

The IVT 2015 baseline scenario

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Bösch, Patrick M.; Müller, Kirill; Ciari, Francesco

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Patrick M. Bösch, IVT, ETH Zürich
Kirill Müller, IVT, ETH Zürich
Francesco Ciari, IVT, ETH Zürich

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Patrick M. Bösch
IVT, ETH Zürich
CH-8093 Zürich

Kirill Müller
IVT, ETH Zürich
CH-8093 Zürich

Francesco Ciari
IVT, ETH Zürich
CH-8093 Zürich

Phone: +41 44 633 39 52

Fax: +41 44 633 10 57

patrick.boesch@ivt.baug.ethz.ch

Phone: +41 44 633 33 17

Fax: +41 44 633 10 57

kirill.mueller@ivt.baug.ethz.ch

Phone: +41 44 633 71 65

Fax: +41 44 633 10 57

ciari@ivt.baug.ethz.ch

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Abstract

This paper presents the new IVT 2015 baseline scenario for MATSim. It represents a typical workday in Switzerland in the year 2015. The main population is available as a 1% and 10% sample, as well as undiluted. It features attributes, preferences, facilities and households. A cross-border population and a freight population complement the main population. The former represents people coming to Switzerland from abroad, whereas the latter represents freight traffic on a typical workday. The network and the public transport system are based on Open Street Map data and on the official SBB HAFAS schedule. Furthermore, the code, which combines the different input data to coherent, fully functional MATSim scenarios, is discussed from a technical point of view. In a third part, the paper presents the default scenario configuration (configuration file, scoring function and replanning strategies). This configuration is tailored to the population and network described above. The ensemble provides a solid base for future MATSim transport studies at the IVT.

Keywords

Transport Simulation, Agent-Based, Scenario, MATSim, Switzerland, Zurich

1. Introduction

In transport simulations, the quality of the input has a high impact on the quality of the output. A consistent and reliable input scenario is required to obtain robust results, realistic insights and useful conclusions. MATSim (Horni et al., 2016) is a multi-agent transport simulation framework co-developed and applied at the Institute for Transport Planning and Systems (IVT). A minimal MATSim scenario consists of a population of agents and a network, representing the real population and the transport infrastructure of the study area. The modular structure of MATSim allows extending this minimal configuration in several ways. For example, if the modeler can specify more detailed and extensive information on the transport demand or supply, or the enhancement of the scenario with count data.

This paper presents the new Switzerland MATSim baseline scenario for the IVT. The scenario represents an average workday of the entire Swiss population in the year 2015. It goes beyond earlier approaches (Stahel, 2014; Horni and Vitins, 2011; Horni and Balmer, 2016) in its level of detail and its extensive data supply. It also comprises the most up-to-date version in input data available at the IVT. Depending on the application, the full scenario can be cut or diluted, for example to the Greater Zurich region for local studies, or to a sub-sample of the population for faster processing. The population of agents, including the activity chains, extends the efforts of Balmer (2007) by defining households and household income, both consistent with the socio-demographics and activity chains at the person level. This allows simulating agent-specific values of travel time and joint inter-household decisions. On the supply side, the network and public transport model developed by Bösch and Ciari (2015) is used. This model also represents the situation of the year 2015. Public transport counts, street traffic counts, foreign commuters, and a representation of freight traffic further enhance the scenario. A framework of scripts and processes enables easy creation of a fully functional MATSim scenario from the data input. This framework, together with the default configuration, including scoring function and replanning strategies, is presented in this paper too.

The structure of the paper follows an earlier presentation of an IVT scenario (Horni and Vitins, 2011). The first section, Input Data, presents the input data in detail, including for example the population, the network, and public transport, and describes the data sources and the necessary transformations. Section 3, Scenario Creation, follows with a presentation of the scripts and processes that were developed to integrate the input data into a coherent, fully functional MATSim scenario. Section 4, Simulation, presents the suggested base configuration of the scenario for simulation in MATSim. The paper concludes with a discussion (section 5) and an outlook (section 6).

2. Input Data

2.1 Population

One of the central elements of every MATSim simulation is the population (subsection 2.2.2, *Typical Input Data*, in (Rieser et al., 2016)). It represents the travel demand in the simulation. A population consists of individual agents representing real people. Each MATSim agent has plans and attributes. A plan, which is an extended and enriched form of an activity chain, defines the sequence of the agent's desired activities. It also specifies where the agent would like to conduct these activities and with what transport mode he plans to move from one activity location to the next. The attributes characterize the agent (mainly socio-demographics, but also for example access to transport modes) and specify its preferences (subsection 6.2, *Person Attributes and Subpopulations*, in (Nagel et al., 2016)). An agent's preferences indicate the desired start time and duration for each activity, irrespective of transport constraints. Household membership – the grouping of agents in households – is also part of the population (subsection 6.5, *Households*, in (Nagel et al., 2016)). Additionally, household attributes specify the available household income, the number of available cars and the bike availability on a household level.

The main population of the IVT scenario is presented in more detail in the sections 2.1.1 to 2.1.3. Sub-populations contribute additional traffic not included in the main population, for example cross-border traffic (presented in section 2.1.6) and freight traffic (section 2.1.7). To allow this additional traffic to react to congestion, it is modelled as single trip pseudo-populations: each agent just represents one (return) trip.

2.1.1 Households

The agent population is based on the detailed register survey (Registererhebung) of the Swiss population of the year 2012 (BFS, 2016d).

The register survey contains basic socio-demographics for all inhabitants of Switzerland, precisely geolocated, and grouped into households. From this dataset, only private households at their primary residence are included. Persons at their secondary residence are removed. The registered residence may differ from the factual (weekday) residence; this is not corrected. Households from very sparsely populated hectares are moved to the closest non-sparse hectare. Implausible households (such as group quarters, prisons, monasteries, and also collective households) are currently removed. In a future version, all persons from the register survey will be represented in the final population.

For the scaling to 2015, the population is rescaled to aggregate constraints using generalized raking (Deville et al., 1993; Müller, 2016a; Alfons and Templ, 2016). The constraints are derived from the register survey preview (for 2015) (BFS, 2016e). The following target values are controlled for:

- the number of persons of each combination of age and gender
- the number of persons of each combination of age class (0–5, 5–10, ..., 75–80, >80), gender, and nationality (Swiss or non-Swiss)
- the number of households of each size

If the household size is left uncontrolled, single-person households are severely overrepresented in the generated population.

This rescaling yields a fractional expansion factor for each household in the register survey, which is then rounded stochastically using the "Truncate-Replicate-Sample" method (Lovelace and Ballas, 2013) using a fast implementation for weighted random sampling without replacement (Müller, 2016b). The result is an integer expansion factor for each household, where the total number of persons matches exactly, and the target values for each of the above combination of categories match approximately.

For each household's expansion factor, three cases are distinguished:

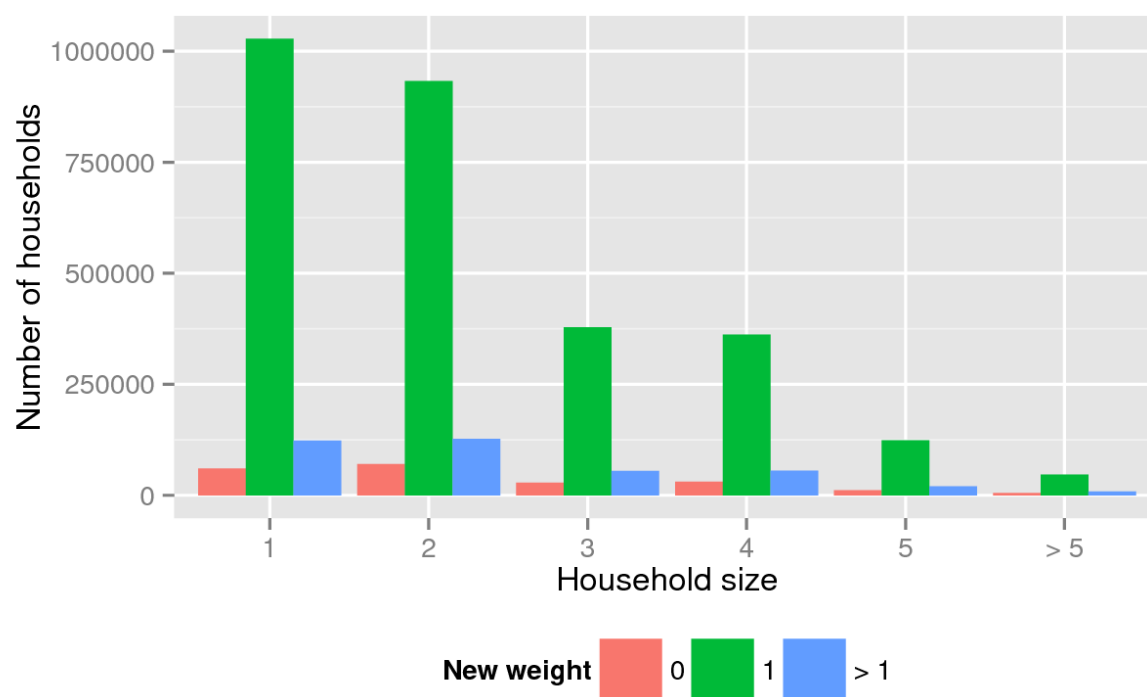
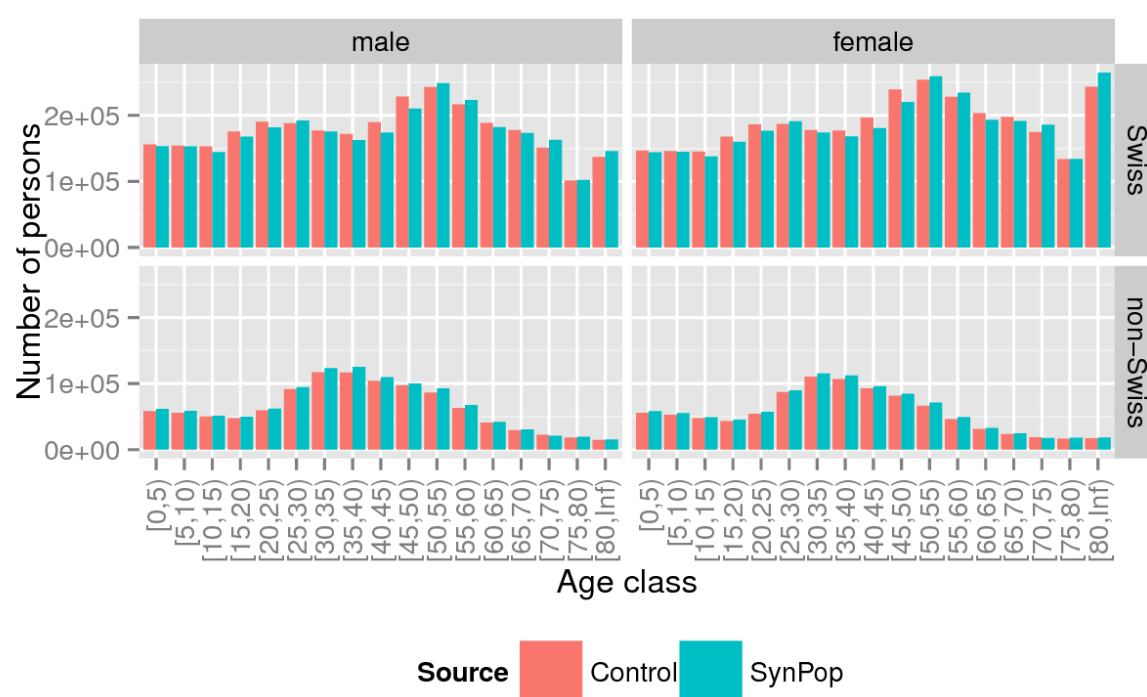
- 0: The household is removed (8.7 %).
- 1: The household remains unchanged (64 %).
- > 1: Copies of the entire household are redistributed randomly over inhabited regions (27.3 %).

Figure 1 shows the distribution of these three cases for different household sizes. The vast majority of the households remains unchanged. The comparison of the synthetic population with the second control totals is shown in Figure 2.

The following attributes are defined for the household population at this step:

- Person and household IDs
- Sex, age, marital status, nationality (Swiss/non-Swiss)
- Home location

For the final population of households, the head of the household is determined using a heuristic that favors older married, economically active males. This is important for the next step, the assignment of activity chains, which is described in the next Section.

Figure 1 Expansion factors for different household sizes.**Figure 2** Comparing the synthetic population with the control totals.

2.1.2 Activity Chains

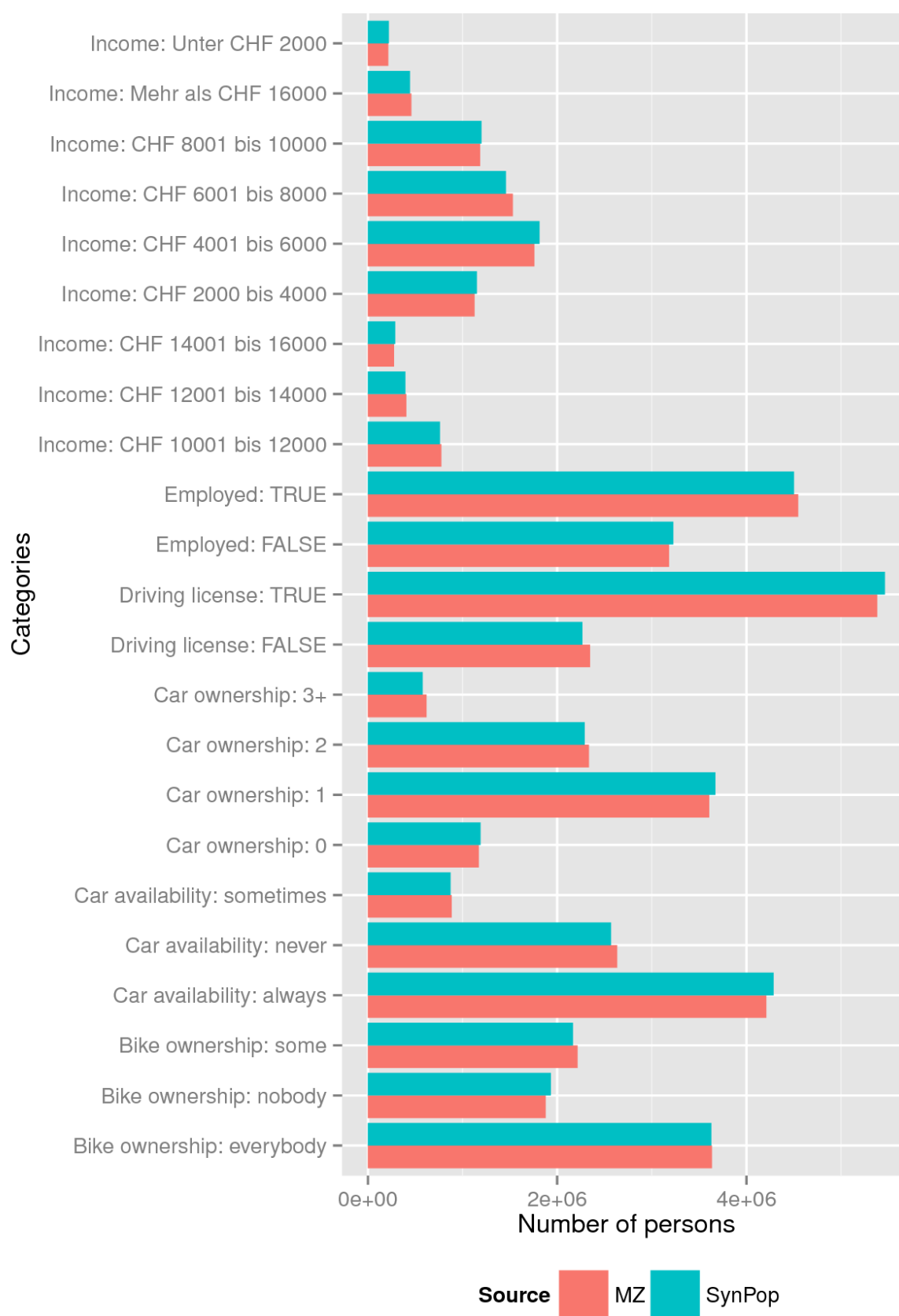
The activity chains are derived from the Swiss transportation micro census of the year 2010 (Mikrozensus Verkehr) (BFS, 2016f), which is a representative sample covering slightly less than 1 % of the Swiss population. For the weekday scenario, only persons that were asked to report their mobility behavior on a weekday are used, which results in a final sample size of about 44'000 persons. Because the income attribute is missing for a substantial share of observations, it is imputed using a simple CART model (Breiman et al., 1984).

Each person in the synthetic population is matched to an observation from the transportation micro census using hot-deck statistical matching (d'Orazio et al., 2006). The matching is performed over age class (6–15, 15–18, 18–24, 24–30, 30–45, 45–65, 65–80, 80+), sex, and marital status: For each synthetic person, only micro census observations that are equal over these attributes are eligible for matching. In addition, observations that are similar with respect to the household size and the type of the home location (agglomeration core, agglomeration non-core, or rural) are preferred. The micro census weights are used naturally in the matching process.

First, a micro census observation is attached to the head of each household. In the next step, all other household members are matched; here, in addition the similarity with respect to income, number of household cars and number of household bicycles is used for the matching. After the matching, all information from the micro census observation is inherited by the synthetic person. In particular, the following variables are available for each synthetic person after this step:

- Driving license
- Car availability
- Employment status
- Season ticket ownership
- Household income
- Number of cars (0, 1, 2, 3+)
- Number of bikes (0, for some household members, at least one for each household member)
- The activity chain: activity pattern, activity and trip durations, trip modes, and Euclidean distance between home and the primary workplace

As expected, the population total for all new variables in the synthetic population aligns well with the weighted micro census data. Figure 3 compares several of the above indicators which were not part of the matching process.

Figure 3 Grand totals for the micro census and the synthetic population by category.

2.1.3 Workplace Location

The commuter matrix is extracted from the structural survey of the Swiss population of the years 2010-2012 (Strukturerhebung) (BFS, 2016g). The data from three survey years cover slightly less than 10% of the Swiss population. In addition to extended socio-demographics, the structural survey contains the location of the home, the location of the primary workplace, and the commute mode. The locations are given at the level of municipalities, and of city quarters for the largest municipalities.

For each employed synthetic person, the workplace is derived as follows. For all persons from the same municipality or quarter and with the same commute mode, workplace municipalities or quarters are sampled at random from the observed commuter matrix, weighted by their relative frequencies. Both the target workplaces and the synthetic persons, are sorted by the Euclidean home-work distance. This ordering determines which synthetic person is assigned to which workplace commune ensuring consistency of activity chains and workplace distances. The precise workplace locations are sampled randomly from the Swiss enterprise census of the year 2012 (Betriebszählung) (BFS, 2016), again weighted by the number of their employees. The number of persons working at a specific location may exceed its capacity, but in expectation the observed workplace capacity corresponds to the number of synthetic persons working there.

For inhabitants of Switzerland that work abroad, only the workplace country is available in the structural survey. This information is carried over to the commuter matrix. Foreign workplaces for the Swiss population are represented by dummy workplaces located at border crossings. If a workplace in another country is selected for an agent, the dummy workplace is sampled from all border crossings to that country that are not further away than 10 km (Euclidean distance), or the closest border crossing. Inhabitants of neighboring countries that work in Switzerland are discussed in Section 2.1.6.

Secondary workplaces are selected by extrapolating the observed position of the secondary workplace in the activity chain relative to the new home and work locations. Here, the workspace closest to the extrapolated position is chosen.

2.1.4 Education Location

For each agent, the education facility is chosen from the closest facilities of the relevant type. For Kindergarten and primary school, always the nearest school is used. For secondary school, high school and university, the nearest 5, 8, or 10 education facilities are computed and sampled from.

2.1.5 Secondary Activity Location

The scenario assumes that MATSim is responsible for the location choice of secondary activities (Horni et al., 2009). The location of all secondary activities is set to the primary home location.

2.1.6 Cross-Border Population

The cross-border population represents all persons that come to Switzerland from abroad on an average workday. These people come to Switzerland for example to work, for shopping or leisure activities, or just to pass through Switzerland. The new IVT scenario represents this cross-border demand with a single-trip population without any socio-demographics or preferences. A single trip population means that the agents just travel from an origin to a destination, and, depending on the activity, back. It carries the subpopulation tag “cb”. The population originates from cross-border facilities (presented in section 2.3.3). “cb” agents travel by car or with public transport.

The cross-border population does not include the outgoing cross-border demand, which is Swiss residents going abroad, as the main population already includes those (see section 2.1.3).

The scenario differentiates between three different cross-border populations. The work population represents cross-border commuters from abroad working in Switzerland, the secondary activity (SA) population represents people from abroad coming to Switzerland for leisure or shopping, and the cross-border transit population represents people who just pass through Switzerland. All agents start their plan at a cross-border facility (see **Origins**) with a “cb-home” activity and end their plan at the same or, for transit, at a different cross-border facility also with a “cb-home” activity. In between, the work and secondary-activity agents conduct an activity at a suitable facility; the transit agents just move from their origin to their destination (see **Destinations**).

Origins

The demand is based on the Grenzzaehlung 2007 (BFS, 2009). This report states, for aggregated border sections for the year 2007, how many people from which origin used what border crossing for what purpose. Additionally, Sigmaplan (2009) reports, for each border crossing, how many vehicles used that crossing in 2007. By reconstructing the division of border crossings into the aggregated border sections, an average profile – how many crossings from what origin for what purpose – was created for each border crossing (Facility-IDs CB-XXX). These counts represent the number of agents whose travel in Switzerland originates from that border crossing for work, SA, or transit. For rail-based cross-border demand, the first respective border train station in Switzerland is used as the origin / destination (Scenario-Facility-IDs CB-200X).

The demand of the major international airports in Switzerland is also included (Facility-IDs CB-100X): Zurich, Geneva, Berne and Lugano, with more than 100'000 passengers per year each. As the Basel airport is located outside of Switzerland, it is assumed to be already included in the non-airport border crossings. The airport demand is based on the annual reports of the respective airports. Airport passengers are all assumed to come to Switzerland for SA. People coming for business purposes are treated as SA demand, because cross-border work only represents regular commuters. People arriving by airplane usually stay longer than one day. The annual reports of the airports state, however, that the number of incoming and outgoing passengers per day are usually in a similar range. The return trip airport demand is therefore assumed to represent both. It is assumed that 50% of the airport populations are traveling by car, and the other 50% by public transport.

The cross-border work demand is scaled from 2007 to 2015 based on the respective increase in work commuters in this time (BFS, 2016b). The cross-border SA and transit demand is scaled uniformly to 2015 based on the population growth of Switzerland for the respective years (BFS, 2016a).

Destinations

To define the destinations of the transit population, the incoming transit population (see **Origins**) is distributed randomly over the other border facilities, weighted by their total traffic. Where available in the Grenzzählung 2007 (BFS, 2009), same-country transits have a special weight.

To define the destinations of the SA population, a SA facility within 20 km of the border crossing is assigned randomly to each incoming person, weighted by the number of SA activities offered by a SA facility.

To define the destinations of the work population, a Swiss municipality is selected at random, weighted by the number of cross-border commuters per municipality from the respective origin country. The BFS (2016b) provides these counts for each municipality in Switzerland. A random work facility is selected within a 10km radius around the municipality's centroid.

Departure Times and Activity Durations

For each agent, the departure times and the durations for the activities are randomly drawn from the observed departure and duration for the respective activity in the main population (see section 2.1.2).

For work, only the initial work departures per activity chain are considered. For SA, all departures for a shopping or leisure activities are considered. For transit, all departures of all activity types are considered.

For the work durations, the duration from the beginning of the first work activity until the end of the last work activity per activity chain are considered. For SA, the durations of each SA activity is considered.

2.1.7 Freight Population

The freight population represents the freight traffic in Switzerland. Like the cross-border population (section 2.1.6), this population is implemented as a single-trip population (just one single trip from an origin to a destination per freight agent). This population carries the subpopulation tag “freight”. Each agent conducts a “freight” activity at an origin facility until a planned departure time, then travels with mode “car” to the destination and finishes the day there with another “freight” activity. Like cross-border agents, freight agents have no socio-demographics or preferences, only a “freight_type” attribute (“UtilityVehicle”, “Truck”, or “HeavyDutyVehicle”).

Origins and Destinations

The freight traffic is based on the freight traffic matrices in the Swiss National Transport Model (NPVM) 2010 (ARE, 2016). These matrices specify an average number of trips per day for each origin-destination relationship for each freight type. A freight agent is created for each of the full trips plus, with probability of the remainder, one additional agent. The particular origin and destination facilities are randomly drawn from the work facilities within a 10km radius around the centroid of the respective zones.

The non-Swiss zones in the NPVM 2010 were manually assigned a high-volume, highway cross-border facility in the according geographical direction. This facility represents the origin or destination for any relationships from and to the respective zone.

The freight demand is scaled from 2010 to 2015 based on the Swiss freight transport statistics (BFS, 2016c).

Departure Times

For each freight agent, the departure time is randomly drawn from the observed distribution of the cumulative hourly departures for the “business activity” and “service” trips in the Swiss Micro census 2010 (BFS and ARE, 2012), table G3.4.3.1. Within the drawn hour, an exact time is randomly drawn based on a uniform distribution.

2.2 Network and Public Transport

Another central element of every MATSim simulation is the transport supply. In MATSim, this transport supply usually consists of a street network (subsection 2.2.2, *Typical Input Data*, in (Rieser et al., 2016)) and of a public transport service (Rieser, 2016). For the IVT baseline scenario the transport supply presented in (Bösch and Ciari, 2015) is used (Figure 4).

The network consists of a detailed street network representation based on Open Street Map¹ (OSM). The level of detail of the extracted street network goes down to the level of living and residential streets. The open data source allows sharing the network.

The public transport service is based on the HAFAS² 2015 schedule of the SBB³. The street bound public transport services, e.g. buses, are mapped to the street network and integrated in the traffic. While this allows a simulation of the competition of private and public transport for road space, this also causes some unexpected difficulties when scaling the scenario. In short, when reducing the network capacity to scale to a lower percentage of simulated agents, one has to scale the size of the public transport vehicles too, or they will cause heavy congestion in the network (more details in section 5.2). Competition for the rail network is not simulated.

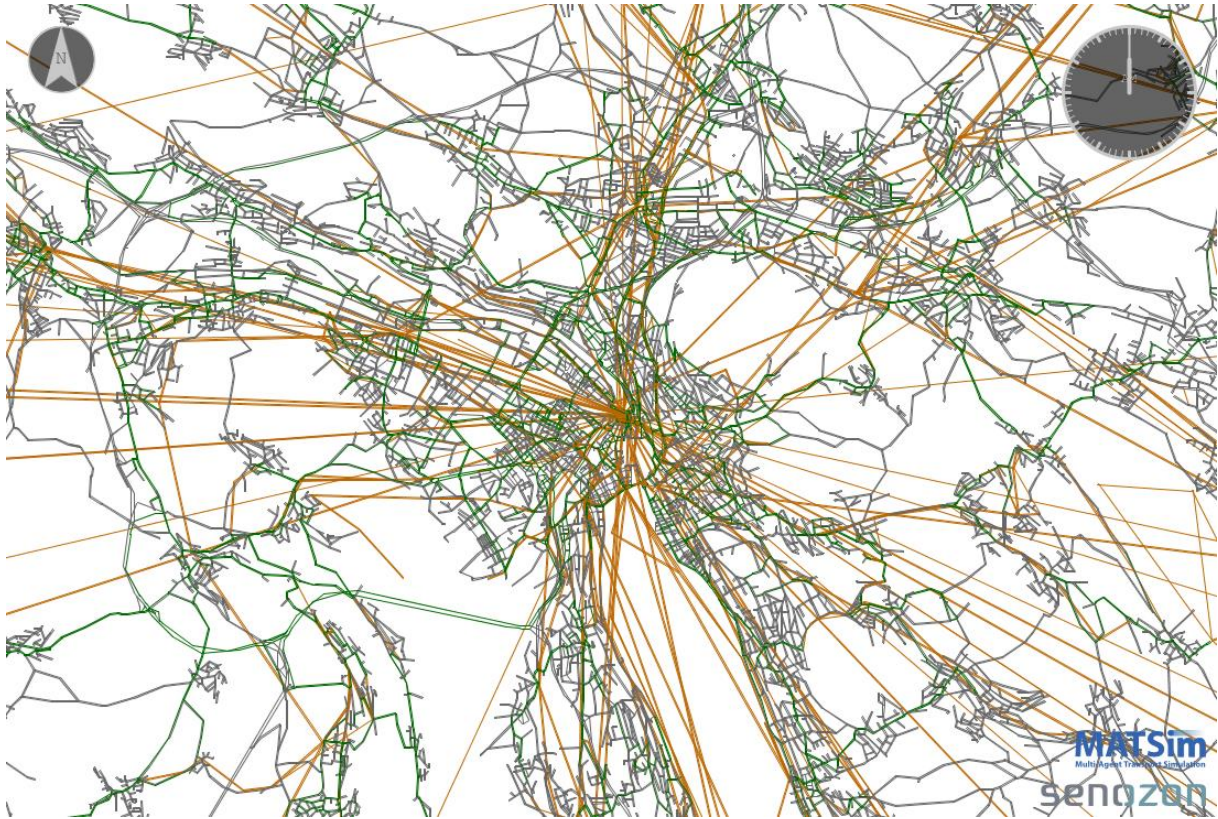
For further information on the network or the public transport service in the IVT baseline scenario, the interested reader is referred to (Bösch and Ciari, 2015).

¹ Homepage, accessed 10.06.2016, <http://www.openstreetmap.org/>.

² Homepage, accessed 10.06.2016, <http://www.hacon.de/hafas>.

³ Homepage, accessed 10.06.2016, <http://www.sbb.ch/>.

Figure 4 Visualization of the street network and the public transport supply for the Zurich area. The road links are colored grey, the mixed links green, and orange the links exclusively for public transport.



Source: Bösch and Ciari, 2015

2.3 Facilities

MATSim supports the usage of facilities to represent activity locations (subsection 6.5, *Facilities*, in (Nagel et al., 2016)). Facilities define opening times and capacity restrictions for the activities a location provides. Both make the activity-based simulation in MATSim more realistic.

This section presents the three categories of facilities included in the IVT baseline scenario. Subsection 2.3.1 presents the main activity facilities. These are home, work and education facilities. Subsection 2.3.2 presents the secondary activity facilities. These are all locations that provide opportunities for leisure and/or shopping activities. The third category of facilities are the sub-population facilities, presented in Subsection 2.3.3. These are – often virtual – locations, which represent sources of additional traffic.

2.3.1 Home, Work and Education Facilities

The register survey of the Swiss population (BFS, 2016d) contains an anonymized identifier of the building. However, due to the rescaling and redistribution, this identifier cannot be used to define the home facilities. Instead, a dedicated facility is created for each household, with unlimited open times and capacity that corresponds to the household size.

The same logic is applied to work and education facilities: For each unique location, a facility is created. The open times are limited to the earliest and latest usage by any agent that uses this facility in the initial demand, and the capacity is determined by the number of agents that work there.

The creation of the education facilities makes use of the Betriebszählung 2012 (BFS, 2016), which contains, among other data, the following information for all work facilities in Switzerland: The location, the type of work (NOGA_08-Code) and the number of full time positions there.

To create the education facilities, the types of work (NOGA_08-Codes) falling under education were selected and grouped to five categories. These categories were created based on the age of the students. They were

- Age less and equal 6: Kindergarten and younger
- Age more than 6 but less and equal 12: Primary school
- Age more than 12 but less and equal 16: Secondary school
- Age more than 16 but less and equal 20: High school or apprenticeship
- Age more than 20: Universities and higher education

The capacity of an education facility is derived from its number of full time employees, and an estimate of the average number of students per full time employee. The latter is obtained from the total number of full time employees in all education facilities of a category, and the number of students in this category provided by the Schülerstatistik 2013/2014 (BFS, 2016h).

In summary the values were derived as follows:

- Location: BZ12 location rounded to the next multiple of 100 (hectare)
- Capacity: Students per full time position (described in the text) multiplied with the BZ12 number of full time positions

Facilities with the same rounded locations (on the same hectare) and offering the same category were combined into one facility adding the capacity. The open times are set to the earliest and latest usage by any agent that uses a facility in the initial demand. For the public version of the

education facilities, the description was removed and the category was replaced with the more general activity type in the ID.

2.3.2 Leisure and Shopping Facilities

Leisure and shopping facilities represent activity locations for secondary activities (SA). For the new IVT baseline scenario, these facilities are based on the Betriebszählung 2012 (BZ) (BFS, 2016). The BZ contains, among other data, for all work locations in Switzerland the location, the type of work (as NOGA_08-Codes) and the number of full time positions at that location. The types of work representing leisure and shopping were manually selected and grouped into activity categories useful for the MATSim simulation (e.g. for leisure for example “Gastro” or “Sports”). For each of these activity categories, typical opening times were manually determined (see Table 1). This work builds on previous work by Meister (2008), who determined these opening times for earlier IVT MATSim scenarios.

To calculate the capacity of each SA facility, a typical number of maximum simultaneously served customers per full time position was determined for each category (Table 1).

For shopping facilities, the capacity is based on the number of served customers per full time position per day in the Migros section “Detailhandel” (Migros, 2014). To account for the fact that not all customers served over a day appear at the same time, but to also account for peak hours, the number is divided by three (assumption). This results in a shopping capacity of 7.6 customers per employee.

For leisure facilities, the capacity per full time position was estimated manually for each type of leisure service. For example, it was estimated that in a nightclub one full time employee could serve 20 customers (incl. cleaning, security, administration, etc.), while in cinemas one full time employee could serve 100 customers.

By multiplying these capacities per full time position with the number of full time positions per facility, the capacity per facility was calculated.

Table 1 Opening times and capacity per employee used for the creation of the secondary activity facilities.

Type of Activity	Type of Business	Open From	Open Until	Capacity per Employee
<i>Shop</i>	<i>Malls</i>	08:00	20:00	7.6
<i>Shop</i>	<i>Groceries</i>	08:00	20:00	7.6
<i>Shop</i>	<i>Gas Stations</i>	00:00	24:00	7.6
<i>Shop</i>	<i>Non-Groceries</i>	08:00	18:00	7.6
<i>Shop</i>	<i>Services (Banks)</i>	09:00	17:00	10*
<i>Shop</i>	<i>Services (Other)</i>	08:00	18:00	7.6
<i>Leisure</i>	<i>Gastro (Restaurants)</i>	09:00	24:00	10
<i>Leisure</i>	<i>Gastro (Bars)</i>	09:00	24:00	20
<i>Leisure</i>	<i>Sports (Sports Grounds)</i>	09:00	22:00	50
<i>Leisure</i>	<i>Sports (Clubs)</i>	16:00	22:00	25
<i>Leisure</i>	<i>Sports (Other)</i>	09:00	22:00	20
<i>Leisure</i>	<i>Exhibitions</i>	08:00 - 10:00	18:00	15 - 30
<i>Leisure</i>	<i>Theaters (Cinemas)</i>	14:00	24:00	100
<i>Leisure</i>	<i>Theaters (Other)</i>	14:00	24:00	10
<i>Leisure</i>	<i>Other (Gambling)</i>	09:00 / 14:00	24:00	10
<i>Leisure</i>	<i>Other (Theme Parks)</i>	09:00	18:00	75
<i>Leisure</i>	<i>Other (Other)</i>	09:00 / 14:00	18:00 / 24:00	5 - 30

*: Fix per location, not per employee.

An additional source for leisure and shopping facilities are the cross-border facilities. Next to the origins and destinations of the cross-border population (section 2.3.3), these facilities represent also any abroad activity opportunities for the Swiss population. As can be seen in Figure 5, they are located where the respective real border crossings are located (manually reconstructed from the report by Sigmaplan (2009) with Google Maps⁴). The capacity is equal to the number of inhabitants of Switzerland leaving through that crossing for a secondary

⁴ Homepage, accessed 10.06.2016, www.google.ch/maps.

activity on an average workday (calculated analogously to the incoming demand as described in section 2.1.6).

The capacities of all leisure and shopping facilities are scaled to 2015 based on the population growth of Switzerland for the respective years (BFS, 2016a).

2.3.3 Sub-Population Facilities

As part of the sub-population creation process, as described in the sections 2.1.6 and 2.1.7, these populations are assigned to a dedicated set of facilities.

Cross-border (CB) facilities, including airports, represent not only activity locations for Swiss agents (section 2.3.2), but represent also the sources of any cross-border traffic (section 2.1.6). Their location (Figure 5) was reconstructed manually as described in section 2.1.6. Work, leisure and shopping facilities used by CB agents, are copied upon selection and the copy is added as a CB activity facility.

Figure 5 Locations of the cross-border facilities (grey triangles).



Freight facilities are constructed similarly to the activity facilities of the cross-border population. As soon as a work facility is selected as a freight origin or destination (section 2.1.7), this facility is copied and the copy is added as a new freight facility.

To create own facilities for sub-populations has the disadvantage of a multiplication of the number of facilities and adding of some SA capacity, but, and this is a strong advantage, it facilitates the sharing of subpopulation independently of the rest of the scenario, as well as the recombination of subpopulations for specialized scenarios.

2.4 Count Data

Count data represents the hourly or daily number of vehicles or passengers on a given link, public transport vehicle, or passing through a public transport station. MATSim supports the use of count data for validation purposes (subsection 6.3, *Counts*, in (Nagel et al., 2016)).

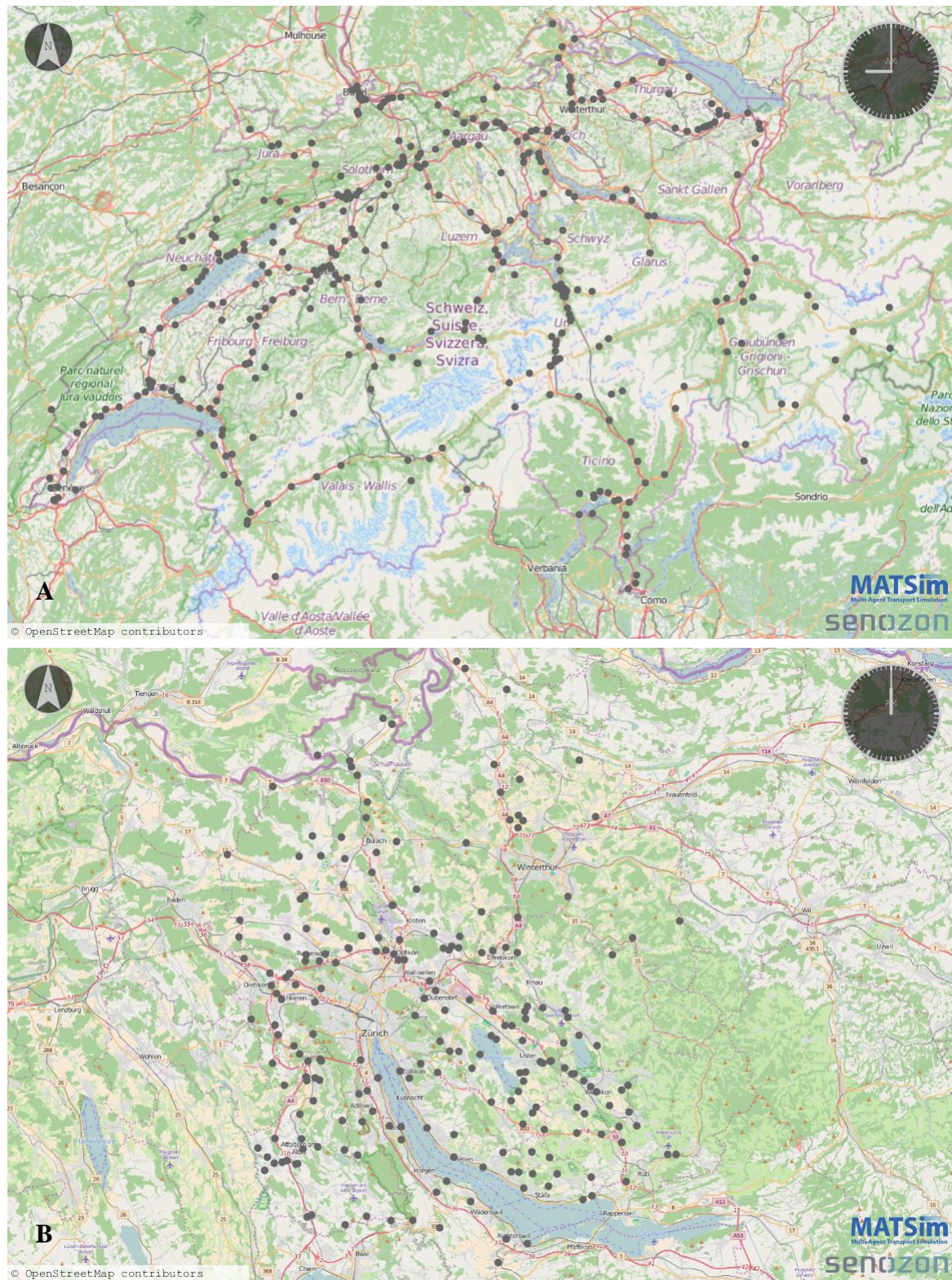
The new IVT baseline scenario comes with two kinds of count data. Street count data (section 2.4.1) allows validating the simulated traffic on street links with the real world traffic on that link. Public transport count data (section 2.4.2) allows the validation of passenger volumes at the main train stations in Switzerland and on given links. To account for the data structure of the count data used, customized MATSim count modules⁵ were developed for the IVT baseline scenario. A detailed presentation of this module is not given here, as the behavior is identical to the existing MATSim count modules.

2.4.1 Street Counts

In Switzerland street count data is collected by the ASTRA for the highways and the main arterial roads (ASTRA, 2016), by the Cantons for the main cantonal roads (e.g. Kanton Zürich (2016)) and by large communities and cities for special purposes. In the current set-up of the IVT baseline scenario, the public ASTRA count data is used to validate the main flows in Switzerland (Figure 6-A). The ASTRA count data is available as directional hourly sums for the full year. For the Zurich area, the public Zurich cantonal street count data increases the resolution of street count stations (Figure 6-B). The Zurich count data is available as average directional workday sums. Count data from other cantons or cities can be integrated if a future sub-scenario (see section 3.2) requires this higher level of detail for an additional region.

⁵ The MATSim package playground.boescpa.ivtBaseline.counts.

Figure 6 Locations of the street count stations (Subplot A: ASTRA count stations, Subplot B: Zurich count stations).

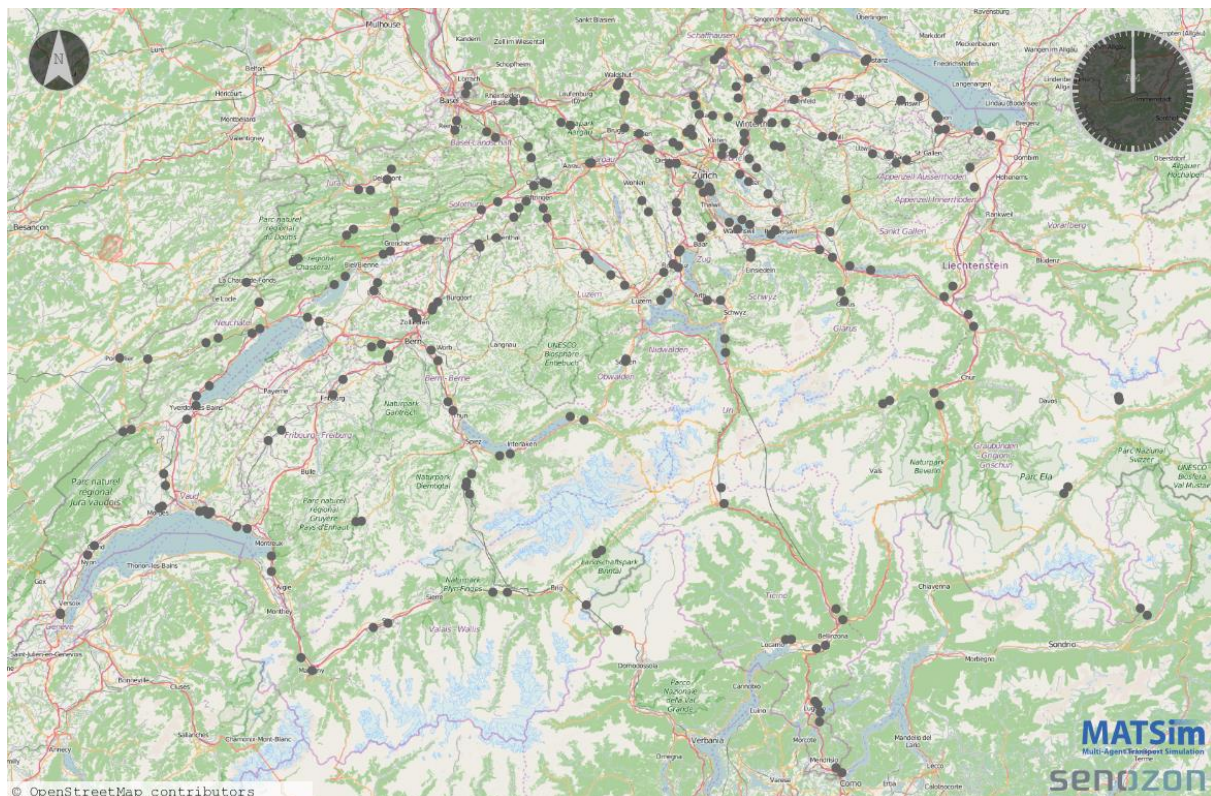


2.4.2 Public Transport Counts

The main source for national public transport count data in Switzerland are the Swiss Federal Railways (SBB). The SBB collects passenger count data for different public transport lines, as well as for passengers leaving and entering at train stations. The SBB provided an aggregated extract of this proprietary count data for the validation of public transport. They also provided the average daily passenger volumes for selected railway links and the average hourly passenger volumes for the biggest train stations in Switzerland. As shown in Figure 7 for the link counts, this data covers well the main flows on the national railway network.

At the moment, no count data other than the above-mentioned SBB data is implemented. Additional public transport count data could be integrated if available.

Figure 7 Locations of the public transport link count stations (tuples represent both directions).



3. Scenario Creation

This section presents the processes and scripts developed to integrate the input data (section 2) into a coherent and functional MATSim scenario. The idea is that, depending on the needs of the current case study, the different input elements can be flexibly modified and integrated into a runnable MATSim scenario.

The basic process is to create first a Switzerland scenario of the required level of detail and with the required elements (presented in section 3.1), and to afterwards cut this scenario to the required sub-scenario (section 3.2). To publish the sub-scenario and/or to share it with other groups, any IVT exclusive or proprietary elements must be removed from the scenario. This anonymization process is presented in section 0.

3.1 Integration Process

The input data (section 2) is available in different forms and with different levels of detail. For example, the main population is available as 1%, 10% or 100% of the Swiss population and each of these with 5 different random seeds. These result in 15 different main populations, each coming with its own set of attributes, facilities and households. To account for this extensive database and to allow for ad-hoc scenario creation, an integration process was designed to semi-automatically create functional scenarios from these sources.

The first step of the integration process is to unify⁶ the main activity facilities with the secondary activity facilities and the border crossing facilities. Of these additional facilities, only one default version exists (sections 2.3.2).

Based on this unified facilities, in a second step, the cross-border and the freight sub-populations can be created with scripts. The CB script⁷ creates the cross-border population (section 2.1.6), and the freight script⁸ the freight population (section 2.1.7).

The third step of the process is the actual integration of the scenario. A preparation script⁹ was designed to create automatically an integrated, fully functional IVT baseline scenario. As input, the script requires the various data files of the scenario and the different populations. The script

⁶ For example with the MATSim class `playground.boescpa.ivtBaseline.preparation.FacilityUnifier`.

⁷ The MATSim class `playground.boescpa.ivtBaseline.preparation.crossborderCreation.CreateCBPop`.

⁸ The MATSim class `playground.boescpa.ivtBaseline.preparation.freightCreation.CreateFreightTraffic`.

⁹ The MATSim class `playground.boescpa.ivtBaseline.preparation.PreparationScript`.

prepares and completes the facilities, corrects and completes the agents and brings the different parts (populations, facilities, network, etc.) together to one coherent scenario. For a more detailed documentation, the interested reader is referred to the documented, open-source code of the script.

3.2 Sub Scenario Creation

This section presents the spatial reduction of full Switzerland scenarios, as created with the integration process (section 3.1), to sub-scenarios.

The most important point, when spatially reducing a scenario, is the handling of any boundary effects. Different approaches are possible.

Traditionally in IVT MATSim scenarios (e.g. Horni and Vitins, 2011), all agents that have any relation to the target area are kept completely in the simulation. This also requires however, keeping all transport possibilities completely in the simulation. This can cause a substantial overhead if public transport is fully simulated.

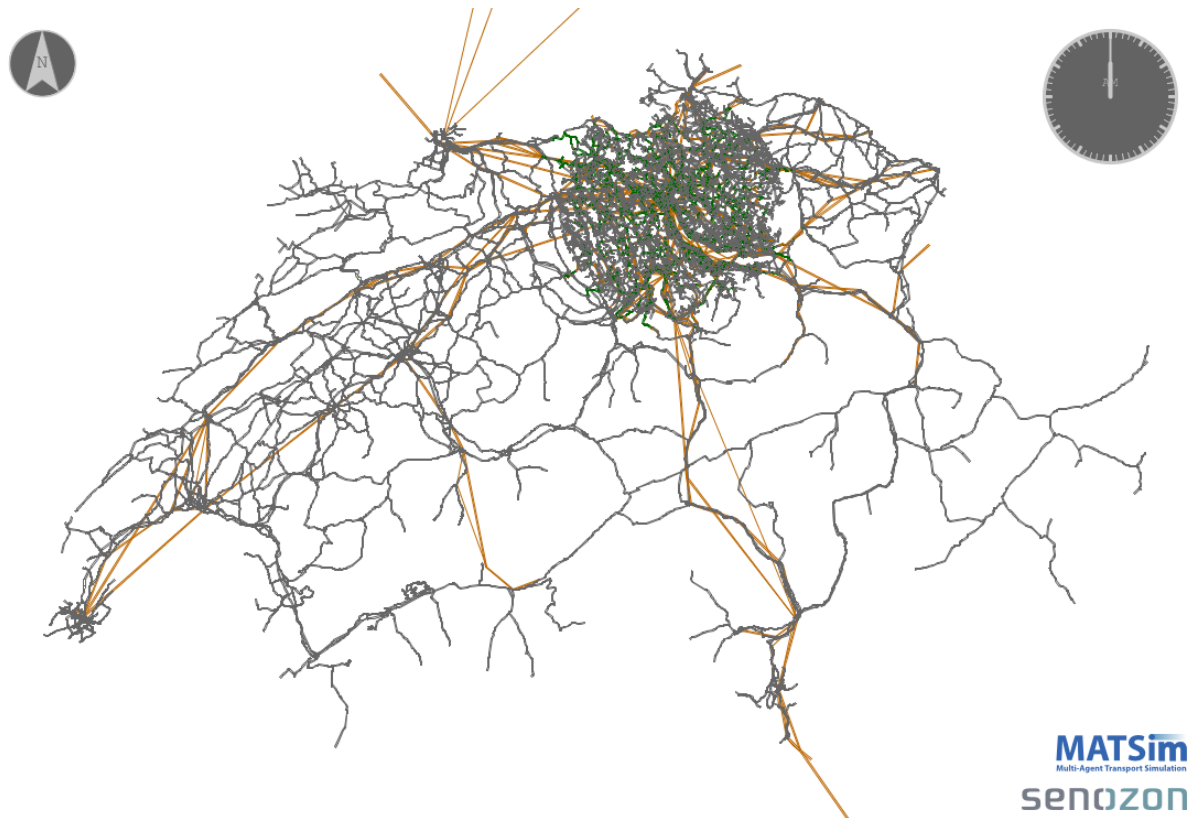
A second approach, which was implicitly used for the creation of the Switzerland scenario (e.g. sections 2.1.6 and 2.3.2), is to cut the activity chains of any agents that cross the border of the scenario area and locate the agents at the border. As national borders represent more substantial boundaries than e.g. cantonal boundaries or even abstract spatial boundaries, this approach might work for the nationwide scenario, but it creates too many inconsistencies for sub-scenarios.

For the IVT baseline scenario, the following approach is proposed. Any agents that have any relation to the target area, but spend also parts of their daily plan outside, remain completely in the scenario, as suggested by the traditional IVT approach. However, to overcome the requirement to provide full transport supply, these agents carry the new “subpopulation” tag “outAct”. This enables to remove modal choice from their replanning options (see section 4.3), which in turn allows to considerably dilute the public transport service and street network outside the target area without losing these agents for the respective mode.

In the dilution process, the street network is reduced to the arterial links and the public transport service is reduced to the lines that have at least one stop in the target area (see Figure 8 for an example). A script¹⁰ is provided for an automated sub-scenario creation.

¹⁰ The MATSim class playground.boescpa.ivtBaseline.preparation.ZHCutter.

Figure 8 Visualization of the street network and the public transport supply for the Zurich scenario. The road links are colored grey, the mixed links green, and the public transport exclusive links orange.



3.3 Anonymization

Any IVT baseline scenario, be it a full Switzerland scenario (section 3.1) or a spatially reduced sub-scenario (section 3.2), contains information that is proprietary. At the same time, the ability to share the new scenario was one of the main goals of the new IVT baseline scenario. To resolve this issue, an anonymization script¹¹ was developed. The script removes or dilutes any proprietary information and thus makes the resulting scenario sharable.

For details, the interested reader is referred to the source code of the script which is publicly available.

¹¹ The MATSim class playground.boescpa.ivtBaseline.preparation.Anonymizer.

4. Simulation

A MATSim simulation is set up with a controller, called “Controller”, which requires a configuration file as input (subsection 2.1, *Running MATSim*, in (Rieser et al., 2016)). The configuration file, called “Config”, specifies not only what input data to use for each part of the simulation (network, population, etc.), but it also sets the parameters for the simulation dynamics. The Config is therefore the central control instance of any MATSim simulation. Section 4.1 presents the default Config for the IVT baseline scenario.

Another crucial element, that defines the dynamics of a MATSim simulation, is the scoring function (Nagel et al., 2016b). The default scoring function is generally a good choice. For the IVT baseline scenario however, a customized, more detailed version, which also requires more input data, is used. Section 4.2 presents this scoring function.

The third main element that influences the dynamics of a MATSim simulation are the replanning strategies. Replanning strategies define the dimensions and the ranges an agent can explore to optimize its plan as part of the co-evolutionary process in MATSim (Nagel et al., 2016b). Section 4.3 presents the default replanning strategies suggested for the IVT baseline scenario.

4.1 Config

The scenario creation process presented in section 3.1 automatically creates a default Config for the IVT baseline scenario¹². This ensures a consistent IVT Config that is always up to date with the newest developments in MATSim. While the interested reader is referred to the source code for details, the main differences to the default MATSim Config are the definition of the special scoring function (section 4.2), the set-up of the replanning strategies (section 4.3), and the introduction of non-standard MATSim modules (e.g. location choice). A special configuration of the MATSim controller is required to support these changes. The IVT baseline Controllers¹³ represent templates.

One important configuration, which is to mention here, is the way modes are simulated. The scenario explicitly simulates only motorized private and public transport. The other modes, that is walk, bike, and transit walk, are teleported. The teleporting time is determined by the beeline teleport distance.

¹² With the MATSim class `playground.boescpa.ivtBaseline.preparation.IVTConfigCreator`.

¹³ The MATSim classes `playground.boescpa.ivtBaseline.RunIVTBaseline` and `playground.boescpa.ivtBaseline.RunIVTBaselineCalibration`.

4.2 IVT Scoring Function

In MATSim, the scoring function determines how agents score their day (Nagel et al., 2016b). In particular, it determines how the agents value activities and legs over time, as well as any deviations from opening times in facilities and from the agents' preferences.

The default scoring function in MATSim scores each activity separately (subsection 3.2, *The Current Charypar-Nagel Utility Function*, in (Nagel et al., 2016b)). While this seems intuitive, it means that an agent values an 8h shift of work with a break like two independent shifts. If the typical duration for work is set to 4h to account for this separate scoring, it prevents the possibility to work for example 5h in the morning and 3h after the lunch break.

To solve this issue, different typical durations for each activity of the day are proposed for the new IVT baseline scenario. To illustrate this in the above example, if an agent's initial plan suggests that he would like to take the lunch break after 5h work in the morning and work afterwards for 3h, this will also appear in the preferences like this (see section 3.1). Combined with unchangeable latest start times and earliest end times for work and education activities (see subsection 4.3), this gives the plan the necessary stability to cause the typical peak hours in the simulation but also enough flexibility for the agents to defer a shop activity in the afternoon if the congestion is too bad.

This improvement comes at a price however. Instead of one preferred duration for each activity type, each agent needs several preferences for each activity. By assuming the Micro Census derived initial plan of each agent as the most realistic plan for this agent, these preferences are created from this plan (see section 3.1).

Legs are scored with the default scoring function. The parameters (value of time per mode, monetary distance rate per mode, etc.) for the leg scoring in the new IVT baseline scenario are derived from the literature (VSS, 2009; VSS, 2009a; Schmutz, 2015). Only the alternative specific constants should be optimized as part of the calibration process.

4.3 Replanning Strategies

As mentioned above, the replanning strategies define the choice dimensions the agents can explore to optimize their plan during the co-evolutionary process in MATSim (Nagel et al., 2016b). MATSim allows to define different strategies for different subpopulations. The new IVT baseline scenario makes use of this possibility. This subsection presents and motivates the replanning strategy proposed for each subpopulation.

4.3.1 Main Population

The main population has the most replanning options of all populations in the IVT baseline scenario. The agents can change the modes, do rerouting, and change the times of activities to avoid traffic in the temporal dimension (these standard MATSim-replanning options are described by Horni and Nagel (2016)). Work and education are excluded from the time change option¹⁴ however, as they are assumed to have very strict start and end times for most people. Another option is location choice (Horni et al., 2016a). Location choice lets agents change the locations of their secondary activities (leisure, shopping etc.) depending on traffic. By default, this option is activated only for calibration simulations. In MATSim, the calibration process consists of adjusting core parameters in the Config until the agents' behaviors result in the same average behavior as the real population's. After the calibration process, it is assumed that the agents have determined suitable activity locations and location choice is not active by default anymore.

4.3.2 Sub-Scenario OutAct Population

The outAct population represents agents of the main population that have activities outside the target area of a spatial sub-scenario (section 3.2). These agents have the same choice dimensions as the main population with the exception that they cannot change mode. The reason for this strategy is the diluted transport supply outside the main scenario area, as explained in section 3.2.

4.3.3 Cross-border and Freight Population

These two populations (presented in the sections 2.1.6 and 2.1.7) can only reroute. Time, mode and location changes would be unreasonable as they represent only additional traffic and not explicit agents.

¹⁴ The MATSim class `playground.ivt.replanning.BlackListedTimeAllocationMutatorModule`.

5. Discussion

5.1 Input Data

The input data presented in section 2 represents the most recent data that is currently available at the IVT. Especially the level of detail and the number of attributes available for the main population, combined with a multi-modal transport supply, represents a new level of richness in IVT MATSim scenarios.

The subpopulations cross-border and freight are on similar levels of detail and realism as in earlier IVT scenarios (Horni and Vitins, 2011). This is sufficient as already these earlier approaches provided good results.

For the facilities, compared to earlier versions, the crucial improvement lies in the descriptions. A differentiation between primary schools and higher education or between a restaurant and a sports club is now possible. This allows more detailed activity type information. Most importantly here, gas stations are now explicitly tagged and located – an information crucial for example for studies on shared fleets where refueling of the vehicles is an issue.

The public transport counts represent a new and important validation tool. Now it is not only possible to confirm the modal split of public transport, but also to confirm that the passenger flows in the major stations are correct.

5.2 Scenario Creation

The provided scripts (section 3) facilitate the creation of fully functional scenarios with different spatial sizes (full Switzerland vs. sub-scenarios) and sample percentages (1%, 10% or 100%). Even though these scripts require some familiarization to use now, as one of the future steps they should be designed more robust and with easier input to make them more user-friendly.

The same applies to the anonymization tool. Now, it is designed conservatively in the sense that it removes all sensitive information. More flexibility would be good. This however, also requires more detailed information why certain features should not be shared respectively what the recipient would have to fulfil to receive this information legally.

While these scripts are useful, they are also dangerous. Dangerous because they lure the user into not considering too deeply what he is actually doing. For example, they allow doing the spatial cutting process to create a sub-scenario with a few clicks. This makes it easy to ignore boundary effects (section 3.2). However, a discussion of these effects is required for every sub-scenario because the cutting process has direct influence on the results. For example, first tests with a Zurich scenario extracted from the Switzerland scenario revealed that the travelled

distance averages were too small. There are strong indications that this is due to the non-inclusion of the “outAct” population (section 3.2) in the analysis, as this population is responsible for the long to very long trips. Inclusion of the “outAct” population however, would have implications for the trip durations and the scores achieved as they only have a limited transport supply, as explained in section 3.2.

A similar issue concerns the sample percentage of the population. Even if populations of different percentages are readily available, they should be used only with care. The sample percentage has a substantial influence on simulations. Good examples are car-sharing studies: To avoid over-supply, a reduced population would intuitively mean a reduction of shared vehicles. A reduction of the number of vehicles however, also means a reduced availability per area, which means an under-supply of the population. The results in (Bösch et al., forthcoming), especially figure 2B, suggest that one should not go below a 5% to 10% sampling of the population to avoid this issue.

Similarly, the scaling of the population affects also public transport. To account for the fewer vehicles in the network, usually the flow capacity in the network is scaled down with the number of agents. If street-bound public transport shares the roads with private transport (Bösch and Ciari, 2015), this scaling of flow capacity also affects public transport. Unfortunately, public transport cannot be scaled similar to the population – reducing a bus every 10 minutes in a 100% scenario to a bus only every 100 minutes in a 10% scenario is not reasonable. The suggested solution for this issue is to reduce the size of the public transport vehicles. E.g. instead of a 2.5 standard-vehicle-unit bus in a 100% scenario, the bus is only 0.25 standard-vehicle-units in a 10%.

5.3 Simulation

The default simulation configuration and replanning strategies, as suggested and motivated in section 4, should only be seen as a replacement of the official MATSim default values by default values based on IVT experience. Every user should go through the full configuration for every simulation and adapt the configuration where needed. The same applies for the suggested scoring function.

6. Conclusion and Outlook

6.1 Conclusion

This paper presented the new IVT baseline scenario. In particular, it presented the different input data, a framework of scripts and procedures to create functional scenarios from that input data, and a proposed default configuration (configuration file, scoring function, and replanning strategies) for the scenario. With the publication of this paper, the IVT baseline scenario is released for usage within IVT and – in an anonymized form – by partners of the IVT.

This paper can also serve as a reference for users of the scenario and as a starting point for future, similar efforts. The presented data sources can give an idea where to get the raw data underlying a scenario. The creation of the input data from the raw data and the basic processes are applicable to the creation of any MATSim scenario. The scripts and the configuration are specific for the IVT baseline scenario, but as templates, they can be of use for future efforts in the creation of other MATSim scenarios.

The new IVT baseline scenario represents the most up-to-date and most comprehensive scenario at the IVT today. The population, including households and facilities, represents the most extensive, most up-to-date and the most detailed version created up to now. The multi-modal network and its integrated public transport service make full use of the capabilities of MATSim. Cross-border and freight subpopulations represent the additional traffic required for realistic simulations. Integration scripts create fully functional MATSim scenarios from the input data with only a few commands. Updated and customized configuration files, simulation modules and replanning strategies represent the experience at the IVT in MATSim simulations.

In short, having had in mind that the output can only be as good as the input, the authors hope that the new scenario can build a solid base for MATSim simulation studies at the IVT and its partner groups in the coming years.

6.2 Outlook

Different passages in the paper indicate potential future work. The new IVT baseline scenario, even if officially released with this publication, is still – and probably always will be – in development. This section gives an overview of the upcoming developments.

A very important, upcoming improvement is the update of the network and the public transport supply to a new version. Poletti (2016) is currently developing an improved version of the work

presented in (Bösch, 2015). Much of the future work suggested by Bösch (2015) plus additional, new improvements are implemented.

Another planned improvement concerns the subpopulations (sections 2.1.6 and 2.1.7). The destination choice of work activities will be refined with SHP-files that define the precise borders of communities and zones instead of the current, simpler radius-based approach.

In terms of user-friendliness of the scenario creation scripts, several improvements are planned. As mentioned in section 5.2, the scripts should become more robust and the input arguments should be facilitated. An example for these improvements is the introduction of configuration files for these scripts. In addition, the whole scenario creation process, as described in section 3, could be more integrated and facilitated for the user.

A future goal is to complement the set of available baseline scenarios at the IVT with a 2030 version and a weekend scenario. First attempts were already made in this direction, but a lot of work is still required to bring every element into coherent state.

A more substantial possible future update of the scenario would be a change to the new vehicle concept in MATSim (subsection 11.1, *Vehicle Types and Vehicles*, in (Nagel et al., 2016a)). This separation of agents and vehicles is not only conceptually more sound, it also enables new studies (e.g. on the role of vehicles in households or on autonomous vehicles) and more detailed analysis (e.g. tracking not only of individual agents but also of individual vehicles). It would therefore be a substantial enrichment of the new IVT baseline scenario.

7. Acknowledgements

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Finally, yet importantly, the authors would like to thank all those who created MATSim scenarios at the IVT before and thus gathered the experience and knowledge on which this project builds.

8. References

- Alfons, A. and M. Templ (2016). grake: Generalized Raking as Described by Deville et al. (1993). R package version 0.1-1. <http://grake.github.io/grake>
- Balmer, M. (2007) Travel Demand Modeling for Multi-Agent Transport Simulations: Algorithms and Systems, *PhD Dissertation*, ETH Zurich, Zurich.
- Bösch, P.M., F. Ciari and K.W. Axhausen (forthcoming) Required Autonomous Vehicle Fleet Sizes to Serve Different Levels of Demand, *Transportation Research Record*.
- Bösch, P.M. and F. Ciari (2015) A Multi-Modal Network for MATSim, paper presented at the *15th Swiss Transport Research Conference*, Ascona, April 2015.
- Breiman, Leo, Jerome Friedman, Charles J. Stone, and Richard A. Olshen. Classification and regression trees. CRC press, 1984.
- Bundesamt für Raumentwicklung, ARE (2016) Nationales Personenverkehrsmodell, *Homepage* (last accessed 10.06.2016), <http://www.are.admin.ch/themen/verkehr/00256/00513/index.html>.
- Bundesamt für Statistik, BFS (2016) Betriebszählung, *Homepage* (last accessed 10.06.2016), www.bz.bfs.admin.ch.
- Bundesamt für Statistik, BFS (2016a) Bevölkerungsstand und -struktur – Indikatoren, *Homepage* (last accessed 14.06.2016), <http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/02/blank/key/bevoelkerungsstand/02.html>.
- Bundesamt für Statistik, BFS (2016b) Detaillierte Ergebnisse der GGS, *Homepage* (last accessed 10.06.2016), <http://www.bfs.admin.ch/bfs/portal/de/index/themen/03/02/blank/data/05.html>.
- Bundesamt für Statistik, BFS (2016c) Leistungen im Güterverkehr, *Homepage* (last accessed 14.06.2016), <http://www.bfs.admin.ch/bfs/portal/de/index/themen/11/05/blank/01.html>.
- Bundesamt für Statistik, BFS (2016d) Registererhebung, *Homepage* (last accessed 22.06.2016), http://www.bfs.admin.ch/bfs/portal/de/index/infothek/erhebungen_quellen/blank/blank/statpop/01.html.
- Bundesamt für Statistik, BFS (2016e) Vorschau Wohnbevölkerung 2015, *Homepage* (last accessed 22.06.2016), https://www.pxweb.bfs.admin.ch/Selection.aspx?px_language=de&px_db=px-x-0102020000_202&px_tableid=px-x-0102020000_202\px-x-0102020000_202.px&px_type=PX.
- Bundesamt für Statistik, BFS (2016f) Mikrozensus Verkehr, *Homepage* (last accessed 22.06.2016), http://www.bfs.admin.ch/bfs/portal/de/index/infothek/erhebungen_quellen/blank/blank/mz/01.html.

- Bundesamt für Statistik, BFS (2016g) Strukturerhebung, *Homepage* (last accessed 22.06.2016), http://www.bfs.admin.ch/bfs/portal/de/index/infothek/erhebungen_quellen/blank/blank/rs/00.html.
- Bundesamt für Statistik, BFS (2016h) Schülerstatistik, *Homepage* (last accessed 15.06.2016), <http://www.bfs.admin.ch/bfs/portal/de/index/themen/15/02/data/blank/02.html>.
- Bundesamt für Statistik, BFS (2009) Alpen- und grenzquerender Personenverkehr 2007, *Report*, Eidgenössisches Departement des Innern, Neuenburg.
- Bundesamt für Statistik, BFS, and Bundesamt für Raumentwicklung, ARE (2012) Mobilität in der Schweiz, Ergebnisse des Mikrozensus Mobilität und Verkehr 2010, *Report*, Neuenburg.
- Bundesamt für Strassen, ASTRA (2016) Schweizerische automatische Strassenverkehrszählung (SASVZ), *Homepage* (last accessed 10.06.2016), <http://www.astra.admin.ch/verkehrsdaten/00299/00301/>.
- Deville, J.-C., C.-E. Särndal and O. Sautory (1993) Generalized raking procedures in survey sampling, *Journal of the American Statistical Association*, **88** (423) 1013–1020.
- Horni, A. and M. Balmer (2016) Switzerland, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 411-412, Ubiquity-Press, London.
- Horni, A. and K. Nagel (2016) More About Configuring MATSim, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 39-49, Ubiquity-Press, London.
- Horni, A., K. Nagel and K.W. Axhausen (eds.) (2016) *The Multi-Agent Transport Simulation MATSim*, Ubiquity, London.
- Horni, A., K. Nagel and K.W. Axhausen (2016a) Destination Innovation, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 173-183, Ubiquity-Press, London.
- Horni, A. and B.J. Vitins (2011) The Zurich Scenario: A Technical Overview 1.0, *Working Paper*, IVT, ETH Zurich, Zurich.
- Horni, A., D.M. Scott, M. Balmer and K.W. Axhausen (2009) Location choice modeling for shopping and leisure activities with MATSim: Combining micro-simulation and time geography, *Transportation Research Record*, 2135, 87-95.
- Kanton Zürich, Tiefbauamt (2016) Verkehrsdatenerfassung, *Homepage* (last accessed 10.06.2016), <http://www.tba.zh.ch/internet/audirektion/tba/de/fachunterstuetzung/verkehrsdatenerfassung.html>.
- Lovelace, R. and D. Ballas (2013) ‘Truncate, replicate, sample’: A method for creating integer weights for spatial microsimulation, *Computers, Environment and Urban Systems*, **41**, 1–11, September 2013.

- Meister, K. (2008) Erstellung von MATSim Facilities für das Schweiz-Szenario, *Arbeitsberichte Verkehrs- und Raumplanung*, 541, Institute for Transport Planning and Systems (IVT), ETH Zurich, Zurich.
- Migros (2014) Migros Geschäftsbericht 2014, *Report*, Online Article (last accessed 10.06.2016), <https://report.migros.ch/2014/>.
- Müller, K. (2016a) MultiLevelIPF: Implementation of algorithms that extend IPF to nested structures, <http://krlmlr.github.io/MultiLevelIPF>. R package version 0.3-2.
- Müller, K. (2016b) wrswoR: Weighted Random Sampling without Replacement, <http://krlmlr.github.io/wrswoR>. R package version 1.0-1.
- Nagel, K., M. Rieser, and A. Horni (2016) MATSim Data Containers, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 62-66, Ubiquity-Press, London.
- Nagel, K., M. Rieser, and A. Horni (2016a) QSim, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 82-84, Ubiquity-Press, London.
- Nagel, K., B. Kickhöfer, A. Horni and D. Charypar (2016b) A Closer Look at Scoring, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 25-37, Ubiquity-Press, London.
- d’Orazio, M., M. D. Zio and M. Scanu (2006) Statistical Matching: Theory and Practice, John Wiley & Sons, June 2006.
- Poletti, F. (forthcoming) Multimodales Verkehrsinfrastrukturmodell aus OSM (Working Title), *Master Thesis*, ETH Zurich, Zurich.
- Rieser, M. (2016) Modeling Public Transport with MATSim, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 108-114, Ubiquity-Press, London.
- Rieser, M., A. Horni, and K. Nagel (2016) Let’s Get Started, in A. Horni, K. Nagel and K.W. Axhausen (eds.) *The Multi-Agent Transport Simulation MATSim*, 9-23, Ubiquity-Press, London.
- Schmutz, S.A. (2015) Effect of analytical units and aggregation rules on mode choice models, *Master Thesis*, ETH Zurich, Zurich.
- Schweizerischer Verband der Strassen- und Verkehrsfachleute, VSS (2009) SN 641 822a – Kosten-Nutzen-Analysen im Strassenverkehr – Zeitkosten im Personenverkehr, *Schweizer Norm*, VSS Zurich, Zurich.
- Schweizerischer Verband der Strassen- und Verkehrsfachleute, VSS (2009a) SN 641 827 – Kosten-Nutzen-Analysen im Strassenverkehr – Betriebskosten von Strassenfahrzeugen, *Schweizer Norm*, VSS Zurich, Zurich.
- Sigmaplan (2009) Grenzübergreifender Personenverkehr auf der Strasse 2007 – Hochrechnung der Grenzzählung, *Report*, Bundesamt für Statistik, Eidgenössisches Departement des Innern, Bern.

Stahel, A. (2014) MATSim 2030 – Switzerland Scenario, *Work Report*, IVT, ETH Zurich, Zurich.