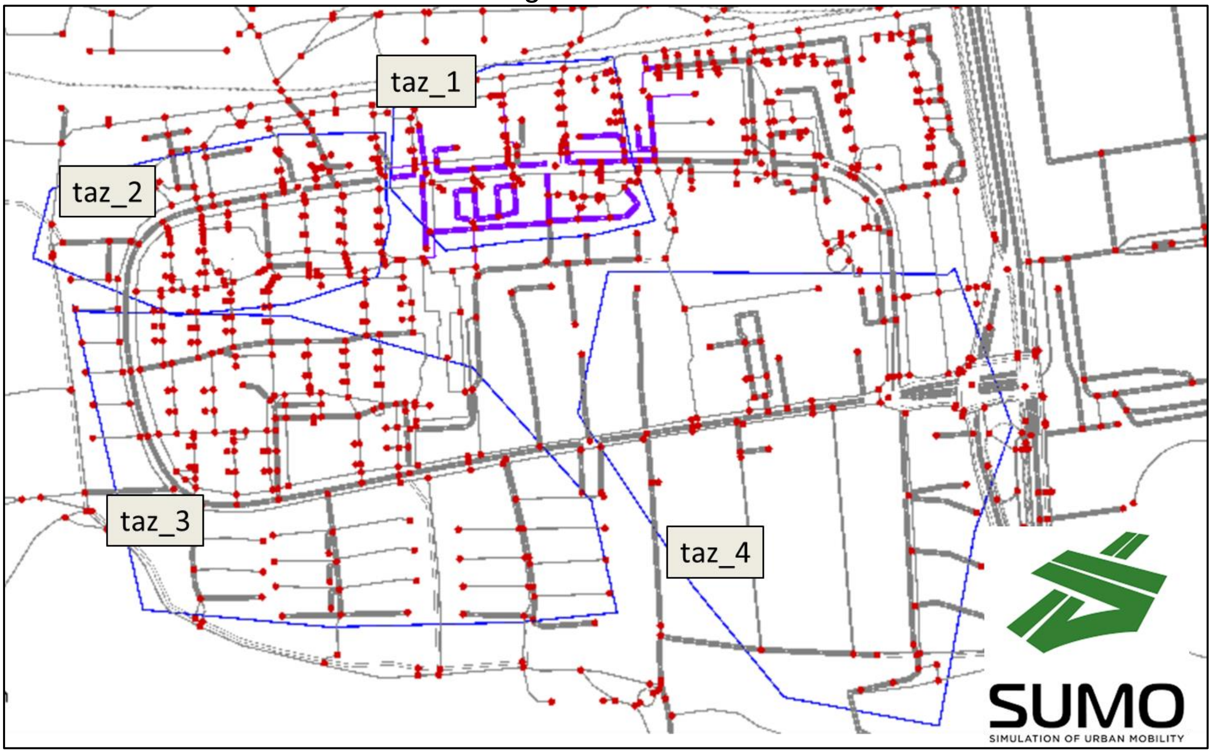

Figure 1: The examination area Schwarzer Berg with defined Traffic Assignment Zones (TAZ) in SUMO Netedit

After the TAZ are set, the lanes are defined where stops are possible. Fig. 1 also shows those lanes of taz_1 in purple that have been defined as possible stops. For the other TAZ, the lanes with possible stops are also selected. As described above, traffic demand is an important input parameter. In this example, an overall demand for the total examination period of 24 hours is set. Additionally, a specific hourly traffic load curve is created. This curve describes the proportion of total demand per hour and in this example it consists of 24 values and has a morning and an afternoon peak hour (see fig. 2).

```
od2trips.exe -n osm_taz.add.xml -d od-matrix.txt --persontrips
true -s 1 --timeline.day-in-hours --timeline
0,0,0,0,0,1.3,7.0,9.3,6.7,4.2,4.0,3.8,4.1,4.6,5.0,6.7,9.6,9.2,
7.1,4.8,3.5,2.7,2.2,0 -o person.trips.xml --verbose -c
persons.odconfig
```

origin and destination matrix | hourly traffic load curve

```
* From-Time  To-Time
0.00 24.00
      taz_1          taz_1     130.00
taz_1          taz_2     41.00
taz_1          taz_3     5.00
taz_1          taz_4     0.00
      taz_2          taz_1     41.00
taz_2          taz_2     200.00
taz_2          taz_3     15.00
taz_2          taz_4     43.00
      taz_3          taz_1     41.00
taz_3          taz_2     200.00
taz_3          taz_3     15.00
taz_3          taz_4     43.00
      taz_4          taz_1     41.00
taz_4          taz_2     200.00
taz_4          taz_3     15.00
      taz_4          taz_4     15.00
```

Figure 2: Example of a 24 hour traffic load curve and the demand from each TAZ to every other TAZ

In a next step, an origin and destination matrix that describes the demand from each TAZ to every other TAZ is required (see also fig. 2). The trip requests within a TAZ are also possible. In addition, scripts are required to provide information on other aspects, such as the number of vehicles and intermodal travel chains. The description of this example is shortened. The use of SUMO for simulation is multifaceted and allows the setup of many different operating concepts. Therefore, many more settings are conceivable here. As a result of the simulation, SUMO generates output scripts to evaluate the outcome.

6. INSIGHTS AND EXPECTED RESULTS OF THE SIMULATION

The simulation is executed with the previously described settings. Fig. 3 shows a section of the simulation of On-Demand Mobility in SUMO. The vehicles (yellow) are picking up the passengers (blue) according to the setting before defined and corresponding to the prepared algorithm.

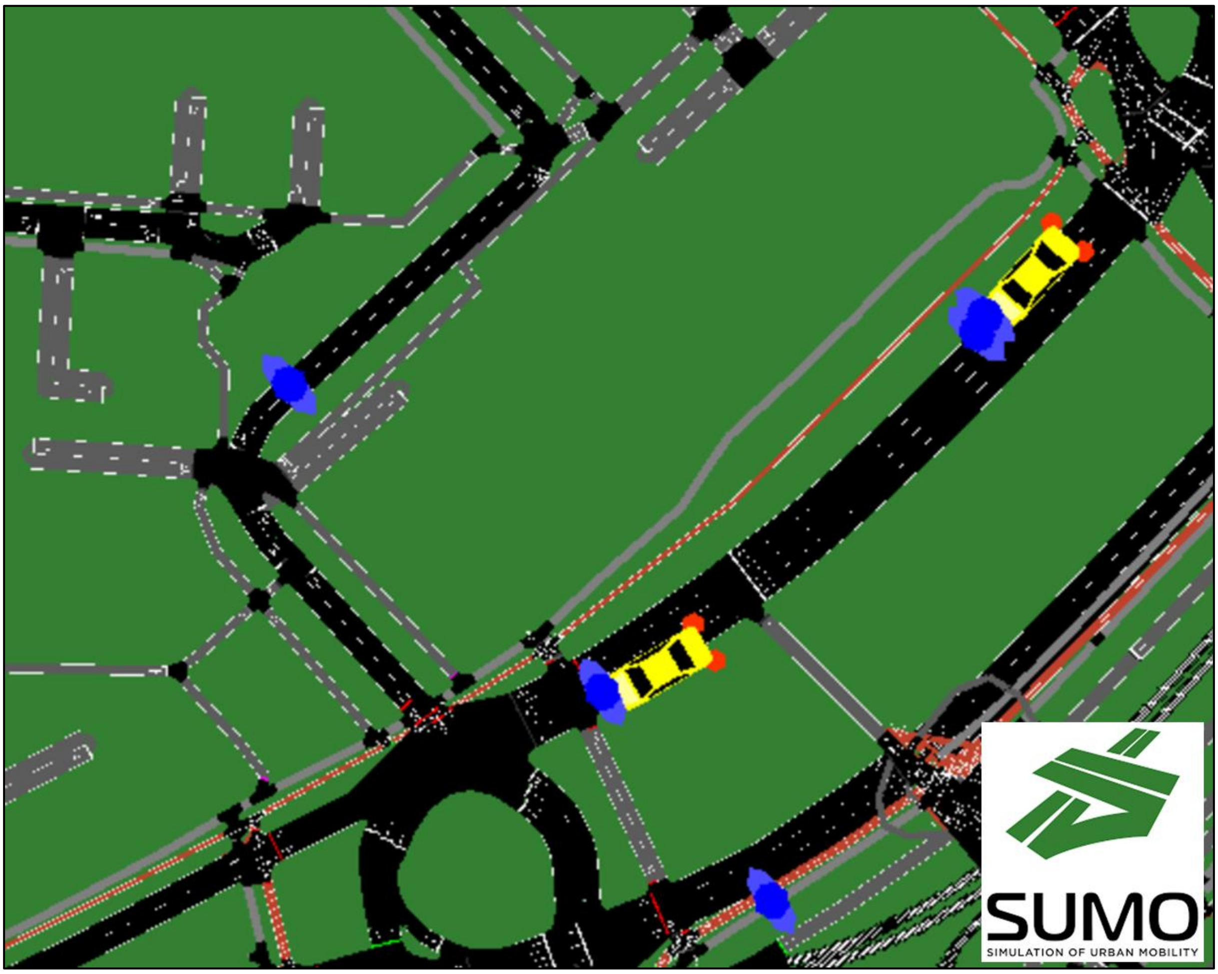

Figure 3: Simulation of On-Demand Mobility running in SUMO

On-Demand mobility concepts are conceivable in several characteristics and operating concepts, therefore the selection of the framework conditions and scenarios of the simulation is relevant. As a preliminary consideration when developing an operating concept or a simulation scenario, the integration and interaction with existing transportation solutions is an important issue. Thus, On-Demand transport can be offered as an additional service to regular public transport and thus complement the already existing mobility options. Alternatively, stand-alone solutions are also possible, in which conventional, timetable- and line-bound transport is replaced in whole or in part (Enoch et al. 2004). Replacement or supplementation of the existing regular service can take place both spatially (same or extended service area) and temporally (during the same or different service times).

The demand assumed in the simulation represents a further influencing variable when setting up a traffic simulation. On the one hand, it can be assumed that the demand is static, evenly or unevenly distributed over time. On the other hand, it is also possible to take into account a dynamic demand that is linked to transport mode selection criteria and a mode choice model of the simulated agents.

When performing simulations with different parameters, it can be observed that different results are obtained depending on the setting of the simulation and the assumptions made. In particular different traffic load curves, numbers of available vehicles and the temporal and spatial distribution of the trip requests have a great influence on the result of the simulation. Hence a thorough preparation of the simulation is required. It has also been found that a large number of different evaluation parameters exist. Especially interesting regarding to On-Demand Mobility seem to be the waiting periods, the ETD and the travel time of the passengers, the pooling rate as well as the ratio of the empty journeys to the distance that was driven with passengers.

7. CONCLUSION

This paper describes the structure of a simulation scenario with the simulation tool SUMO. The aim of the paper was to discuss and evaluate proposals for the conception of a simulation of On-Demand mobility. It was shown that a thorough examination of the objectives and the framework conditions of the study is necessary prior to the simulation. The core of a simulation of On-Demand mobility is the algorithm that defines and applies the rules according to which trip requests are to be bundled. This algorithm has a strong influence on the results of the simulation runs and should therefore always be considered when evaluating and interpreting the results. A simulation makes it possible to try out different operating concepts with different assumptions and to analyse the results and effects. These can be used to investigate the cause-and-effect relationships of On-Demand mobility and also serve as a basis for further investigations as well can serve as a preparation of the introduction of a mobility system into the real world.

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