1 SUMO-Cadyts calibration with limited data quality

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1.1 Abstract

Traffic simulation has been often used to support decision making in traffic management. Such simulation requires a large amount of fine data which cannot be easily obtained in practice especially when a large network is considered. Under this circumstance, the respective calibration work is challenged. In this study, the route choice calibration of SUMO and Cadyts is applied with a real case study in Hefei, China, to examine (1) to which extent the calibration can achieve and (2) which issues need to be especially taken into account. With the resource limitation the network data is based on the OSM with insufficient quality. Major adjustments are made on the number of lanes, turning lane allocations, speed limitations and traffic signal plans. The last two parts still suffer from the limited data quality. The collected flow data for calibration is also limited for only 15 minutes at five major intersections during different moments in the evening peak hour. The relative absolute error is used as the performance indicator. The results show that the simulation quality is improved with the given limited data and quality, but only to a certain degree, namely the percentage of the investigated links with a flow deviation less than 30% has increased from 38% to 72%. The spectrum of the relative errors has been greatly narrowed after the calibration. Gained experiences related to the application of SUMO-Cadyts calibration are also pointed out as references for further applications.

Keywords: SUMO, Cadyts, Route Choice Calibration, OptimUM

1.2 Introduction

Microscopic traffic simulation has been successfully and extensively applied both for investigating different traffic manoeuvres, phenomenon and problems and for quantitatively evaluating various design alternatives and management strategies. Such kind of traffic simulation has also become an essential tool for supporting decision making in traffic management. In order to obtain accurate results traffic network needs to be calibrated firstly. More and more traffic related data has become available with use of innovative technologies, such as Bluetooth and GPS, and can be used for calibration purposes. However, traffic flows are still the most often used data for network calibration not only due to their easy availability and accessibility, but also due to that lots of well-developed calibration models use traffic flows as reference data. Cadyts [8, 4, 2] is one of these calibration models and has been coupled with different simulation software, such as SUMO [12, 9], MATSim [10] and DRACULA [1]. These couplings have been successfully tested with some academic synthetic networks respectively. Furthermore, the large traffic network of the City of Zurich has been well calibrated with use of MATSim and Cadyts.

MATSim is a complex agent-based simulation and focuses on traffic flow simulation, re-planning and so on. In comparison to that SUMO also focuses on traffic simulation, but more on the simulation of driving behaviours in road sections, between lanes and at/within intersections as well as the simulation of vehicular communication. Each trip has only one origin and one destination, i.e. no trip chains are considered, in SUMO. Besides, SUMO needs much finer network data than MATSim, such as signal timing plans or priority rules at intersections and the allocation of turning lanes at intersections. In practice, such information cannot be easily obtained especially when dealing with a large city network and is often partially collected and partially estimated with best knowledge. Under this circumstance, the respective data quality is quite limited. Thus, this paper focuses on the performance of the SUMO-Cadyts calibration with limited data quality and examines to which extent the calibration can achieve and which issues need to be especially taken into account.

1.3 Approach

Cadyts is a Bayesian-based route choice calibration model. As mentioned before, the coupling of SUMO and Cadyts has been established and been tested with some academic synthetic networks [2, 5, 6]. Cadyts can also deal with congested conditions [3].The basic concept of the SUMO-Cadyts calibration is that SUMO's DUAROUTER generates draws from a prior distribution of route choices so that the equilibrium of route alternatives is reached. The calibration model Cadyts makes adjustments such that a prior distribution of route choices turns into the posterior distribution given all available traffic flow measurements.

Generally, Cadyts adjusts trips' route choices together with the respective departure times after each traffic simulation until the convergence or the predefined number of iterations is reached. The route choice calibration and the traffic simulation (together with its own route choice model) interplay with each other during iterations. However, such a way does not work with SUMO. SUMO's route choice model, i.e. the Gawron model [7], does not take travellers' perception about travel time into account, i.e. drivers use only the respective fastest route, while the logit-based models do consider travellers' perception as an error term in the respective equations. The Gawron model modifies Cadyts' results after each calibration and it leads to an inconsistent correction of the route choice distribution and a poor calibration performance. Thus, the interaction between SUMO and Cadyts is reduced as follows: DUAROUTER is used to generate route alternatives for each driver before applying the SUMO-Cadyts calibration. After that, Cadyts and SUMO (only traffic simulation) start to interplay with each other until the predefined number of iterations or the convergence is reached. The script cadytsIterate.py serves for the interplay of Cadyts and SUMO traffic simulation. It is possible to scale the traffic demand, i.e. the number of trips, with Cadyts just in case that the original demand is underestimated. The whole calibration process is illustrated in Figure 1.1.

1.4 Real Case Study

The applied network is based on the network built in the project OptimUM which is financially supported by the Helmholtz Association and Chinese Academy of Sciences (CAS). This project aims at investigating traffic-related environmental issues with use of traffic simulation and camera monitoring in the science and technology park of the Hefei City, China. This science and technology park locates at the western side of Hefei downtown (see Figure 1.2). Due to the resource limitation, the simulation network is based on the OpenStreetMap (OSM). However, the respective information

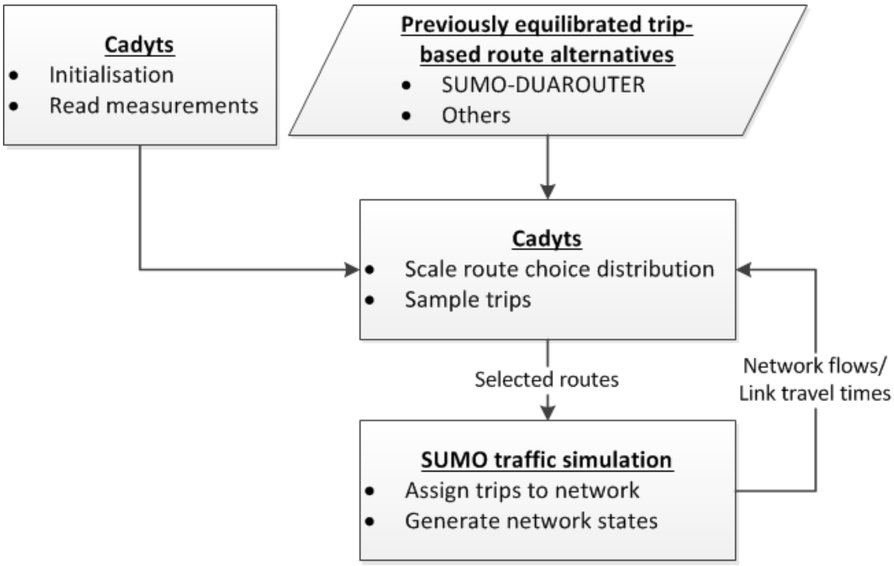
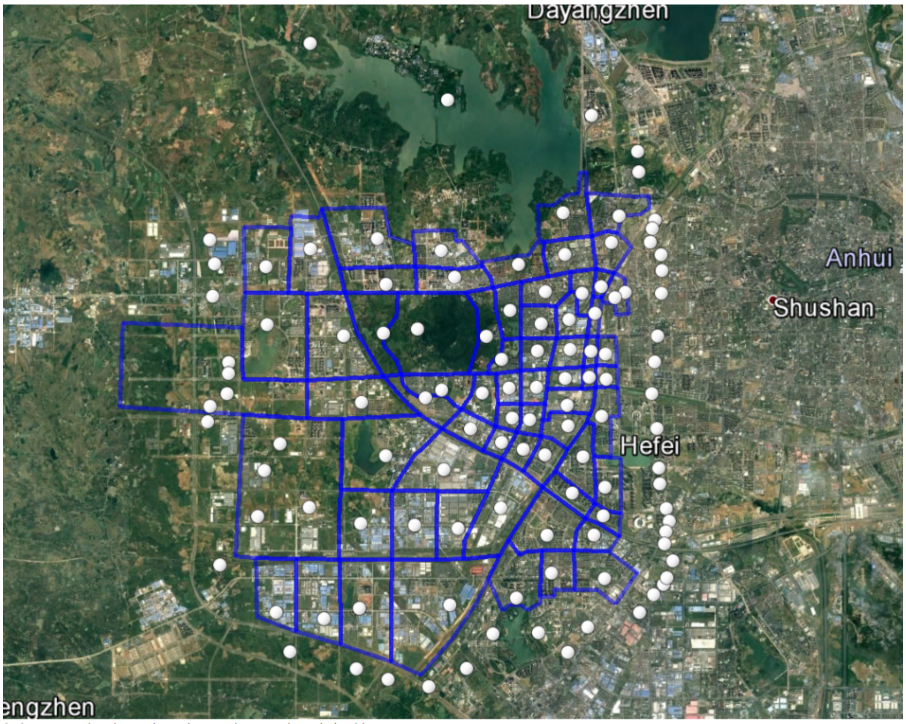


Figure 1.1: SUMO-Cadyts Calibration process

in the OSM is very limited. The network data and the traffic signal data are therefore partially collected and partially estimated with best knowledge. The built network is shown in Figure 1.3.

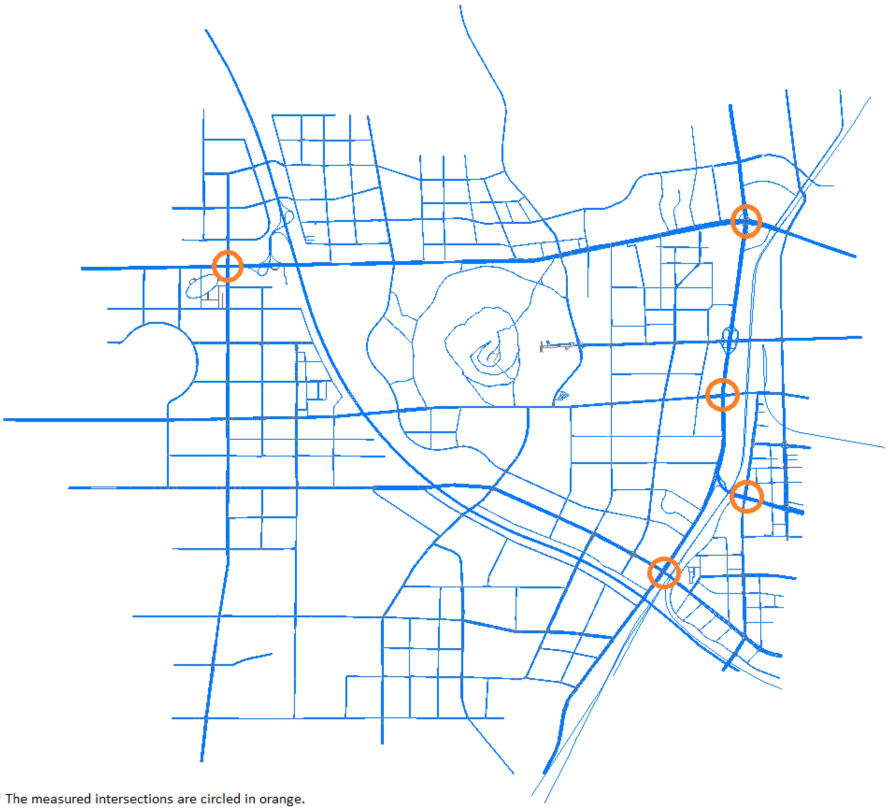
Moreover, the applied traffic demand is derived from the existing VISUM daily traffic model and only trips with cars and trucks are available. This daily traffic demand is then converted to hourly traffic demand according to the respective time series of traffic flow data. There are totally 115 traffic analysis zones (TAZs) where 68 zones are within the study cordon. The other 47 TAZs are virtual zones for addressing internal and through trips. The respective centroids are shown as white circles in Figure 1.2. The total number of trips is around 40,000 during the evening peak period between 17 and 19 o'clock. Furthermore, traffic counts at 21 edges closed to the major intersections, shown in Figure 1.3, are manually collected for 15 minutes during the evening peak period and are used as reference data in the calibration. The collected flows are between 100 and 650 vehicles.

According to the observation, the major intersections in the study cordon often suffer from traffic congestion during the peak period. Many flexible driving manoeuvres, such as frequent lane changing, using road shoulders, turning lanes used as through lanes or the other way around and headway shortening, have been executed in order to find gaps and to drive through the congestion areas as quickly as possible. Some of these driving manoeuvres, which increase the corresponding road and intersection capacities during congestion, cannot be simulated with SUMO yet. To deal with such manoeuvres in the calibration, teleporting time is set as 150 seconds and the gap acceptance is reduced in SUMO. For generating route alternatives with DUAROUTER, the teleporting time is however set as 300 seconds so that there are sufficient route alternatives for each trip. The gap acceptance parameter in SUMO's car following model is correspondingly reduced as well. Moreover, the simulation begin time is adjusted, i.e. to set the time earlier than the trips' planned begin times, since the trips' begin times may be adjusted by Cadyts. In addition, the traffic demand is scaled with 1.5 times in the calibration to ensure a sufficient traffic demand. This additional demand will be used only when more trips with certain routes are needed, given the flow measurements.



* The TAZs within the study cordon are the areas bounded in blue.
* The centroids of the TAZs are indicated as white circles.

Figure 1.2: The investigated network area in Hefei, China



* The measured intersections are circled in orange.

Figure 1.3: The layout of the investigated simulation network

1.5 Results

1.5.1 Deviation between measured and simulated flows

The absolute relative error is used for evaluate the calibration results although the empirical GEH formula [11] is often used for comparing two sets of traffic flows. The main reason is that the collected traffic counts are for 15 minutes while the GEH formula requires hourly traffic volumes. Due to the shortage of man power all link flows are counted for 15 minutes in the peak period, but not at the same time. The flow conversion from 15 minutes to 1 hour is thus discarded in order to avoid the possible error propagation (error enlargement).

Figure 1.4 indicates that the difference between the simulated (the orange squares) and measured link (the blue diamonds) flows is quite large before calibration. Most of the flows on the measured links are underestimated with the simulation. There are only 38% of links with an absolute relative error less than 30%. After the calibration, the respective percentage increases to 72%. The number of the links with the underestimated (more than 20%) flows has then reduced from 71% to 33%. When observing the simulation, it is also noticed that one of the main reasons for the flow underestimation is traffic congestion that impedes vehicles reaching the measured location in the measurement period (15 minutes). In addition, a few of the link flows are overestimated. It might also be due to traffic congestion which makes vehicles choose other 'cheaper' routes.

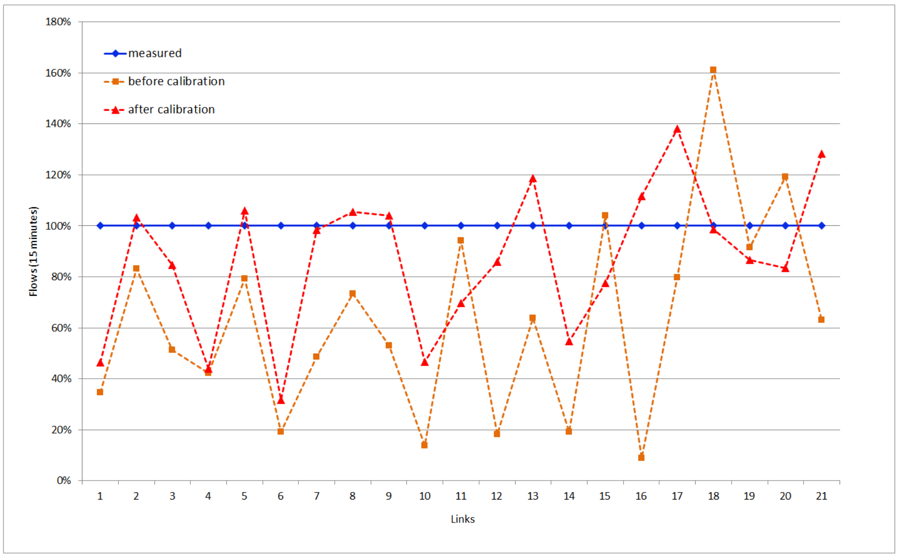


Figure 1.4: Link flow comparison before and after the calibration

As reference comparison the GEH-values with 15-minutes flows are calculated for all measured links. Table 1.1 shows that 67% of the measured links have a GEH-value less than 5 and the corresponding calibration results are an acceptable fit. Such finding corresponds to the results based on the relative absolute error. 14% of the links have possible model errors or bad data and 19% of the links are with high probability of modelling error or bad data.

Furthermore, the range of the error distribution becomes significantly narrower after the calibration (see Table 1.2). The link absolute relative errors spread quite regularly in the spectrum between 0.1 and 1 before the calibration. After the calibration, the corresponding errors are between 0.1 and 0.7 where around 60% of the links have an absolute relative error less than 20%.

Table 1.1: GEH-evaluation based on the 15-minutes flows

GEH-threshold	Meanings	Percentage of the links
< 5	Acceptable fit, probably OK	67%
$5 - 10$	Possible model error or bad data	14%
> 10	High probability of modelling error or bad data	19%

Table 1.2: Distribution of the link absolute relative errors

Relative absolute error	Before calibration (%)	After calibration (%)
< 0.1	14	29
$0.1 - 0.2$	10	29
$0.2 - 0.3$	14	14
$0.3 - 0.4$	10	5
$0.4 - 0.5$	10	5
$0.5 - 0.6$	10	14
$0.6 - 0.7$	10	4
$0.7 - 0.8$	9	0
$0.8 - 0.9$	19	0
$0.9 - 1.0$	4	0
> 1.0	0	0
Total	100	100

1.5.2 Gained Experience

Instead of the link-based calibration, Cadyts calibrates route choice distribution in a given network according to the given route alternatives and link flow measurements. If the given route alternatives do not cover the measured links, Cadyts cannot make any route choice adjustment and the results will be miserable. The quality of the calibrated demand, i.e. the routes, is highly dependent on the locations of the collected data. The more the precisely collected data could cover the mainly used routes in a study network, the more representative the calibrated demand would be. Therefore, attentions need to be paid to the following issues when the SUMO-Cadyts calibration is adopted.

1. Route alternative generation

   DUAROUTER is responsible for generating route alternatives with the given demand and network characters. It searches a new fast route for every trip at each iteration. If a new route is found, it will be added in the respective route set. Therefore the number of iterations needs to be appropriate and the network data needs to be 'reasonable' in order to collect sufficient route alternatives. Furthermore, the option 'keep all routes' should be activated in order to avoid some routes being thrown away.

2. Teleporting time setting

   Generally speaking, an adequate teleporting time setting is necessary in SUMO in order to prevent possible deadlocks during simulation. Teleporting time adjustment is also a way to partially reflect the different driving manoeuvres in different areas and situation in the simulation. However, a short teleporting time may result in insufficient route alternatives, since the edge travel times are underestimated and only a certain amount of routes will be found.

3. TAZ connectors' definition

In this study, a TAZs-based OD-matrix is used for generating link-based trips. It is therefore necessary to define the links for connecting each TAZ to the given network. The defined connecting links greatly influence route searching results as well as route alternatives. Thus, attention needs to be paid to this issue. For example, the overlapping of the connectors between TAZ should be avoided.

4. Priority rules and intersection configuration setting

   As mentioned before, intersection capacity plays a crucial role in the temporal distribution of trips in the network and the respective route alternatives/choices. Besides traffic signals, priority rules and intersection configuration, such as the number and the length of left-turn or right-turn lanes, also decide intersection capacity and need to be taken extra care of in the simulation network.

5. Lower traffic demand

   Given a low demand the calibrated link flows can still be lower than the measured ones after calibration with the demand adjustment. It is suggested to execute the calibration with the results of the previous calibration in order to adjust the overall demand again. Such a way needs to be used with caution, since underestimated link flows may be possibly due to inaccurate signal timings, intersection configuration, the allowed travel speeds and driving behaviours in the network. In this situation, increasing demand will only result in more traffic jams.

6. Flow data collection

   Flow data is used as restraints for adjusting the respective amount of routes (trips) in the calibration. The more the data collection cover the major used routes, the better the calibration quality and the more representative the calibrated results will be. Thus, traffic flows at major corridors and intersections should be collected according to the given analysis period.

1.6 Conclusions

It is known that microscopic traffic simulation needs much finer and precise data than macroscopic traffic simulation. The data quality has a great influence on the calibration results. Not like a synthetic network, the data for a real network is often with limited quality and some data is not easily to obtain, e.g. signal timing plans. Moreover, different parameters with regard to car-following, driving and route choice behaviours also need to be considered and, if necessary, adjusted to insure the simulation quality in SUMO. All these issues make the calibration with microscopic simulation much more challenging especially when dealing with a large network.

According to the results, the SUMO-Cadyts calibration with a limited data quality can still improve the simulation quality, especially that the spectrum of the errors is greatly reduced to a narrow range. These results are however not promising yet, especially when the GEH-values are considered. It is mainly since the input data quality greatly influences the road and intersection capacities which affect not only the number of the vehicles passing the measured location at each time interval, but also the travellers' route choices and their route choice sets. More accurate signal timing plans and speed limitations can help to improve the results. Moreover, the simulation of driving behaviours in road sections, between lanes and at/within intersections can affect road and intersection capacities as well. Accordingly, two current adjustable parameters in SUMO, namely the gap acceptance and the teleporting time, are adjusted to reflect local people's driving behaviours during peak hour periods. Further investigation and modelling on local people's driving behaviours are still needed for better simulating driver behaviours in China and help to deliver representative simulation results.

Besides the insufficient data and data quality, the short time interval for traffic flow data collection may also be the reason for the unsatisfied calibration results. Due to traffic congestion some of the simulated vehicles cannot reach the measured locations in time within a short time interval. Traffic flow measurements with a short time interval further challenge the accuracy of the calibration with microscopic traffic simulation. Calibration with limited data quality should perform better when the time interval for data collection covers both the peak and off-peak periods for mitigating the congestion effect.

In this case study, the used flow data are only on 21 links which are mostly at the intersections on the eastern side of the network for examining the influence of the insufficient data quality on the calibration and the representation of the actual traffic conditions. The measured flow data does not cover all of the main corridors currently. Therefore, the derived demand (routes) is only partially representative of the true demand. More flow data at corridors are required for obtaining a representative traffic demand.

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