MICRO MEETS MACRO: A COMBINED APPROACH FOR A LARGE-SCALE, AGENT-BASED, MULTI-MODAL AND DYNAMIC TRANSPORT MODEL FOR BERLIN

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Abstract

Transport models demanded by public transport companies today should not only deliver the basis for future planning of the regional transport system, but also provide detailed information about passenger flows of different user groups to deliver a founded basis for their future business strategies. This paper presents the successful transformation of a static macroscopic model into an integrated activity based demand and dynamic assignment model performed for a real application on the Berlin/Brandenburg Metropolitan Region. While the two models clearly differ in their methodology overall key values can be reproduced showing similar results. It is shown that by the use of the activity chain distributions and their timing activity based demand can be reproduced with respect to the trip distribution of the origin-destination matrices from the macroscopic model. The process flow defined in this paper allows to use both models for planning purpose, case studies and effect analysis, enabling public transport companies to analyze effects on the macroscopic level of detail as well as on the agent based level to capture specific customer groups and/or time ranges during the day. Furthermore, the traffic flow simulation also takes into account the interactions between motorized individual transport and public transport offering the analysis of disturbances of the public transport schedules on an operative level.

INTRODUCTION

This paper is based on a unique project for the Berlin/Brandenburg Metropolitan Region. Various questions have to be answered from different stakeholders: On one hand, the urban development of the region for the next five years has to be taken into account due to the opening of the international airport BBI in the south-east of Berlin at 2012. At the same time, the airport Tegel in the nord-west of Berlin will be closed. This special situation will produce a shift in land use as well as in the traffic demand of the region. Furthermore, the public transport access to the airport Tegel is served by the Berlin transport company BVG (*1*) via buses at the moment. That situation will change in the case of the BBI airport, since it will be connected by services of the "Deutsche Bahn" DB, e.g. by a suburban railway system. As a consequence, the model should not only deliver the basis for future planning of the regional transport system, it also has to provide detailed information about passenger flows of different user groups that are of high importance for the BVG to deliver a founded basis for their future business strategies.

To fulfill the above mentioned needs, the team of PTV (*2*), senozon (*3*) and VSP, TU Berlin (*4*) offered a combined model based on both, a static macroscopic model with PTV Vision VISUM (*2*) as well as an integrated activity based demand and dynamic traffic assignment model with MATSim (*5*). In that situation it is of very high importance that both models are based on the same data sources as well as both model processes interact with each other, resp. exchange data and model constraints.

Theoretical Background

The traditional way of transport modeling usually is based on a four-step process (*6, 7*). This approach involves demand separated in zones and a transport infrastructure connecting the zones. The final and fourth step "route assignment", distributes the zone connecting trips among the various connection options, e.g. different routes of the street network. As a consequence of this, the resulting demand distribution is entirely unrelated to the essential cause of traffic, the individual traveler and its behavior. Furthermore, the four-step process provides figures for the average amount of traffic, only. However, modern transport planning asks more and more for its temporal distribution, in order to optimize the usage of existing transport infrastructure by specified user groups, e.g. spreading user specific demand during peak periods instead of building new road infrastructure.

To overcome the shortcomings of the four-step process, demand generation can be embedded in a concept of daily activity demand from which the need for transport is derived (*8*). This concept is called activity-based demand generation (ABDG) and focuses on the analysis of individual synthetic travelers instead of trips. The synthetic travelers form the synthetic population that is statistically equivalent to a representative sample of the real population. ABDG assigns a so-called *plan* to each synthetic traveler. Each plan holds a sequential list of activities and trips connecting these activities. Since these choices are applied to individual travelers the spatial and temporal consistency of individual travel behavior can be ensured.

Various work, i.e. Meister (*forthcoming 9*) have already addressed that ABDG can be based on random utility theory (e.g. SACSIM, CEMDAP (*10, 11*)) or on psychological decision rules (e.g. TASHA (*12*), ALBATROSS (*13, 14*)). Approaches referring to subgroups instead of individual travelers include PTV VISEM (*15*).

Common to most ABDG approaches so far is the aggregation to origin-destination (OD) matrices in the traffic assignment step. Again, individual activity plans are stripped to disconnected trips loosing the information of the individual. According to some predefined criterion, the following dynamic traffic assignment (DTA) assigns then routes to the OD-flows (*16*). The network loading algorithm iterates between a router and a traffic simulation and stops when reaching a fixed point (*17*). DTA implementations can be found in VISTA (*18*), DynaMIT (*19*) and in a dynamic version of PTV VISUM (*20*).

Conceptually, DTA is not restricted to route choice, but can be extended to mode choice, departure time choice, and other choice dimensions as well (*21*). Thus, the whole plan generated in the ABDG process can be seen as a unit of decision (*22*). Coupling ABDG and DTA has been done conceptually and practically by applying a feedback mechanism between CEMDAP and VISTA (*23*).

In this paper, a multi-agent simulation is used to integrate ABDG and DTA. This approach features synthetic travelers throughout the whole modeling process, including the assignment step, and allows to access the traveler's information (demographics, socio-demographics as well as their plan) at any time (*24*). TRANSIMS, for example, offers an iterative route assignment (*25*). Adding more choice dimensions to the ABDG process decreases the computational performance, since calculations become more and more complex and some of the iterative "replanning" modules are computationally complex by themselves, e.g. the integrated activity-based discrete choice model system of Bowman and Ben-Akiva (*26*). To solve this issue, each agent can hold multiple plans in its "memory" and marks one of it as active for the next iteration (*27*). An evaluation is attached to each plan, but only the active plan's score is updated after the iteration. Plans not marked active are ignored for the current iteration, but may be active in a later iteration. This allows to only modify single aspects of a plan, e.g. the route, and to start replanning with the same "base" plan from memory for multiple times. This not only reduces the search problem by performing a step-by-step improvement of the plan, but effectively distributes ABDG over several replanning processes.

The structure of the paper is as follows: The next section gives a brief overview about the project and their process steps, followed by modeling processes for the macro-model with VISUM and the microscopic modeling with MATSim. Then, the paper presents a comparison of both models' results. The paper concludes with an outlook and possible future applications. Please note, that — even the project contains both the model for the actual state as well as a prediction for 2015 — this paper focuses only on the modeling process and the comparisons for the actual state.

PROJECT OVERVIEW AND PROCESS STEPS

Figure 1 shows the overall process flow for the project. First, the data sources are prepared for VISUM and then used to model trip based traffic demand with EVA to produce OD-matrices. Next, the VISUM static assignment process is used to model traffic flows for the region. These processes are already well known to the stakeholders, since this first step produces a fully operational VISUM model containing landuse, population, infrastructure networks, transit schedules, transit vehicle fleet and trip based demand. To convert this macro-model into MATSim's activity based demand and dynamic assignment model, transformations from VISUM data formats into MATSim XML based data representations have to be performed. But to convert, resp. model activity based demand out of static OD-matrices, information about chain based travel demand has to be added and diluted with the matrices of the macro-model. With that step, the complete scenario for the MATSim relaxation process is prepared. The optimization itself is restricted to the route, time and mode choice dimensions. MATSim location choice (*see 28*) is left out in that step to guarantee the same travel location distribution as given by the macro-model. After the opti-

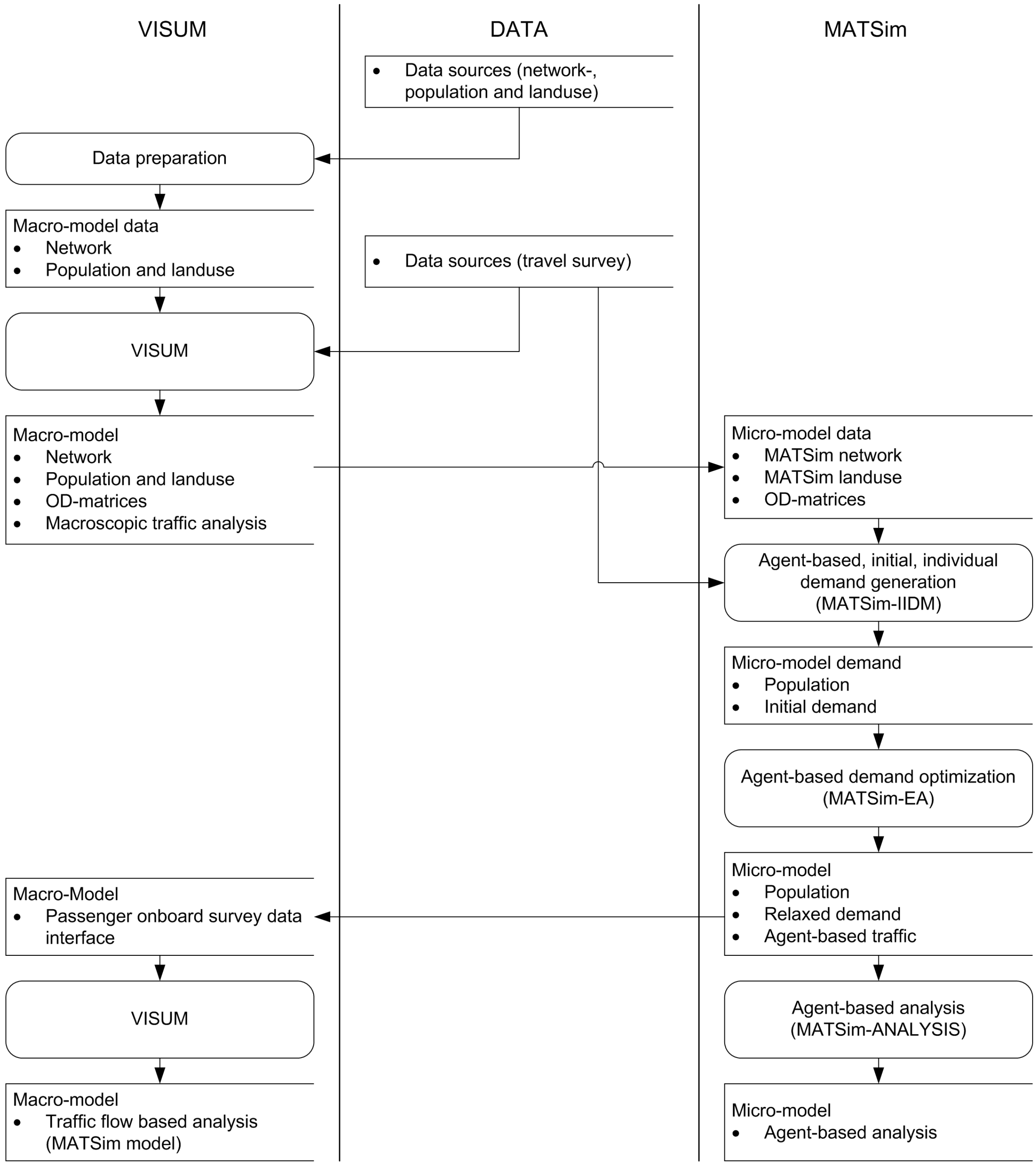


FIGURE 1 Project process overview

mization process the MATSim model delivers a relaxed activity based demand for all inhabitants of the Berlin/Brandenburg Metropolitan Region as well as the microscopic, agent based mobility flows of that region. In the post-process stage the micro-model can be analyzed in two ways: (i) by different heterogenous agent groups, their travel demand and/or their use of transport and (ii) by conversion into the so-called "passenger onboard survey module" of VISUM to analyze traffic flows of MATSim in the macro-environment.

MACROSCOPIC MODELING WITH VISUM

This section gives a brief overview of the used data sets processed as well as the trip based demand modeling process and the static assignment in VISUM.

Data Sources

Landuse and population data

For the model, the Berlin/Brandenburg Metropolitan Region is divided into 1,537 traffic analysis zones (300 for the inner city circle, additional 893 for the greater City and 344 for the agglomerations around Berlin) containing information about:

- Inhabitants separated into eight age groups, work classes, car- and bike ownership,
- Education facilities, e.g. Kindergarten, school, university and training places,
- Places of employment in total as well as per economic sector,
- Square meters of shopping separated by daily and other shopping activities,
- Leisure facilities and
- Parking information on three pricing levels 25, 50, and 75 euro cent per 15 minutes.

For the base year of 2008, overall about 3.4 million inhabitants live in the city of Berlin and an additional million in the surrounding agglomerations. Around 1.6 million workplaces are available in the city, which also holds about 760 schools at ca. 880 different facilities for 170,000 pupils at primary school and 160,000 at secondary school. The different universities in the Berlin/Brandenburg Metropolitan Region provide higher education for about 25,000 students.

The development of shopping facilities has been increasing rapidly in the last decade. In the last few years additional 270,000 m^2 of shopping area are built resulting in a total of about 4.5 million m^2 for the Berlin/Brandenburg Metropolitan Region.

The level of motorization in Berlin varies from zone to zone ranging from 252 to 426 vehicles per thousand inhabitants (with an average of 317 for Berlin). Additionally, the SrV 2008 travel survey data set (*29*) delivers bike densities of about 718 bikes per thousand inhabitants, also with a large variance between different zones inside Berlin.

Network data

BVG Berlin provided the complete public transport network inclusive the schedule data for 2007 containing 195 bus, 22 tram and 10 subway lines and additional 6 ferries. To complete the public transport supply of the whole area 15 suburban, 42 regional and 6 intercity train lines are added for the modeling process together with additional 224 bus and 10 tram lines of other public transport authorities in the surrounding agglomerations of Berlin. Description of the 96 different public transport vehicles (i.e. capacities, number of wagons and operation modes) are given and assigned to the 530 lines of the region. While the vehicle description operated by the BVG is very detailed, default values of the vehicle attributes are assigned for the remaining lines.

The transport network model represents the infrastructure of 2008 for all major and minor roads and consists of about 115,000 street segments for the whole area of interest, 98,000 motorized individual transport (*mit*), 7,000 *bike*, 5,000 *walk* and 7,000 public transport (*pt*).

Travel Data

With access to the SrV 2008 travel survey (*29*) a very comprehensive data source is given for the traffic demand modeling process in VISUM. The SrV reflects the Berlin municipality and — in a lower dense version — also the municipalities around Berlin. The sample size of Berlin covers about 1% of the population of Berlin with about 22,000 households (weighted) and ca. 39,000 persons interviewed while about 34,500 reported at least one trip at their valuation date. On average, these mobile persons performed 3.43 trips per day, whereas the whole person sample averaged at 3.03 trips per day with variation from 2.7 to 3.36 trips per day dependent on the zone.

Mode shares vary as well in the region with an overall modal split of 32.3% *mit* (car), 26.5% *pt*, 12.6% *bike*, and 28.6% *walk*. Travel time and travel distance distribution per mode are also taken into account for the generation of the OD-matrices. Additionally, the vehicle occupancy is taken into account for the 23 modeled activity pairs.

Finally, external traffic is added to the modeling process. Given the "Gesamtverkehrsmodell Berlin" (*30*) additional OD-matrices for long distance, freight traffic and traffic from and to the airports of Berlin are included in the modeling process. In addition to previous transportation models of Berlin, also tourist traffic is taken into account modeled again as additional OD-matrices for individual and public transport. To estimate adequate traffic demand, occupation statistics of accommodations in Berlin is taken into account. In Summer, about 60,000 guests are staying over night in Berlin. Statistics about guests at private accommodations as well as one day visitors are not well measured but estimated with about additional 40,000 persons. Tourist survey data of other tourist places (*31*) reported that in average 3.6 trips per day are performed by visitors staying over night and 1.6 trips per day by one day visitors. The overall number of trips is estimated and added to the model with:

- 86,400 trips by 60,000 persons staying over night (with 3.6 trips/day, 40% *pt* share)
- 28,800 trips by 20,000 persons staying over night (private, with 3.6 trips/day, 40% *pt* share)
- 6,400 trips by 20,000 one day visitors (with 1.6 trips/day, 20% *pt* share)

For the above modeled groups of tourists, location choice is estimated by a gravitation model based on 467 hotels, 277 places of interest, 1,957 restaurants, 311 museums and 41 shopping centers in Berlin with the assumption over destination type shares of 40% places of interest, 25% restaurants, 15% museums and 20% shopping.

Modeling Process in VISUM

All the above mentioned data sets are assigned to the VISUM modeling process as shown in Figure 2(a). The generation of traffic demand matrices for individual transport is performed with EVA (PTV Vision VISUM 2). It separates the demand in activity groups; in this case into 23 different groups defining origin and destination activity types . For each of them EVA, splits the demand into the four given transport modes (*mit*, *pt*, *bike* and *walk*) while using the resistance parameters: travel time, distance costs, availability of the modes, parking costs, access/egress travel times and waiting times as well as ride costs for public transport.

The static assignment process is split up into the VISUM iterative assignment process for *mit* and the schedule based, none iterative assignment for *pt*. Therefore, the modeling process can be described in three steps (see Figure 2(b)):

1. Calculation of the necessary resistance parameters based on the street and public transport network

2. Iterative calculation of demand and traffic assignment for *mit*

3. *pt* assignment

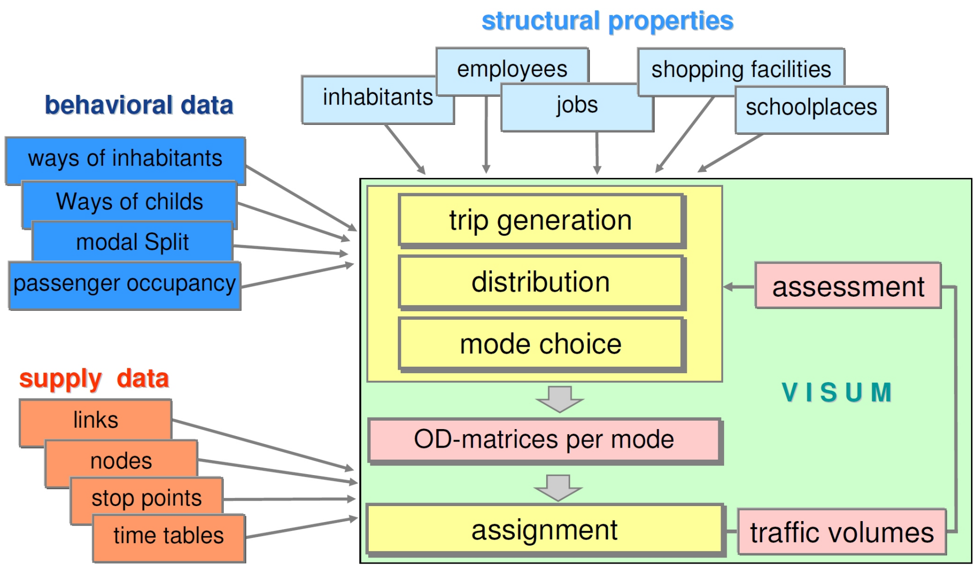
The model is validated and calibrated in 5 steps based on the SrV travel survey as well as on the VBB 2007 public transport survey (*32*):

1. Trip generation
   - Number of trips per demand group
   - Validation of target activity distribution for work and education

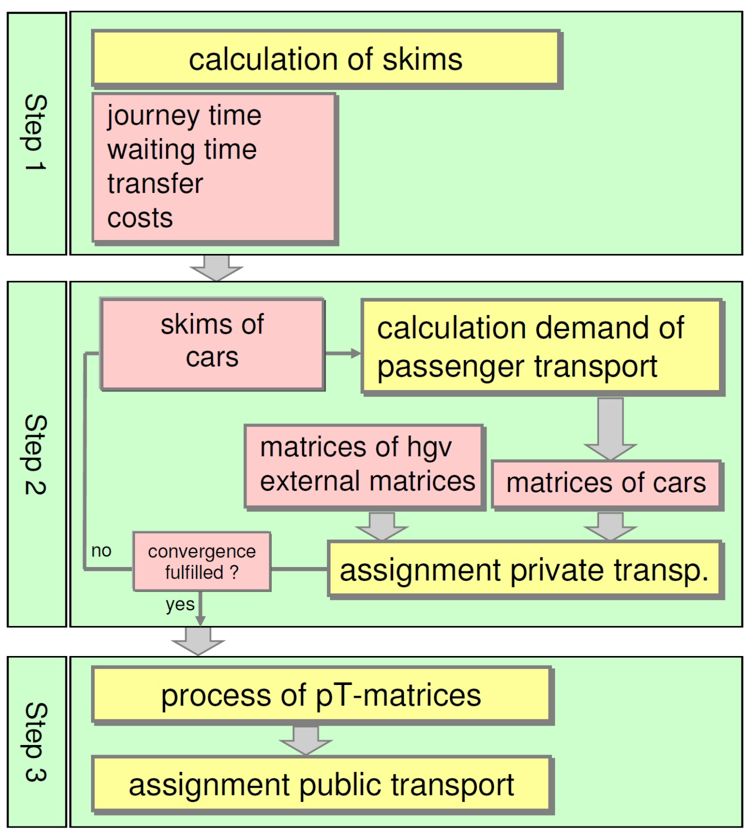
2. Trip distribution
   - Travel distance distribution per demand group
   - Travel time distribution per demand group
   - Traffic volumes per destination type and traffic zone
   - Traffic volumes for selected screen lines
   - Comparison of produced commuter trips with work statistics from the Bundesagentur für Arbeit (*33*)

3. Mode choice
   - Travel distance distribution per demand group
   - Travel time distribution per demand group
   - Mode share per demand group
   - Overall mode share
   - Comparison of the produced public transport trips with the VBB survey data of 2007

4. Assignment (*mit* and *pt*)
   - Passenger volumes at train and bus stops
   - Passenger volumes per *pt* line (subway, tram and bus)
   - Traffic volumes per line



(a) VISUM process overview



(b) VISUM process steps

FIGURE 2 Macro-modeling process

MICROSCOPIC MODELING WITH MATSIM

As shown in Figure 1 the outcome of the demand and static assignment model of VISUM is the input for the modeling process in MATSim. In more detail, the micro-model has to respect

- The *mit* street network,
- The *pt* network, lines and their schedules,
- The zonal based demographic population distribution,
- The zonal based land use information,
- The zonal based location choice distribution given by the 92 OD-matrices (four transport modes times 23 activity groups) and
- The additional traffic for long distance, freight, airport and tourist traffic.

Since the zonal based data on infrastructure, land use and population is too coarse for the microscopic demand modeling process, additional land use information on block level has to be taken into account to distribute potential activity locations inside zones. Finally, no activity-chain and timing information is available from the trip based, static macro-model. Therefore, these data sources have to be added in the modeling process while respecting the distribution from the trip based demand.

All the above is part of the first step of MATSim's scenario and *initial individual demand modeling* process (*MATSim-IIDM, 34*) before the relaxation process (MATSim's second step, *MATSim-EA, 34*) can be performed. The following section describes in detail, how the conversion and scenario modeling is implemented.

Macro to Micro: Multi Modal Network, Public Transport Schedule and Vehicle Types

The VISUM network nodes and their coordinates are directly converted into MATSim node representations. For the street segments, the conversion process has to generate one (for one-way streets) or two links (for two-way streets), since they are always directed in the MATSim format. The incident nodes as well as length, number of lanes, allowed transport modes, free speed, link capacity and street segment type are assigned to the links.

The public transport schedule, their lines, vehicles, and stops can be directly converted from the VISUM model since its public transport assignment is schedule based and thus available. Some vehicle types contain default values, if no detailed data is available (e.g. long distance trains). The conversion into MATSim scenario description reflects these defaults by setting large attribute values such that no artificial traffic bottleneck will occur during the simulation.

A very common situation in network representations of macro models is that some street segment attributes do not need to reflect reality if they are not used in the separate assignments for *mit* and *pt*. Therefore, some post-processing has to be performed for the MATSim network: Some segments define capacities and/or free speed equal to zero for *mit* mode (e.g. train tracks, closed streets or oncoming traffic lanes in one-way streets). The *mit* mode type is removed in the MATSim network representation for these links. In macro models, traffic is induced by so-called *connector links* linking zones with selected nodes of the network. As a side effect, it can happen, that the network is not strongly connected without any side-effects in the assignment process. In

MATSim, the network has to be strongly connected to guarantee to reach any *mit* link from any other *mit* link. Therefore, it is necessary to extract the largest strongly connected *mit* network. In summary, 7,104 links with 0 values, 1,963 links with no transport modes, and 2 not strongly connected links are removed from the *mit* network.

Other post-processing steps have to be performed for network links used by *pt*. Since MATSim models and simulates the interaction of *pt* and *mit* traffic (*35*), certain link attributes have to be adapted to reflect the given *pt* schedules. Some link speeds define too low travel times from one *pt* stop to another of a given *pt* line which would produce a service delay even on empty streets. The free speed attributes of those links are increased to meet the schedules. Furthermore, some link capacities used by *pt* are set too low such that *pt* vehicles would already produce spill backs even without interaction with *mit* traffic. These links are typically located at entrance or exit links of large bus stops like the bus stop at "Zoologischer Garten" in Berlin.

TABLE 1 Access and egress times and types per vehicle type

Vehicle type	access time [sec. per person and door]	egress time [sec. per person and door]	access/egress type
Ferry	2.00	2.00	serial
Bus	1.85	0.90	parallel
Tram	1.45	1.34	serial
Subway	1.31	1.12	serial
Suburban train	1.20	1.11	serial
Regional train	1.18	1.46	serial
Others/default	0.05 [per vehicle]	0.05 [per vehicle]	serial

At last, MATSim also simulates access and egress delays at public transport stops which are dependent on the vehicle type, the number of doors and the door operation mode (*36*). These attributes are not available from the VISUM models. Based on passenger surveys conducted by VSP in 2010 and 2011 (*37*) the vehicle types are enriched by this information as shown in Table 1.

Macro to Micro: Population and Activity Based Demand

Here, the target to produce the initial, individual demand for MATSim is to reflect the SrV survey while respecting the trip distribution of the macro model for each activity group and for each mode of transport. The following procedure describes the initial, individual demand generation for the MATSim model.

SrV Survey to MATSim plans

The conversion and filtering of the SrV travel survey data is an important step since it (i) interprets the given raw data and (ii) it makes it easier to work with it in later steps, where the travel demand has to be distributed to the given population.

The household data set from the survey provides information about (i) home location (on municipality and statistical zone level of detail), (ii) household size, (iii) number of cars, motorbikes and bicycles, (iv) number of shared season tickets and (v) income classes. The person data set contains the additional information about (a) age, (b) gender, (c) employment type, (d) education type, (e) driving license and (f) user type for public transport (defines if a person uses public transport very often, seldom or never). These data are used to define the demographic and sociodemographic description of each person interviewed in the survey. It is also used to assign *mit* availability and season ticket ownership.

Finally, the trip table of the survey describes the activity chain of each person interviewed including mode choice per trip, type of activity per destination, departure, travel and arrival time per trip, and, therefore, also the activity duration per location and type. The geographic level of detail for each destination is given by municipality and statistical zones.

VISUM to MATSim population

For each of the 1,537 traffic analysis zones of the VISUM model, the number of inhabitants of 30 socio-demographic homogenous groups (divided by age classes, employment type, resp. education type and *mit* availability) are given. This information is converted into 4,436,363 synthetic persons (MATSim *agents*) for the scenario while their home location is distributed inside the zone according to additional land use information on block level of detail.

Distribution of SrV plans *to the MATSim* population

This step performs a weighted draw of an SrV person for each *agent* of the MATSim population. Both data sets contain the home location. Therefore, the weighted draw is based on the geographic distribution as well as on the socio-demographic groups defined by VISUM. For each agent, a choice set of potential SrV persons near to the agent's home location and of the same person group is created. Then, a random person is selected from that set and his/her plan and demographic and socio-demographic attributes are assigned to the *agent*. This procedure reflects the structural distribution of the activity based demand of the survey in space without concerning about artifacts given by the zonal borders, but it still allows one to generate a feasible size of the choice set.

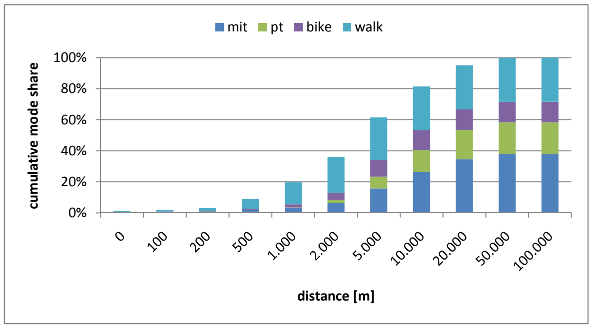
Geocoding the Activity Based Demand

This last step assigns a location for each activity of the activity based demand (except for the already assigned home location). In principle this can be called "location choice". But since the MATSim model has to reproduce the location choice already performed by the macro model (that produces the 92 OD-matrices), location choice is therefore reduced to a weighted draw from the given OD-matrices. For each trip of each MATSim *plan*, based on the given start and end activity, the mode of transport and the traffic analysis zone of the start activity, the representing OD-matrix of the VISUM model is selected and the destination zone is drawn by the distribution of the matrix. For work and education activities, the procedure is done only once per *plan* and assigned to all activities with the same type.

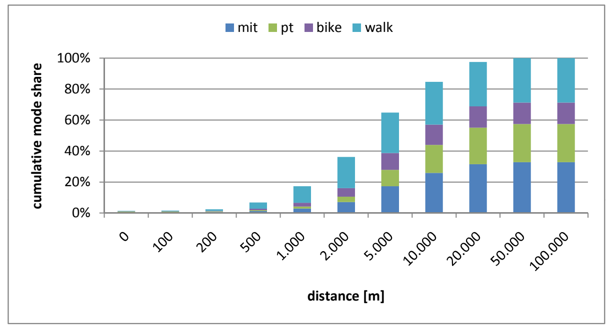
As a result, all activities are now assigned to a traffic analysis zone of the VISUM model. Again, to assign a coordinate inside the zones land use information on block level of detail is used in the same manner as done for the home locations while respecting one single coordinate for the main activity types, i.e. work and education.

Comparison of the Initial, Individual Demand Modeling Process with the SrV Survey Data

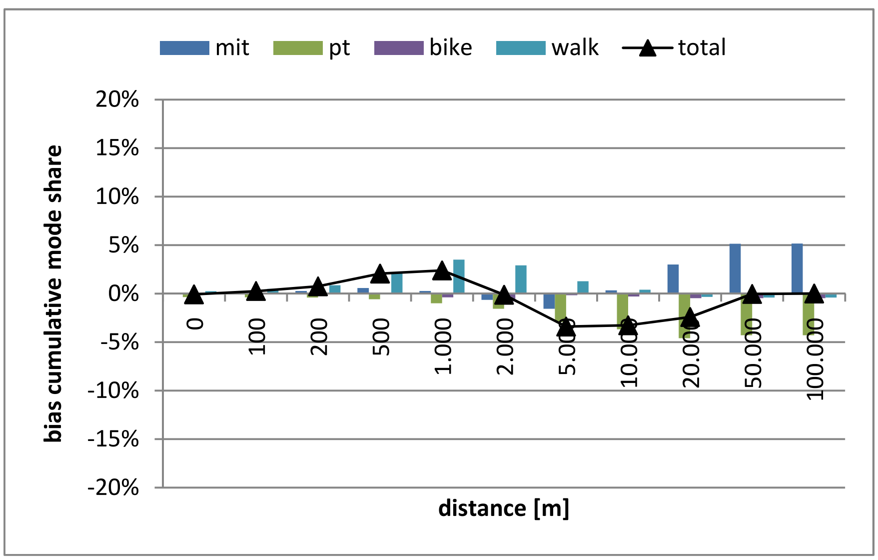
The quality of the produced initial demand can be compared directly with the travel survey data set. Especially, comparisons of distance distributions in total, as well as for each mode of transport shows the quality of the activity chain distribution and also of the distribution of the chosen locations. With that, this type of analysis also presents (in an indirect way) the quality of the location choice of the macro model. Figure 3 shows that the differences are below 5% in total as well as for each mode which reflects the accuracy of the modeling process.



(a) IIDM: cumulative distance distribution initial demand



(b) SrV: cumulative distance distribution initial demand



(c) Bias cumulative distance distribution IIDM vs. SrV

FIGURE 3 Comparison of crow-fly distance distribution between IIDM and SrV survey

It is to mention that the figures shown here compare only the crow fly distances of the trips. This is of importance since reported travel distances of travel survey data are usually of low quality because of large errors in personal perceptions. To avoid this fact, the distances are calculated according to the post-processed geocoding of the reported trips. They are based on lower geographic resolution (municipality and statistical zone level) but the error of perception can be eliminated.

Macro to Micro: Additional Traffic

Also, additional long distance, freight, airport and tourist traffic has to be added to the MATSim model. This can be done by simply converting the given matrices from the VISUM model into additional "non-population representative" agents holding a single-trip-plan with start and end activity based on the given traffic analysis zones. Again, the coordinates inside the zones are chosen based on the building blocks.

MATSim Scenario Generation

At last, the demand has to be connected to the network. Since all activities contain a specific coordinate and are not bounded to a zone anymore, simply the nearest link to the coordinate is chosen as entry and exit link of the *mit* mode while certain links are left out (e.g. motorways). For access to the public transport infrastructure via *pt* stops, MATSim agents chose them automatically during the relaxation process and therefore, no assignment has to be done.

MATSim Relaxation Process

To take into account the various effects of the dynamic interaction in the traffic simulation, i.e. traffic flow interaction and activity timing, the initial, individual demand generated above has to be relaxed with MATSim's co-evolutionary optimization process, i.e. Balmer et al. (*38*). For the synthetic population of the Berlin/Brandenburg Metropolitan Region the agents are able to optimize in the dimensions: route, time and mode choice.

For the "non-population representative" agents defining additional traffic only time and route choice is allowed to respect the predefined modes from the macro model. The utility function used to calculate the generalized utility of performed daily plans is based on Charypar and Nagel (*39*) while extended by additional terms for the different mode types. Furthermore, monetary costs per transport mode is added to the function representing ticket and acquisition costs for *mit*, *bike*, and *pt*. For public transport, agents determine the least cost path with regards to walking time to and from *pt* stops, in-vehicle travel time, transfer time, waiting time, and line switch costs. The model is calibrated and validated against the SrV travel survey with focus on mode choice, travel time and travel distance distribution as well as on traffic volumes for *pt* and *mit* by performing an experimental design method. Please note, that a detailed description of the calibration process is left out here since it would exceed the scope of this paper by far.

COMPARISON OF MACRO AND MICRO MODEL

This section focuses on the comparison between the macro and the micro model rather than the validation to measured data since it is to show the similarities, resp. differences of the two models.

Table 2 presents performance indicators used by BVG. First, the usage of different transport modes operated by the BVG are compared. In general, the numbers match well. The macro model serves slightly more trips with the subway lines, whereas the micro model serves more trips

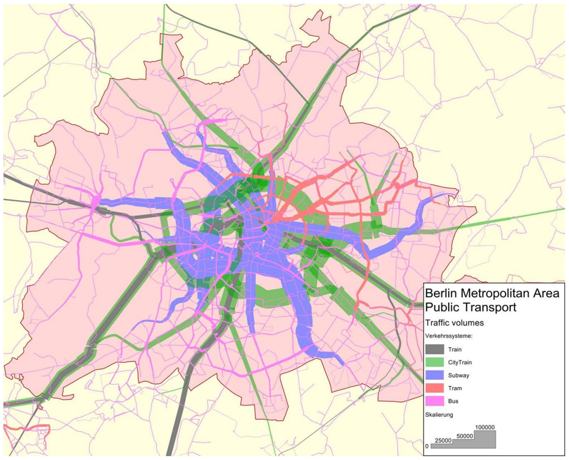
TABLE 2 Public transport figures for macro and micro model - Subway, Tram, Bus and Ferry values include BVG lines only

	macro model	micro model
total number of trips	3,230,792	3,577,075
total number of transfers	2,075,463	1,981,710
total number of passenger trips	5,306,255	5,558,785
total number of passenger trips - subway	1,710,603	1,414,513
total number of passenger trips - tram	490,176	524,081
total number of passenger trips - bus	1,211,724	1,600,294
total number of passenger trips - ferry	1,293	348
total number of passenger kilometer - subway	8,031,010	7,885,233
total number of passenger kilometer - tram	1,557,465	2,183,910
total number of passenger kilometer - bus	3,733,028	5,914,468
total number of passenger kilometer - ferry	1,274	1,038
average in-vehicle travel time per trip	17 min 45 s	20 min 07 s
average number of transfers per trip	0.642	0.554
total number of trips without transfers	1,548,525	1,950,921
total number of trips 1 transfer	1,316,325	1,306,173
total number of trips 2 transfers	339,799	284,648
total number of trips >2 transfers	26,143	35,333
share of trips without transfers	0.479	0.545
share of trips 1 transfer	0.407	0.365
share of trips 2 transfers	0.105	0.080
share of trips >2 transfers	0.008	0.010

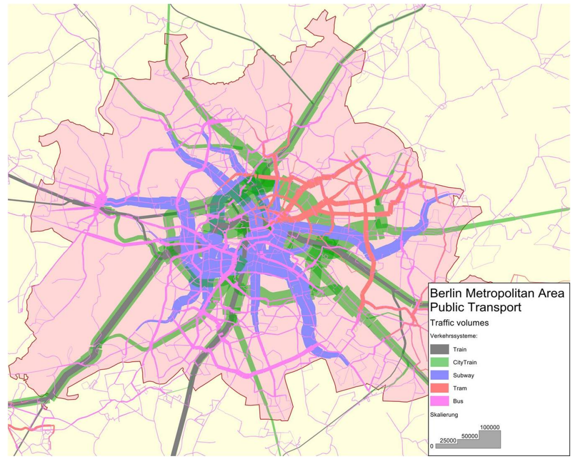
at the bus network. Values for the tram network are nearly the same. Comparing the passenger-kilometers and the passenger trips show shorter trips in the macro model for most transport systems. This is underlined by the average in-vehicle travel time per trip, which differs by about three minutes. The number of trips is slightly higher in the micro model, but the number of transfers is more or less the same. This results in a higher number of transfers per trip in the macro model. In the micro model, trips tend to be longer in travel time and distance. There are more trips served without transfers, especially by the secondary network of bus and tram lines. This may be a direct consequence of the models. Agents of the micro model can freely choose the stop to depart from based on their activity location. Trips in the macro model start and end at *connector links* that are preset by the network designer and limit the route choice, eventually eliminating connections without transfers.

As the *pt* values shown in Table 2 indicate, the traffic patterns of both models are comparable. Figure 4(a) and 4(b) present the corresponding traffic volumes. As mentioned before, slight differences can be determined in the secondary network, especially in parts of the tram network in the north east. As the difference plot in Figure 4(c) illustrates, the micro model features more traffic at the city train network, especially on its north-south and the west-east branches. The macro model has more traffic at the southern part of the circle line and at parts of the subway network.

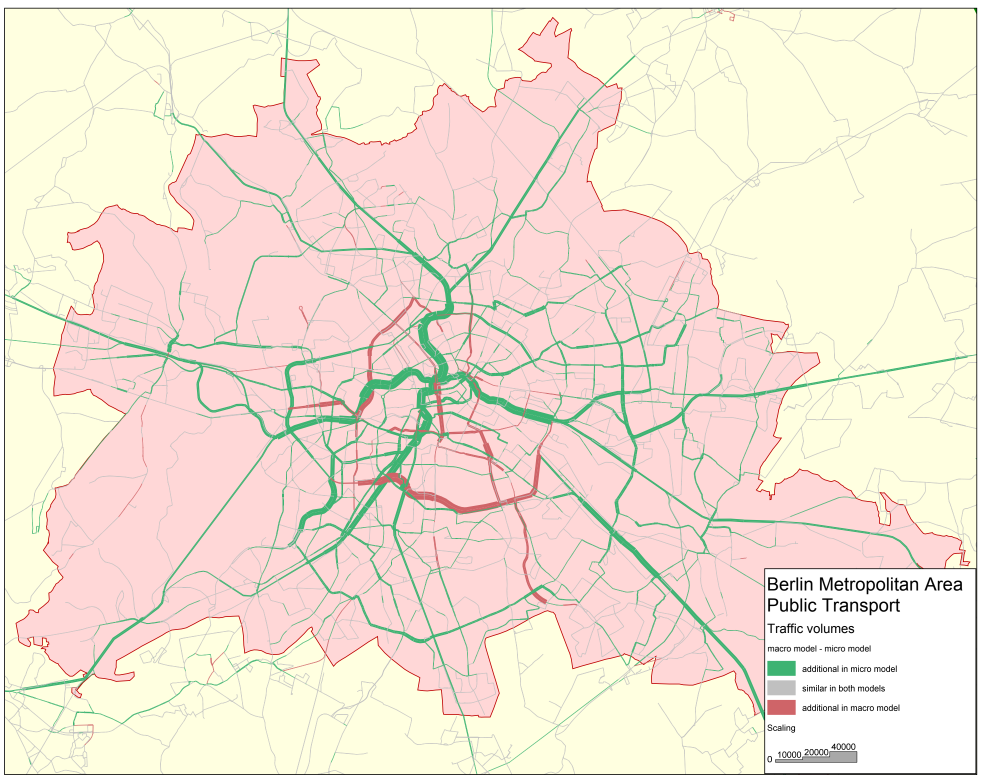
The more detailed view of the area of Alexanderplatz in Figure 5(a) shows the same amount of traffic in both models for most lines. Only the part of the city train running from Jannowitzbrücke to Hackescher Markt features more traffic in the micro model. The high absolute difference of the city train in Figure 5(a) is not backed up by the complementing relative error



(a) Macro model

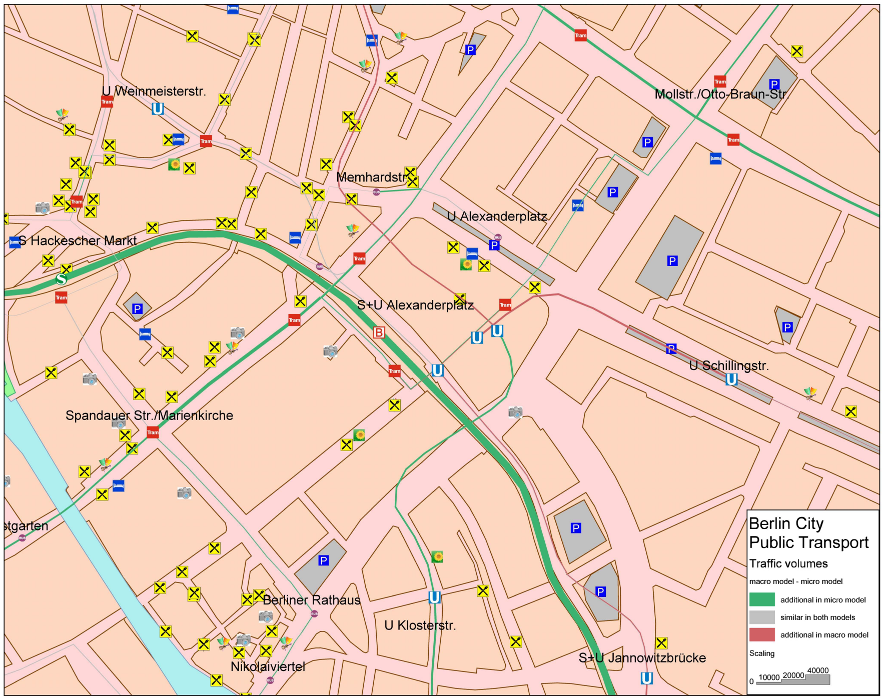


(b) Micro model

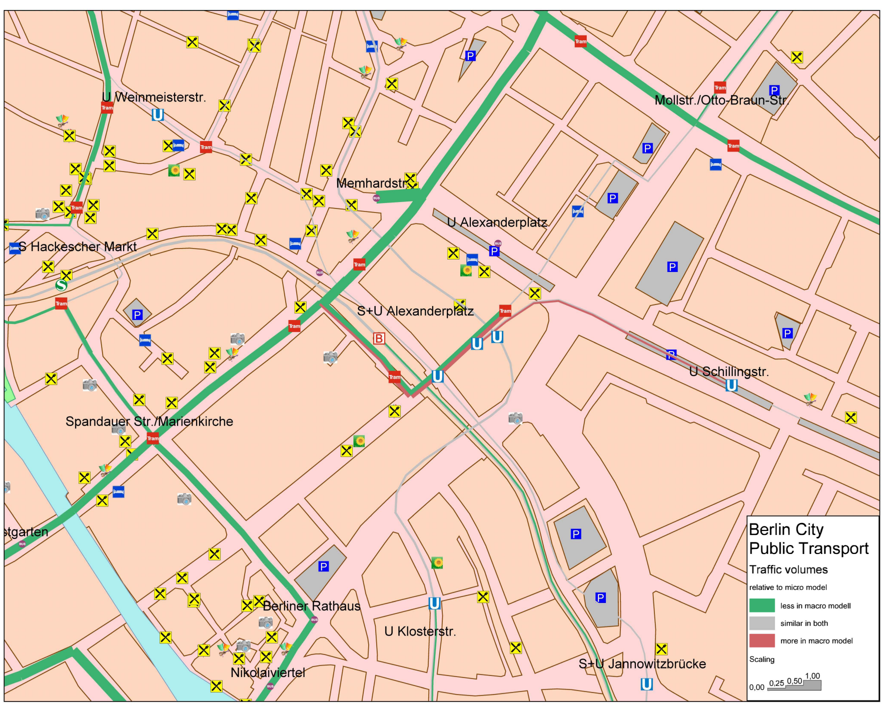


(c) Difference of micro and macro model - A difference of less than 2000 trips per day is considered as similar in both models.

FIGURE 4 Public transport traffic volumes in absolute values



(a) Difference of micro and macro model in absolute values - A difference of less than 2000 trips per day is considered as similar in both models.



(b) Difference of micro and macro model in relative values - A difference of less than 15 % is considered as similar in both models.

FIGURE 5 Public transport traffic volumes - Detail of Alexanderplatz

shown in Figure 5(b). The relative error for train, city train and subway lines is very small. Only the aforementioned tram lines and some bus lines show a somewhat higher relative error, induced by low demand.

To conclude, both models show the same *pt* traffic pattern with the micro model featuring longer trips, but with less transfers.

CONCLUSION AND OUTLOOK

This paper presented the successful transformation of a static macroscopic model into an integrated activity based demand and dynamic assignment model performed for a real application on the Berlin/Brandenburg Metropolitan Region. While the two models clearly differ in their methodology overall key values can be reproduced showing similar results. Furthermore, it is shown that by the use of the activity chain distributions and their timing activity based demand can be reproduced with respect to the trip distribution of the origin-destination matrices from VISUM. From the view of the "Berliner Verkehrsbetriebe" BVG the process flow defined for this project allows them to use both models for planning purpose, case studies and effect analysis while modeling their needs in the VISUM editor environment and performing the model calculation in VISUM as well as in MATSim. As a result they are able to analyze effects on the macroscopic level of detail as well as on agent based level to capture specific customer groups and/or time ranges during the day. Since the traffic flow simulation also takes into account the interactions between *mit* and *pt* the BVG is also able to analyze disturbances of the public transport schedules on an operative level (e.g. due to congestions of car traffic, delays of access and egress times of passengers, and so on). Nevertheless, some issues occurred in this project has to be addressed:

Network representation

The models interpret transportation networks differently which produces certain lacks of consistency. While the MATSim model is very restrictive about their link attribute values, which have direct influence in the traffic flow simulation, some attributes in the macro model do not effect the assignment process. This clearly recalls the fact that the assignment process of the macro model is separated for the different transportation modes but treated in a multi-modal way in the simulation. As an example, there is not always a clear distinction between buses or trams using same or different lanes than cars on a street segment. But for the MATSim network representation, this would be of importance since the street segment would be separated into one link with both modes or two links with one mode per link. To overcome this problem, the macroscopic network has to be extended by this kind of information.

Public transport schedule and transportation network

As shown above, some adaption to network attributes had to be made for the transformation into the MATSim model. Even this process works well, there are still some artifacts remaining due to the time resolution of the public transport schedule (typically in one minute). In this cases, the adaption reflects the schedule within +/- one minute.

A certain accuracy of the public transport is necessary for modeling schedule based traffic assignment in both cases, for macro and micro models. Usually, there is a lack of information in case of line schedules reaching abroad the region of interest. In such situations, it would make sense to artificially increase the line frequencies such that no bottlenecks would occur.

Reconstruction of the activity based demand on the base of origin-destination matrices

The join of these two sources presented in this paper works very well. But it has to be stated that the used data sources — especially the travel survey data set — are the base for *both* demand modeling processes and therefore, fit very well together. It is unclear to this point if the proposed process step will work in any case, i.e. when the data sources are not of that high level of quality and quantity.

Process flow

The process flow presented in this paper suits very well for real world applications and effect analysis for the BVG and is consistent within the generation processes of both models. From a conceptional point of view, the process steps should be reorganized since the reconstruction of activity based demand with the basis of the trip based demand by VISUM is actually a detour. To gain the advantages of both models without this detour, we would suggest the following:

1. Modeling of population, land use, transportation networks and schedules with VISUM using the advantages of various modeling and editor features provided by this software.
2. Modeling the initial, individual, activity based demand via MATSim (or with other activity based models, i.e. *11, 12, 13*, etc.).
3. Compute, calibrate and validate the demand with the co-evolutionary relaxation process of MATSim using at least all four choice dimensions (routes, times, modes, and locations).
4. Convert the relaxed demand into zonal based origin-destination matrices (similar to the work presented in *40*).
5. Run the traffic assignment for the different modes with VISUM.
6. And finally, analyze the outcome again on both tracks; for the macro and micro model.

With this suggestion, no reconstruction of the activity based demand has to be done and both models deliver full functionality for the user. The main reason for the process steps presented here is that the BVG already receives a complete VISUM model without dependencies to the fairly new approach with MATSim. Nevertheless, the proposed "get-together" of a macroscopic and an activity based, microscopic transport model delivers valuable findings for various questions and applications for the BVG.

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