EPiC Series in Engineering
Volume 2, 2018, Pages 25–42
SUMO 2018- Simulating Autonomous and Intermodal Transport Systems

Calibrating Traffic Simulation Models in SUMO Based upon Diverse Historical Real–Time Traffic Data — Lessons Learned in ITS Upper Austria

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Abstract

Traffic information services and traffic simulations represent a crucial element for today's mobility. Traffic data may be gained using different types of sensor technologies and measurement approaches. However, there is no "one fits for all solution" related to the application of sensor technology and providers of traffic information services need to carefully decide when to apply which kind of sensor technology and measurement approach to provide traffic information.

In Upper Austria, ITS Upper Austria represents such a traffic information provider. For the calculation of travel times and delays, real-time traffic sensors and a traffic simulation are currently in use. The latter is required when the amount of current real–time traffic information related to a link is too low for providing reasonable traffic information.

ITS Upper Austria implemented its traffic simulation using the SUMO software. The demand model used for the simulation was built years ago, mainly using data from a household survey in Upper Austria in 2012. Based on this demand model, a route file was composed, which serves as input for the mesoscopic simulation. However, to increase the quality of the simulation, the route file needs to be continuously updated with respect to changing traffic behaviors (e.g. route traces, amount of cars). Different types of sensor data might trigger the calibration of traffic simulation models. For example Floating-Car-data, Bluetooth-data, data gained by permanent counting stations or even traffic times gained within test rides. Triggering updates of the traffic simulation model requires a careful analysis of the data basis and an appropriate update algorithm.

This paper presents a traffic simulation update algorithm based upon diverse traffic data sources. Furthermore, findings related to the applicability of different sensor technologies for triggering simulation model updates are discussed. The findings stem from developments and empirical tests of ITS Upper Austria. The results could inform traffic

E. Wießner, L. Lücken, R. Hilbrich, Y.-P. Flötteröd, J. Erdmann, L. Bieker-Walz and M. Behrisch (eds.), SUMO2018 (EPiC Series in Engineering, vol. 2), pp. 25–42

information service provides when selecting sensor technology or when designing update mechanisms related to traffic simulation models.

1 Introduction

Intelligent transport services (ITS) are an integral part of today's mobility. All over the world, traffic information services are used to calculate and navigate a trip —- either by the car, bike, public service or by foot. End users are expecting a real-time-traffic situation and prediction by these services. ITS provider face a significant effort related to the development and maintenance of such services. From buying and choosing real-time traffic sensors to historicizing real-time-data and building algorithms for traffic prediction, diverse aspects need to be considered.

ITS Upper Austria aims at providing a traffic data platform for Upper Austria and is already known in the SUMO-Community. Referred to it as ITS-West, selected aspects of the project work are already published in former SUMO-Proceedings (2013-2015) [4, 5, 6].

One of the main goals of ITS Upper Austria is to provide near real-time-traffic information by using different real-time sensors and a mesoscopic traffic simulation. It is based on the network of GIP-AT (see Section 3), which is getting updated every two months. Recently, a dense coverage of floating car data in the bigger cities, central locations and main streets triggered by taxis, public transportation systems, emergency cars, private drivers and other sources was achieved by ITS Upper Austria. Furthermore, permanent counting stations are providing data on important streets across Upper Austria. Soon, data will be collected by Bluetooth sensors on the access roads to lager cities. These sources are applied to gain real-time-traffic data. However, in case too little data is collected on a link, the mesoscopic SUMO-simulation is used as fallback. The simulation was built up in 2012 based on data from a household survey in Upper Austria. Today, in 2018, it is urgent to recalibrate and validate the simulation model. Not only the network and driving behavior changes during time, but also every day there is a different traffic situation. In this context, it is necessary to implement automatic updates as well as processes conducted by humans.

Figure 1 shows a conceptual model for the calibration and validation of the SUMO simulation of ITS Upper Austria based on a diagram published in Antoniou et. al. [1]. Initially, data need to be collected, filtered and analysed in advance to the calibration and validation process. Within the data analysis, the data quality needs to be assessed in order to ensure that only data of adequate quality are considered for the model calibration and validation. The "near real time" condition will be evaluated as described in section (see Section 5). Findings from the European Project MULTITUDE indicate that two thirds of all studies of simulation models are done without using any data [1]. However, for a near-real time simulation using pausible data is absolutely necessary.

In this paper, an experience report is given about using real-time-sensor data for the calibration and validation of traffic simulations. The findings are related to existing literature in this field. Moreover, an procedural model is presented, which may support decisions related to the data selection in the context of traffic model calibration and validation.

The paper is organized as follows. In section 2, the project findings are related to the state of the art. Section 3 gives an overview on the historisation and calibration methods applied in ITS Upper Austria. In Section 4 we provide an insight into the different kinds of real-time data used in ITS Upper Austria. Section 5 presents an procedural model, which describes how to use various kind of data for calibration and validation of traffic simulations. Finally, Section 6 concludes the paper.

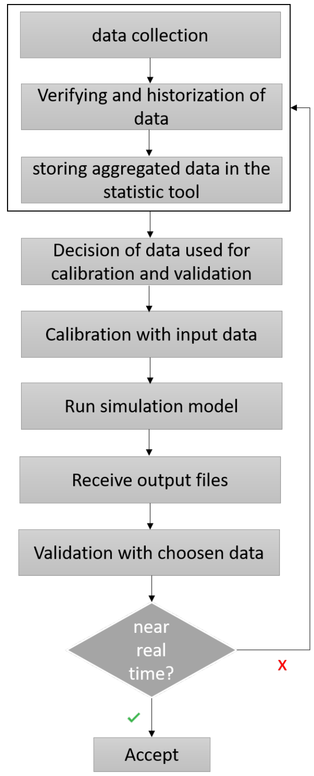

Figure 1: Conceptual diagram for the calibration and validation of the SUMO simulation of ITS Upper Austrian

2 Related Work

Antoniou et. al. presents a procedural model for the calibration and validation of traffic simulations, which is widely adopted in the field of ITS [1] . However, the model represents a generic procedural model, which does not consider different traffic data types in terms of Bluetooth, FCD, or other data types.

The project MULTIDUTE investigates different calibration and valdation approaches for traffic simulations models. One aspect in this endeavor is the necessity of data for the calibration and validation. The project findings indicate that traffic simulation projects typically struggle with the availability of traffic data for the calibration and validation. Therefore, simulations are often based rather on assumptions than on evidence-based data from real traffic situations. Anyway, traffic simulations may also provide acceptable results in situations where no data from real traffic situations is available, e.g. when the effect of a new traffic light mode on the traffic behavior is tested. In general, it is recommended to apply data gained within real traffic situations in order to create valid simulation results [1].

With respect to the data selection, Wunderlich et.al. propose the following guidelines[9] :

- consider the quantity of collected traffic data
- verify historical data

- apply the most recent traffic network data, e.g. the latest geographic integration platform (GIP) version (see Section 3.1), maps etc.

- consider traffic data for different traffic situation, e.g. rush hours, free flow and traffic data with different geographical scope.

Historical data should, if possible, still present the current traffic behavior in a road section. If possible, data should be recent and consistent. The data could be valued by field inspection. This also consists the quality check of traffic network data.

These guidelines represent a valuable input for the procedural model presented in Section 5. The generic model of Antoniou et. al. inspired the procedural model presented in Section 1 [1]. In advance to the procedural model for the calibration and validation of traffic simulations in ITS Upper Austria, the calibration and historisation approach in ITS Upper Austria will be described (see Section 3). Furthermore, the different traffic data sources applied in ITS Upper Austria are detailed (see Section 4).

3 Calibration and Historisation in ITS Upper Austria

Before starting the actual calibration or validation process there is a need to filter the available data set and to assort data with high quality. The road network of Upper Austria consists of over 200 000 links, with more than 110 000 of Functional Road Class(FRC) 0-4. Having a network with this order of magnitude, it is not only a challenge to decide what data should be used, but also what to do when there is no fitting data for a link available. Another important factor is that the road network in Upper Austria is a mesh network, which makes travel information service even more difficult, since the distribution of near real-time traffic sensor measurements usually are more unbalanced than for instance in a star-like network (like in the Salzburg region).

In the subsequent sections an overview of the historisation and calibration method in ITS Upper Austria is given.

3.1 Data Historisation

A prerequisise for historical data is the historisation of traffic data. The documentation should consist of a file-naming structure, an explanation of the sources of data, and a database structure [9].

In ITS Upper Austria all collected sensor data are anonymized and archived in a data base. All collected sensor data are anonymized, to eliminate person relations and then they are archived in a data base. Depending on the daily and seasonal fluctuation of the traffic, this results in approximately 10 to 27 thousand new database entries every half an hour. The collected sensor data is filtered, verified and map matched before they are used for the calculation of the real-time traffic situation. This calculation takes approximately one minute. The publicly available traffic information is updated with new sensor measurements nearly every minute.

The historisation of the calculated traffic situation is not done in real-time, because some data may not have been received in time. Therefore, the historisation of this aggregated data is done later by recalculating the traffic situation of the past in certain time steps (typically

15 minutes steps are used). This historical data are applied among others for calculating time variation curves and for validation.

In Upper Austria the GIP-network is used. The GIP is a joint nationwide transport graph for Austria. Getting updated every two months changes in the network, for example new streets or changed street attribute, need to be considered. Using the different kinds of networks for real-time traffic info it is not only important to develop a historisation for the real-time traffic data, but also to calibrate the simulation. When the GIP-network is used, the network changes more often then using other networks. As an example, regarding the integration of route-files in SUMO the use of a new network only works when the link IDs exist.

In the database structure it is important to save the data of the timestamp record, and the GIP-version for the map matching. Updates of a GIP-version may change ID. Using older data, it is possible that new streets were built since this data was gathered. For this it is a need to decide when a data set is outdated.

ITS Upper Austria designed and developed a statistic-tool for the analyzation of historical data. At the moment floating-car-data and data from permanent vehicle counting stations are included. The statistic-tool can be used for different studies like, traffic variation curves, route selection and traffic prognosis.

A general challenge is the use of the allowed vehicle speed set in the GIP-network. The stored values are often incorrect. It is important for traffic information providers to discuss the need of a correct entry of the allowed vehicle speed on each link. For ITS Upper Austria, it is fundamental to prepare time-variation curves of the average speed with a maximum speed, set by the allowed vehicle speed. There are different opinions on this topic. On the one hand, people say that the travel time is getting distorted when the average speed is used as a maximum. On the other hand, it is important to deliver the fastest travel time, which is allowed by law. Furthermore, the sensibility of the anonymized data has to be preserved. The allowed vehicle speed is also used for the delay calculation of travel time.To generate valid information related to the allowed vehicle speed, listed speed signs for speed limitation have been map matched and used for correcting the stored values in Upper Austria.

3.2 Applied Calibration Methodology

The traffic simulation of Upper Austria includes more than 650 000 routes and more 1 720 000 simulated vehicles at the same time. For the calibration of this simulation ITS Upper Austria applies two approaches: *off-line calibration* and *on-line calibration*.

The off-line calibration is used to develop a realistic simulation and to refine the demand model. For the improvement of the demand model different aggregated historical real-time data will be used in the off-line calibration in the future. The idea is to improve the traffic volume on different routes based on time variations curves. This means, that for the off-line calibration a historisation of traffic data as well as the network-data, GIP network, is necessary (see Figure 2). For achieving a realistic simulation the applied routes and starting time of each simulated vehicle are optimized in the SUMO route file. It should be keept in mind, that the route network is generated by the demand model and the current GIP-network. Is there a change in one of these, the generated routes will also be changed.

In addition, the on-line calibration is used to adapt the simulation to real-time traffic situations. Currently, it is only based on the comparison of simulated and real-world vehicle detector loops (VDL), see Section 5

ITS Upper Austria initially tried to apply a microscopic simulation model. Experiences showed that the offline calibration process is too slow in a microscopic simulation. The off-line

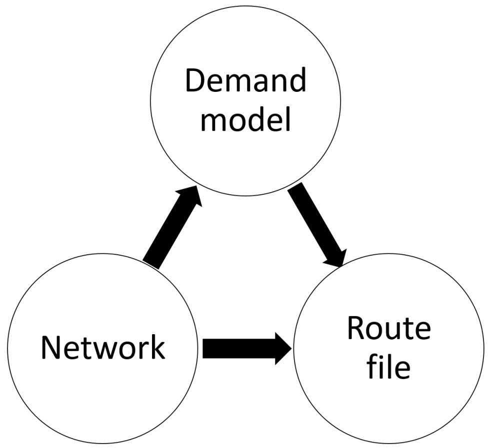

Figure 2: How the network, demand model and route file influences each other

calibration took months, however, a new GIP version is released every two months. The microscopic simulation was also too slow for on-line calibration, where the simulation should keep pace with real world traffic situations. Applying the mesoscopic model, the off-line calibration takes 2-3 weeks and the on-line calibration works even faster than real-time.

Traffic data is historized in ITS Upper Austria based on the GIP version number and the timestamp related to the start date of use. Two graphs will be compared to each other and will be stored as a Graph Edit Distance database. This information can be used for updating VDL locations, adapting off-line calibrated data, as well as comparing historical data and time-variation curves. Additionally, the route sections can be used on different graph versions. This enables that route choices on different networks can be compared to each other. Another benefit from the GIP-historisation is that real time data can be filtered if there was a change in the network.

4 Gaining traffic data in ITS Upper Austria

In this section we provide an insight into the different kind of real-time data as well as their application for the calibration of ITS-Upper Austria. First, the different types of traffic data used in ITS Upper Austria will be described. Second, advantages and disadvantages of the aggregated data from different data types are discussed. The discussion refers to general experiences gained in ITS Upper Austria and specific experiences gained within a sensor test and evaluation conducted at the B127 in Upper Austria (see Figure 3). The B127 is located on the north of the Danube river and ends at the crossing to one of the main bridges in Linz. The bridge connects both parts of Linz, the south including the ancient city center and the north. The B127 represents an important access route to Linz. The B127 includes a carpool lane towards Linz used by taxis and buses. However, the amount of commuters who rely on this access street regularly leads to congestions.

4.1 Data Gained by Vehicle detector Loops (VDL)

Permanent counting stations, or vehicle detector loops (VDL), are a common data source. However, for vehicle information services they are limited in the coverage area and vulnerable

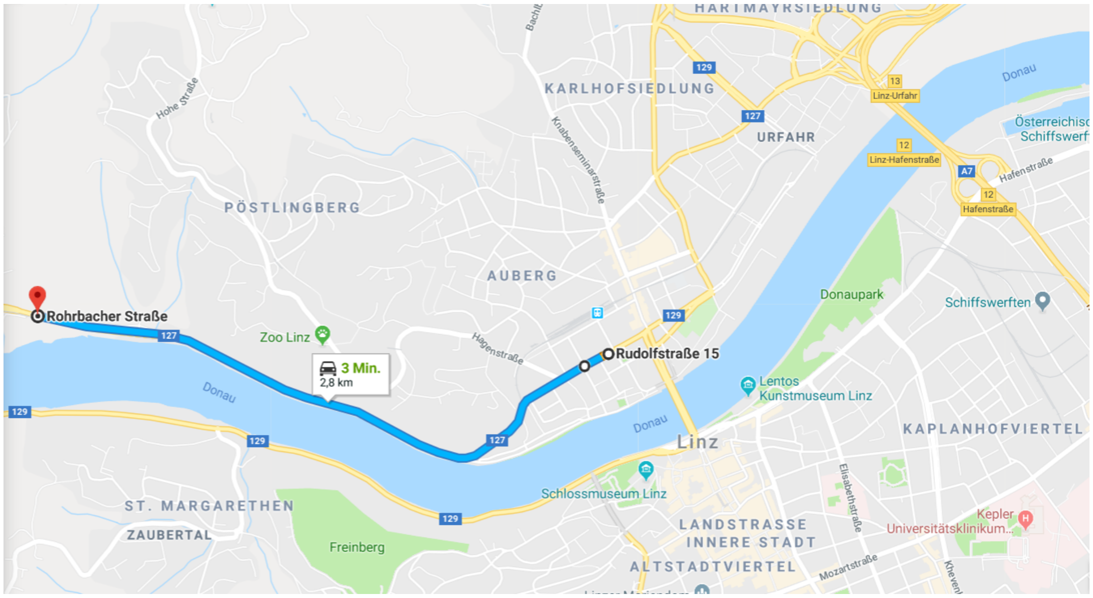

Figure 3: ITS-Upper Austria Statistic–Tool, example for data gained by permanent counting stations

for errors and malfunction [3]. Government or highway authorities typically provide vehicle data, gained by permanent counting stations. Working together with the government of Upper Austria, data from 88 permanent counting stations spread all over Upper Austria is included in ITS Upper Austria. The aggregated data provides information on the interval start time, the day, the edge ID and the measurement/vehicle count. It is possible to set the interval to 15 minutes, 30 minutes or one hour. Also information on the street type and characteristics of the streets are given. Further, the average velocity, v85, and the permitted speed are automatically calculated. Figure 4 shows the statistic tool to calculate data gained by permanent counting stations on the street B127, one of the most important access roads to Linz. The statistic tool, designed by ITS Upper Austria, provides a technical opportunity to analyze and use real-time traffic data. This can be quite helpful when data is assessed within the calibration or validation.

4.2 Floating Car Data (FCD)

The main real-time-traffic information for ITS-Upper Austria is obtained by floating car data. The use of floating car data for traffic information systems is quite popular. In addition to floating car data, Extended Floating Car Data (XFCD) may be applied. Companies like BMW already equip their vehicles with sensors, to be able to provide their own traffic information system – not only based on FCD but also on XFCD. XFCD provides additional traffic information, e.g. ice on the street or measurements of fog [2]. When applying FCD, a traffic information provider needs to select which data is required for the individual application. In ITS Upper Austria, FCD is not only providing all the essential information, but also easy to integrate into any vehicle.

A benefit of investing into floating car data instead of vehicle detector loops, is that floating car data can provide data over a wide area. In urban areas, on main streets and the province

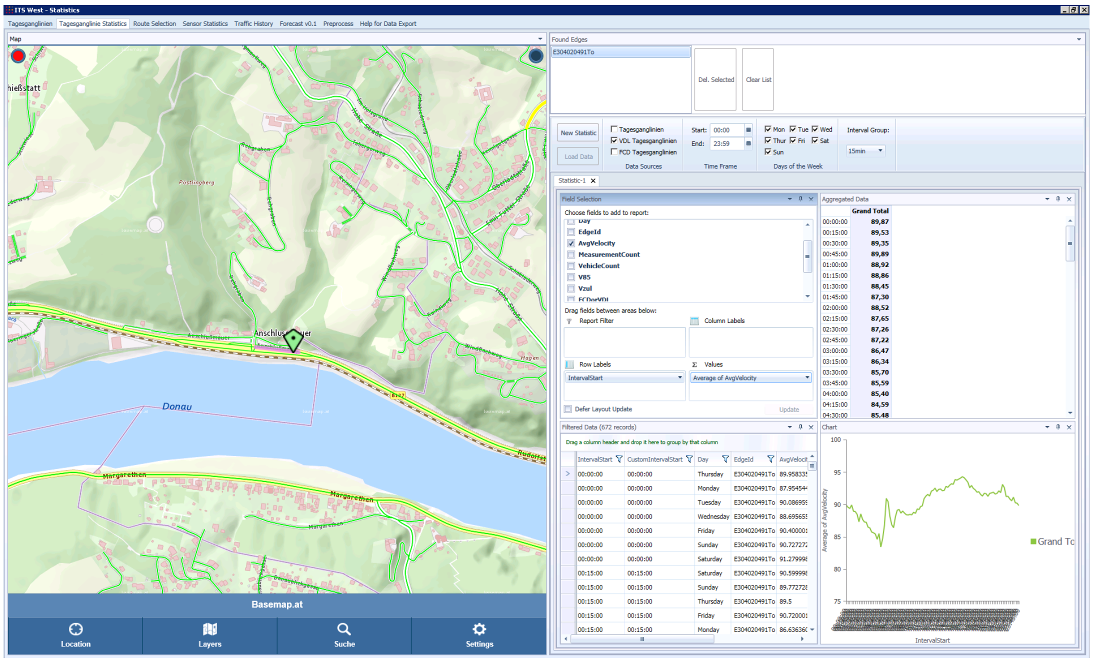

Figure 4: ITS-Upper Austria Statistic–Tool, example for data gained by permanent counting stations

FCD fleets collect most of the data for ITS Upper Austria. Taxis, emergency cars, public transport systems, logistic companies, company cars and private drivers contribute to the collection of this data. Using FCD brings also some challenges. It is necessary to perform map matching and plausibility checks (car parking etc.). In addition, travel time deviations need to be evaluated with respect to specific road characteristics exhibited for example by bus lanes. Another important aspect of FCD is the origin, e.g. FCD obtained by taxi, bus, truck, etc. The origin is important for both, the provision of traffic information and the model calibration and validation.

Another advantage of FCD is the possibility to extend measurements with dump measurements based on the trajectories: if one or more links between two FCD measurements on the trajectory of a vehicle does not contain any FCD measurement, the average speed for these links may be calculated. As shown in Figure 5, the average speed is calculated based on the timestamps and the positions. The latter are used for calculating the distance of the two measurement on the trajectory. The average speed between the positions is received and assigned to this intermediate link. With this method dump FCD can be calculated. Experiences show that the dump data fits very well into the real-time traffic.

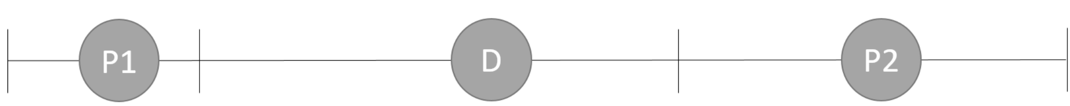

Figure 5: Example for creating a dump FCD

4.2.1 Comparison of FCD and VDL Data

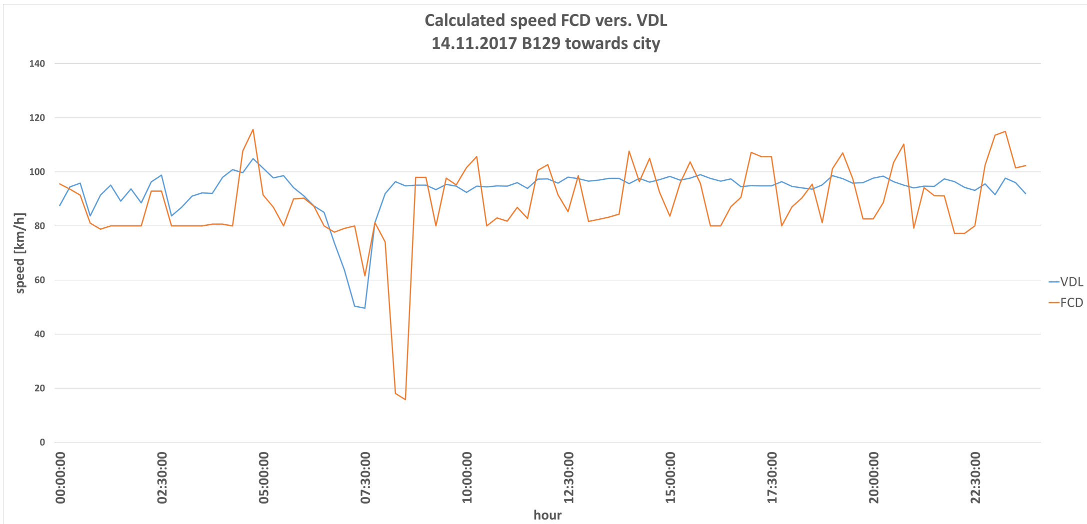

Figure 6: Comparison example for FCD and VDL Data

In Figure 6 the calculated average speed of VDL and FCD on the B127 is shown. Compared to VDL based speed calculations, FCD calculations vary to a higher degree. In this example, VDL data comprise a higher amount of measurements. Therefore, the calculated VDL speed exhibits a higher reliability for near real-time traffic information.

4.3 Bluetooth-Data

To improve the calculation of speed and travel time for the real-time-traffic services, ITS Upper Austria plans to equip access streets of bigger cities in Upper Austria with Bluetooth-sensors. The use of Bluetooth-data for traffic information systems and traffic management is not as popular as FCD. There is only a limited number of studies on the usage of Bluetooth-sensors and often the traffic information provider uses the travel time calculated by the Bluetooth-sensors provider.

In ITS Upper Austria a test and evaluation of different Bluetooth sensor providers was done with data collected in the week of 13.11-19.11.2017. Because the difference between FCD and real-time is too big for a real-time traffic information, ITS Upper Austria decided to test Bluetooth as an additional data source. Three different companies allocated different Bluetooth-sensors at the street B127, depicted in Figure 3. In the test, sensors were installed at two different locations. The first sensor location is in the suburban area of the street (Rohrbacherstraße), the second location is at a junction in the urban area (Rudolfstraße). On this street section traffic jams occur in rush hours with serious effects on the travel time. On the one hand, the calculation of the travel time, done by each company, was compared with each other. Further, an algorithm was designed to calculate the travel time with the raw data of Bluetooth. The goal was to learn how well Bluetooth data fits and what has to be observed when real-time traffic data is calculated with Bluetooth.

4.3.1 Comparison of the Bluetooth-Data with FCD

In the test setting related to the B127, different aspects of the applicability of Bluetooth-data for ITS Upper Austria were analyzed. For the future use of Bluetooth-travel time for calibration and validation, having a near-real time travel time is important. To use Bluetooth-data different algorithms, developed by the providers, were analyzed to investigate which can fit best for a real-time traffic information. Furthermore, ITS Upper Austria decided to develop an own algorithm for the calculation of travel time. To calculate the travel time with this algorithm, the raw data of all three providers were taken. Some Bluetooth providers shared their knowledge about necessary aspects in the calculation of travel time with Bluetooth data. This knowledge was used to develop an own algorithm, which may be used calculate and compare travel times based on the different raw data gained by the Bluethooth sensor providers. Another benefit of the algorithm is the ability to configure the impact of gained real-time data on current the traffic information. Doing so, the alorgithm supported the analysis of different configurations for different traffic situations.

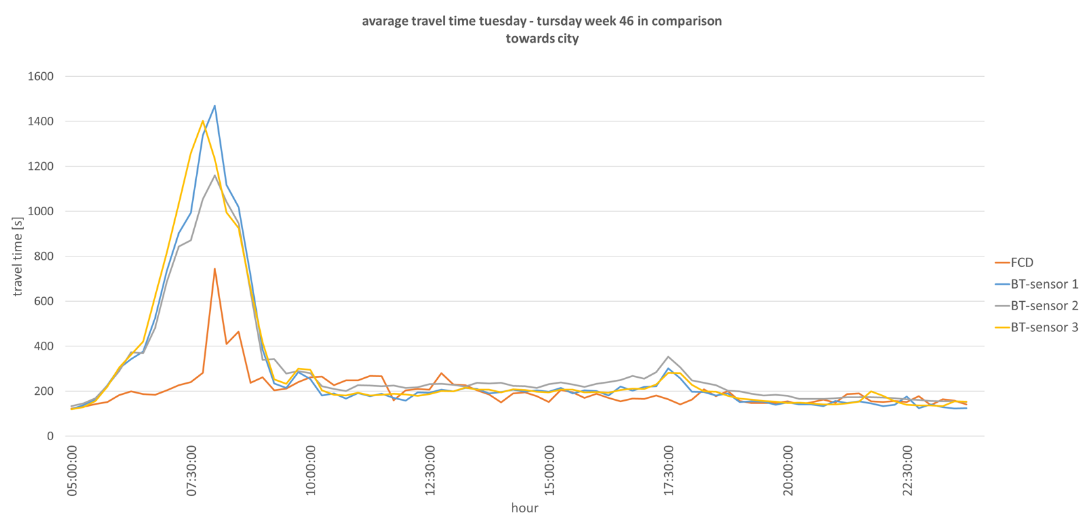

Figure 7: Comparing travel time of FCD with Bluetooth-sensors, calculated by the bluetooth-providers

In Figure 7 the calculated travel time from three different Bluetooth sensor providers is shown. The time variation curve related to this road segment shows that Bluetooth-sensors are providing better data than FCD, which is shown in Figure 8. To understand the reason for this effect, it is important to have a deeper look at the surrounding area and on the FCD-fleets. First, this street segment includes a bus lane. Taxis and vehicles from public transport make up most of the FCD-fleets driving in and around Linz. Using the bus lane these vehicles need less travel time and lead to a too optimistic travel time information. Second, the sensor providers offer different variations in the calculation of the travel time. Two of the providers use dynamic filters for developing the variations. In the different variations the travel time curve was sometimes more and sometimes less smoothed. A less smoothed curve has more peaks and is more sensible to single events. The comparison of the variations indicated that in the rush hours a less smoothed curve is giving better results, but during the day a more smoothed curve may also provide a good quality of data.

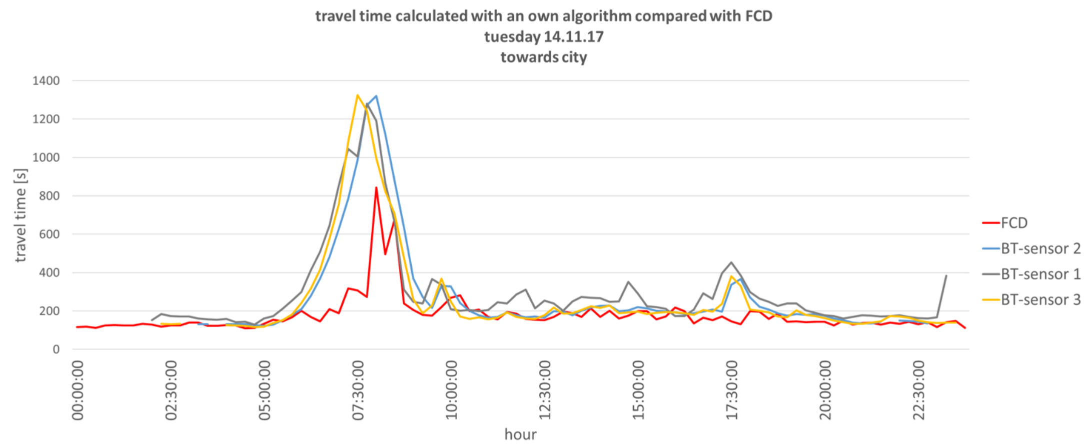

Figure 8: Comparing travel time of FCD with Bluetooth-sensors, calculated with an own algorithm

4.4 Traffic Times Gained with Test Rides

In addition to the use of FCD, VDL and Bluetooth, ITS Upper Austria investigated reference data to evaluate sensor data. Discussions with different experts on traffic information systems and own experiences revealed that test rides can be used as reference data. However, it is important for comparisons that test rides are documented precisely. As an example, ITS Upper Austria compared the Bluetooth data to validate there quality for a real-time traffic information system.

4.5 Other Data Sources

The data sources used by ITS Upper Austria represent only a selection out of possible sources. Other possibilities for gaining real-time traffic data are for example floating-phone-data. Traffic information system providers already started to use floating-phone-data (FPD). Like FCD, FPD supports to provide traffic information for a wide area. One benefit is that there will be more trajectories available than with FCD [8]. The use of webcams represents another possible traffic information source. However, an application for vision based object recognition is required for the data analysis. For validity checks on real-time data, knowledge of locals and experts is a valuable resource. Furthermore, if there is a need for punctual measurement, manual traffic counting could be used. In this case a deviation may arise from human inaccuracy. Moreover, it is possible to apply free data, for example from Google. Google offers two different kinds of traffic data, calculated with an optimistic or with a pessimistic algorithm. Test of ITS Upper Austria indicated that the optimistic algorithm generally fits better for an every-day travel time. However, it is only possible to download a limited amount per account of the data for free.

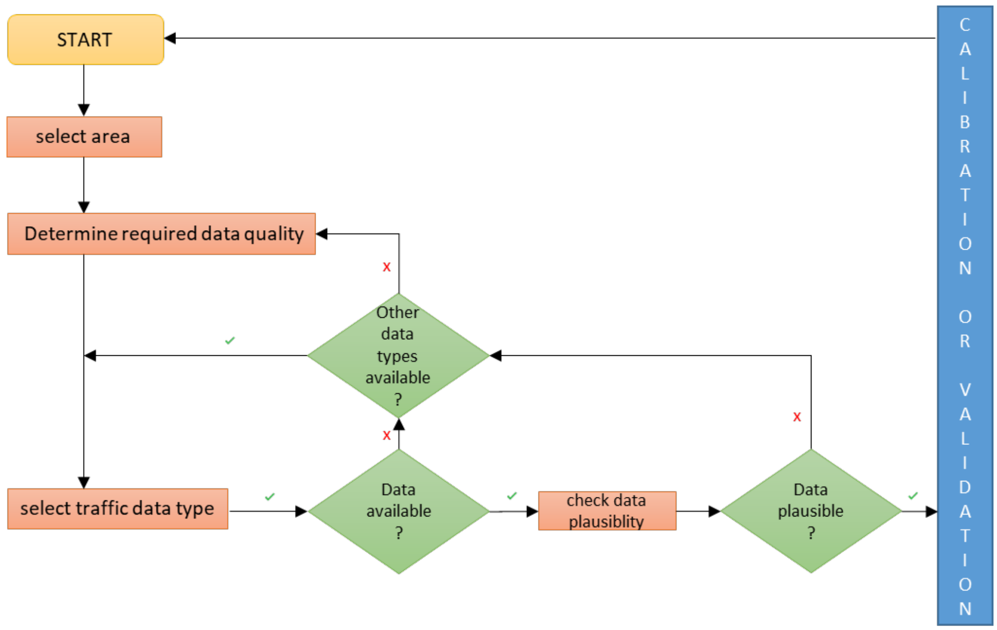

Figure 9: Procedural model for choosing data for calibration and validation

5 Traffic Data Selection Support for Calibration and Validation

This paper focuses on using different types of data for the calibration as well as the validation of traffic models. In order to support the selection of adequate traffic data for this endeavor, a procedural model was developed and will be described subsequently (cf. Figure 9). At the moment, this procedural model includes the off-line calibration and validation of traffic simulation models (cf. Section 3).

In a first step, the target area for the calibration and validation is selected (cf. Figure 9). Following, the required data quality is determined before selecting a specific traffic data type, e.g. Bluetooth or FCD. In some cases, only specific parts of a road network need to be calibrated or validated. For example, if road users observe that calculated travel times significantly deviate at certain roads of the network. In general, the calibrator or validator needs to decide upon the required data quality in terms of acceptable deviations of speed or travel time (cf. “determine required data quality” in Figure 9).

After defining the area and the required data quality, a traffic data type is selected. In the next steps, the availability and plausibility of data for selected area will be assessed. In case no data are available for the selected data type, another traffic data type may be selected and checked. Furthermore, different traffic data types may be applied to parts of the selected area.

If the area, or parts of it, is covered, a data plausibility check of the selected data set is done. Thereby, aggregated data for off-line calibration or validation should be up-to-date and fit to the given road network. For example, in case a new street is built, one needs to consider the changed traffic load within the surrounding area. In order to identify changes within a road network, filtering link IDs represents a helpful means. In general, link ID changes reflect changes in the road network. Therefore, missing or new link IDs may indicate a change in the road network. To validate a potential change of the road network, open street maps or other maps may be used as reference. Changes of the road network do not only concern the calibration and validation, but also route selection and trip files.

The plausibility check also includes the assessment of the traffic data quality. Within this assessment, aggregated traffic data are evaluated with respect to the required data quality defined beforehand. Evaluating the data quality may be a challenging tasks, e.g. in case only limited data for the quality evaluation are available. As simple data reference for a quality assessment the road capacity could be used. However, the authors recommend to conduct test rides in order to generate reference data. Since test rides are time consuming and imply additional effort, one may also apply data of webcams or traffic counting stations within a plausibility test. In case traffic data are implausible, other traffic data types may be considered for calibration and validation (e.g. FCD instead of Bluetooth).

Testing one traffic data type set after each other, it could still be that available data do not fit the defined quality requirements. In this case either the quality requirements could be adapted or new data sources established.

Finally, checking all the different kind of data sources and doing plausibility tests, it may still happen that traffic data are not available. For example in case a new street is built, the allowed vehicle speed could be used. Based on this information SUMO may calculate an average speed and traffic volume.

The presented procedural model is applied by ITS Upper Austria to continiously calibrate and validate the traffic simulation. An instance for the upcoming offline model re-calibration in ITS Upper Austria is depicted in Figure 10.

Within this re-calibration, ITS Upper Austria will start with the calibration and validation of three big cities and their surroundings. In a second step, rural areas will be calibrated. Traffic data quality represent a crucial issue within the re-calibration. The simulation of ITS Upper Austria will be used primary as an addition for the traffic information service. Therefore, high requirements for the quality will be defined.

The benefits of the available traffic data types (see Section 4) have already been discussed in the project team. Before testing the data types with respect to availability and plausibility, one may also perform a ranking based on the experience knowledge related to available data types. In ITS Upper Austria aggregated data are used for the calibration and validation. In order to ensure data privacy, raw data are not considered when taking data collected by sensors into account.

In ITS Upper Austria VDL data will be analyzed first, since they cover a large part of the Upper Austrian road network and allow to count all vehicles passing a dedicated link. Considering the high amount of measurements, VDLs provide good information about the traffic behavior, which is relevant for the calibration of the demand model and the route files. Second, Bluetooth will be considered. In the network of ITS Upper Austria a major improvement by using Bluetooth data is expected. Bluetooth sensors will soon be available on important entrance streets to cities of Upper Austria. The benefits of Bluetooth are discussed in Section 4.3.1. The data will not only have a high quality, but also it will give up-to-date information on the dedicated sections. Bluetooth data may create near-real time traffic information. However, only about 10-12 percent of the actual vehicles passing are measured via Bluetooth sensors. In comparison with FCD one benefit of Bluetooth is that data gained by taxis or buses on dedicated lanes will not bias the travel time. Furthermore, ITS Upper Austria receives a lot of data from FCD fleets. Floating car data are used for the calibration and the validation. In Figure 10 FCD for calibration is marked with “FCD1” and for validation with “FCD2”. It might occur that the the data coverage is too low in some areas. ITS Upper Austria defines

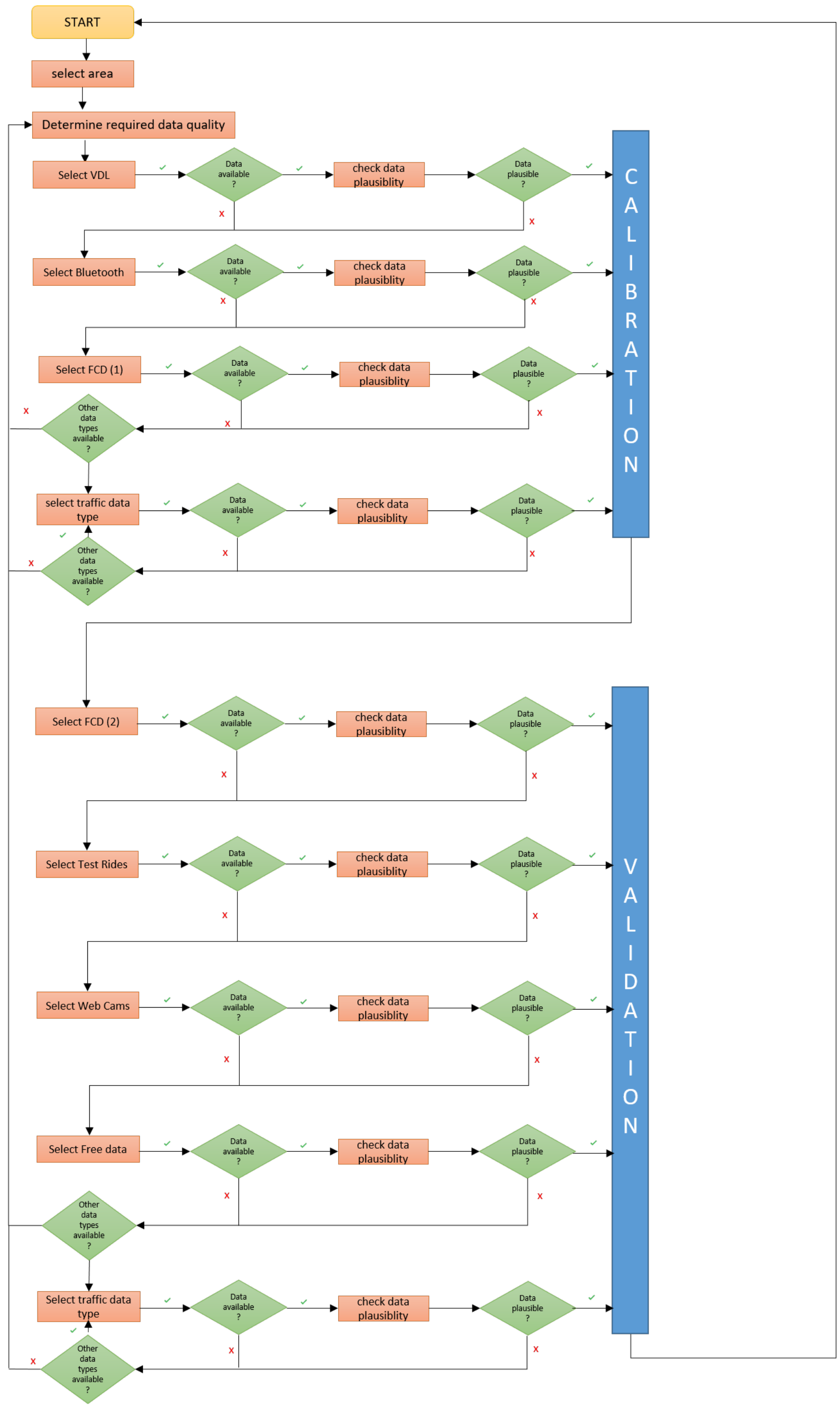

Figure 10: procedural model for choosing data for calibration and validation applied in ITS-UA

requirements for different areas and defines action points(e.g. acquisition fo additional FCD fleets, implementation of VDLs,...) in case deviations from the defined quality of service occur and further data are not available. Lower ranked streets, with less traffic volume, may not be as near-real time as main roads. If the quality is too low other data, like test rides etc., can be taken into account for the calibration. In the depicted procedural model (cf. Figure 10) this aspect is not described.

Within the calibration the different traffic data types will be tested with respect to the coverage and plausibility. If the quality of Bluetooth, VDL and FCD, is too low other data have to be acquired. For example, test rides can be taken into account for the calibration.

The validation will first take FCD into account. When using FCD for calibration and validation, it is important to remember that these data should never be the same (FCD1 $\neq$ FCD2). This may be done by using different days or different fleets. If FCD do not cover the area for validation, test rides are an alternative to gain data. However, as already explained in Section 4.4, test rides imply a lot of effort. In the second validation step, the availability of webcams in an area will be checked and if historical webcam data may be accessed. At the moment ITS Upper Austria is not using webcams for validation, since a vision-based data analysis has not been included in the ITS system so far. Anyway, it is still being considered for future sample tests. If there is a need for further data, one possibility is to use data from Google. ITS Upper Austria already has experience with the use of Google data. It is not always near-real time, but it can fill the gap, when there is a lack in validation data.

Traffic data types for the validation will also be analyzed regarding the coverage and the quality. It still can happen that the considered data do not fulfil the demands. Then further data has to be acquired. It still can happen that there is no data available for some segments. One situation could be that a new street was built. Then ITS Upper Austria will start the calibration by setting the maximum vehicle speed.

This procedural model will be used in future for the calibration and validation of the mesoscopic SUMO-model. There is a static acquisition of traffic data in ITS. The first procedural model is a general model, the other one is based on the experience of ITS UA. Though, the topic is an critical issue, the actual use of the algorithm and further studies will underline the functionality of it.

After collecting and choosing the data, the calibration and validation has to be done. For ITS Upper Austria this means, that on the one hand an on-line calibration and on the other hand an off-line calibration is performed. A calibrated model always needs to get validated. For this the creation of output files in the SUMO simulation can be used. This chapter gives some applicated samples for the calibration of the mesoscopic traffic simulation for Upper Austria.

In the case of the on-line calibration, a mesoscopic SUMO simulation runs in parallel with the *Management Console* (MC) of ITS Upper Austria, which collects the data from various sensors and calculate the traffic information for the Upper Austrian road network. Every 6 minutes, the simulation is interrupted and a `‘‘netstate-dump’’` is created by SUMO about the current status of the simulated network (the time interval can be specified in the configuration file by the `‘‘dump-step’’` option implemented by the team of ITS Upper Austria, see Figure 11). This information is used to produce traffic information for the links, where ITS Upper Austria does not have calculated real-time traffic situation.

As mentioned in Section 3.2, at the moment only real-life VDLs give feedback to the SUMO simulation in the on-line calibration, such that the number of the vehicles counted by the simulated VDLs (called induction loops) are compared with the number of vehicles counted by real-life VDLs. The Traffic control interface (TraCI) is used to give feedback to the simulation of SUMO and resume the simulation for another 6 minutes. Because there is no TraCl available for

```
<configuration>
  <input>
    <net-file value="MySUMONet_0817.net.xml"/>
    <route-files value="OOE_routes_tmp.rou.xml"/>
    <additional-files value="ooe.add.xml"/>
    <mesosim value="true" />
    <meso-multi-queue value="true" />
    <meso-junction-control value="true" />
    <meso-junction-control.limited value="true" />
    <meso-overtaking value="true" />
    <ignore-junction-blocker value="30" />
    <route-steps value="1000"/>
    <no-internal-links value="true"/>
    <sloppy-insert value="true"/>
    <time-to-teleport value="150"/>
    <begin value="0"/>
    <end value="21601" />
    <ignore-route-errors value="true"/>
    <xml-validation value="never" />
    <xml-validation.net value="never" />
    <gui-settings-file value="gui-settings.cfg"/>
    <remote-port>8133</remote-port>
  </input>
  <output>
    <netstate-dump value="KBSPC:9172" />
    <netstate-dump.empty-edges value="false" />
    <dump-step value="360" />
  </output>
  <report>
    <no-warnings value="true" />
  </report>
</configuration>
```

Figure 11: The SUMO configuration file which is used for on-line calibration

the mesoscopic SUMO-simulation, ITS Upper Austria created their own TraCl for the on-line calibration. The following features are included:

- “Simulate To”: SUMO is instructed to simulate until the desired time,
- “Add New Route”: a new route will come with a new ID and its associated Edges added,
- “Add Vehicle”: a new vehicle is added to the simulation. The message contains a new ID and the ID of the route and
- “Remove Vehicle”: A vehicle is removed from the simulation.

The virtual induction loops can be added in an additional file given in the option “`additional-files`” in the configuration file. In the additional file, more than on induction Loop can be created. This means, on a link ID (“`lane`”), a VDL can be set. Every VDL has to get a different ID to distinguish them from each other in the output file. Also, the time interval, how often the data will be saved in the output file, can be set individually. This frequency is defined in seconds. Further, the name of the output file has to be set (“`file="out.xml"`”). It is possible receive the results for every loop in a different file. It is possible to choose the exact position on the link. A good method to do this, is to first have a look on the actual length of the link, were the VDL is set, then the position (“`pos`”) can be set. See an example for the definition of a virtual VDL below:

```
<inductionLoops>
...
        <inductionLoop id="i3_0" lane="E461001057From_0" pos="10.2" freq="360"
```

```
                                        file="out.xml" />
...
</inductionLoops>
```

It is important to notice, that the settings are not limited to the one added in the file. For example, if needed for the offline calibration, also a begin and end interval can be defined. This can be useful, if, as an example, only the peak time is validated at the moment. The output of a created virtual induction loop is written into the specified output file after a certain number of time steps (seconds) defined in the option "`freq`". This output consists of vehicle speed (m/s), flow (vehicles/hour), occupancy (%), number of vehicles that can pass the detector and vehicles which entered but did not pass the detector jet, see an example below:

```
<interval begin="25560.00"
            end="25920.00"
             id="i3_0"
 sampledSeconds="1518.19"
        density="43.26"
      occupancy="5.41"
    waitingTime="0.00"
          speed="21.69"
       departed="0"
        arrived="0"
        entered="341"
           left="334"/>
```

This information is also found in the SUMO User documentation [7]. This output data can be applied also for the validation with different data sets, like FCD.

It is known that TraCI makes the simulation slower, but in the case of our on-line calibration its usage is justified. Namely, we always simulate traffic situation for the upcoming six minutes, then the simulation stops and before it is resumed again, the simulated traffic is adapted to the real-world traffic via TraCI. The whole process (simulation of the upper Austrian traffic in the upcoming 6 minutes, dumping the actual traffic situation to a port, analyzing it, giving feedback to SUMO via TraCI and finally resume the simulation for the upcoming time interval) takes less than 6 minutes, so using TraCI is just fine in such circumstances.

Without TraCI, we should always restart SUMO, load the upper Austrian road network as well as a SUMO trip file containing the demand model of ITS Upper Austria and start the simulation from the beginning of the day. Only the loading of the two mentioned files in SUMO takes more than 2 minutes. Although, the simulation runs fast, it is not fast enough to simulate the upcoming 6 (or more) minutes in evening rush hours (e.g.: around 5pm).

6 Summary

Using data for calibration and validation can be challenging. First, a lot of data is needed to not only cover the ITS Upper Austria network of the near-real time simulation, but also to consider if there is enough data for calibration and validation. Providing real-time traffic information services, a great number of data sets has to be provided. The possibility to use this data for calibration and validation of the SUMO network is a huge advantage. Experience about the use of data can be helpful for deciding on the use of the data. This paper gives an overview about different traffic data types and how they are used in ITS Upper Austria. The pros and cons of the different data sets are discussed based on an example street with high traffic intensity in Upper Austria. Furthermore, this paper presented a procedural model for selecting traffic data types in order to calibrate and validate traffic simulation models.

To summarize, this paper gives an overview about different data sources and provides a basis for selecting and collecting traffic data. The quality of a calibrated model is limited to the quality of the data and the knowledge of the area of the contractor. In the next steps, ITS Upper Austria will apply the procedural model to filter the available data and to start the calibration and validation process of the mesoscopic simulation. Thereby, an off-line and on-line calibration will be done. Since the simulation will be used as an addition to the real-time traffic information, this process will be continuously repeated.

References

[1] Constantinos Antoniou, J. Barcelo, M. Brackstone, H. B. Celikoglu, Biagio Ciuffo, V. Punzo, P. Sykes, Tom Toledo, Peter Vortisch, and Peter Wagner. Traffic Simulation: Case for guidelines. 2014.

[2] Susanne Breitenberger, Bernhard Grüber, Martina Neuherz, and Roland Kates. Traffic information potential and necessary penetration rates.

[3] Fajar Yoseph Chandra, Fergyanto E. Gunawan, Garry Glann, and Alexander A. S. Gunawan. *Improving the Accuracy of Real-Time Traffic Data Gathered by the Floating Car Data Method.* IEEE, Piscataway, NJ, 2014.

[4] Deutsches Zentrum für Luft- und Raumfahrt e.V. Proceedings of the 1st SUMO User Conference 2013.

[5] Deutsches Zentrum für Luft- und Raumfahrt e.V. Proceedings of the SUMO2014 - Modeling Mobility with Open Data.

[6] Deutsches Zentrum für Luft- und Raumfahrt e.V. Proceedings of the SUMO2015 - Intermodal Simulation for Intermodal Transport.

[7] Deutsches Zentrum für Luft- und Raumfahrt e.V. SUMO User Documentation.

[8] Johannes Schlaich. Nutzungsmöglichkeiten von Floating Phone Data.

[9] Karl Wunderlich, Vassili Alexiadis, and Peiwei Wang. Scoping and Conducting Data-Driven 21st Century Transportation System Analyses. 2017.