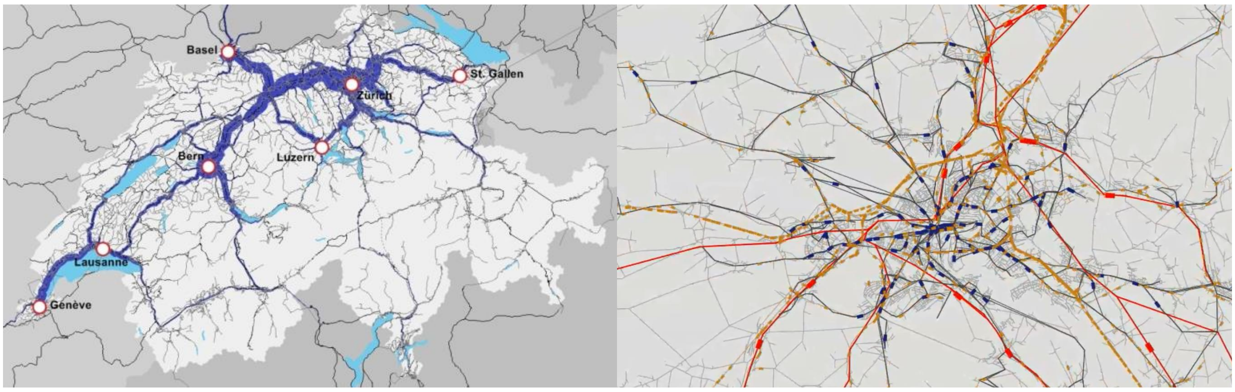

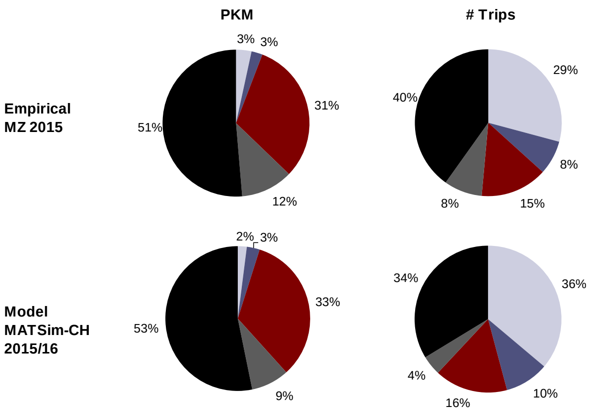

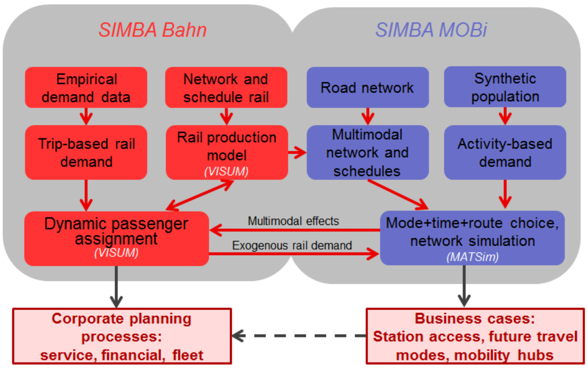

Micro Meets Macro: A Transport Model Architecture Aiming at Forecasting a Passenger Railway's Future.

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Micro Meets Macro: A Transport Model Architecture Aiming at Forecasting a Passenger Railway's Future.

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Abstract

For over 15 years, SBB uses and maintains a macroscopic travel forecasting model, covering all of Switzerland, which supports decisions in service planning, operations planning, fleet requirements and financial planning. It has gained a good reputation among stakeholders for its multi-year consistency and for its prediction success. At the same time, a new microscopic model is being developed, based on MATSim, to allow for evaluation of new challenges such as competition by bus or rail, intermodal extensions of the rail service, or road transportation based on autonomous cars.

The presentation will present a vision of SBB's future model architecture, including how macroscopic and microscopic (i.e. agent-based) approaches will work together, making best gains from their respective strengths. Also will be shown, what type of model applications are being planned, and how the specific needs of a public transport corporation are being addressed, from fleet and capacity planning, to prediction success testing.

Current challenges of model development and model calibration will be presented, including assumptions of future mobility, enhancements of MATSim's public transport algorithms, calibration of utility functions for the agent based model, developments outside of MATSim (synthetic population, activity generation, destination choice), plus work flow automation and necessary IT resources.

Keywords

travel forecasting – state-wide model – national model – rail – public transportation – transit – operator – MATSim – Visum – decision support – ridership forecast – macroscopic – microscopic – agent-based model

1. Introduction

"Rail under control and shaping the future" is SBB's mission statement: SBB wants to master rail operations and rail service in a way that customers' needs are met, while preparing an active role in the future mobility of Switzerland, when new technologies will change the picture.

Applying this mission statement to SBB's transport modelling practice, it is translated into the following general requirements:

- The models used by SBB need to be highly precise concerning rail demand, train loads and capacity; and the models must prove prediction success ("rail under control").
- Since the railroad business is characterised by long-term investments, it is key that the models can provide input to mid- and long-term financial planning (25 to 40 years into the future) and are able to test investment decisions in the context of a future with potential new modes and technologies, which is subject to uncertainty ("shaping the future").

To implement its strategy, SBB seeks targeted innovations. In transport modelling, this requires a new modelling system to be designed and to be put in place. The architecture of the new model system and its implementation are presented in this paper.

After the introduction (section 1), this paper starts out by presenting the practice of travel modelling at SBB and its history (sections 2.1 and 2.2). A description of new requirements in section 2.3 leads to the new model architecture which was developed (section 3). Then section 4 describes how the new architecture is brought to life, including sub-sections for input data, software development, parameter calibration and reality tests. At the end of section 4, a perspective is given of the next steps of development and areas of further research. The paper ends with a summary and conclusions in section 5.

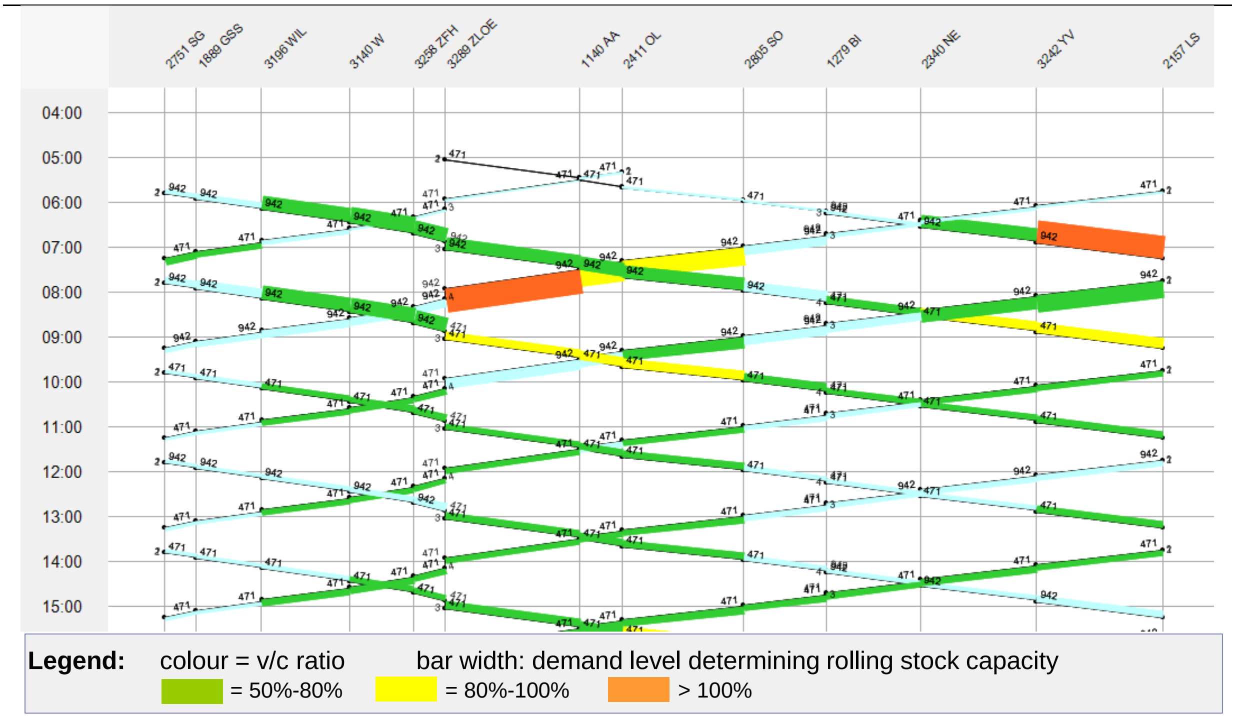
2. Purpose and history of travel modelling at SBB

2.1 Many years of macroscopic modelling practice

The main purpose of transport modelling at SBB is to support management decisions about future service concepts and investments in infrastructure and rolling stock. To fulfill this mission, since 2001, the SBB passenger division develops and maintains a rail-only travel model called "*SIMBA Bahn*" (Olesen et al. 2016). This model integrates demand, detailed level of service and production. On the demand side, the model predicts how ridership will evolve in the future and how it will react to changes in rail service, and how these changes will affect revenue. On the production side, *SIMBA Bahn* calculates line blocking (i.e. train rotations) and on this basis predicts the rolling stock requirements plus the future cost of production. Every year up to 100 model applications are conducted, for service and capacity planning projects in regional, intercity and international markets. The time range of forecasts are either mid-term (from 1 year to 6 years) or long-term (25 years or more).

Figure 1 gives an example of the above described integrated modelling of production and demand in VISUM. It shows the rail schedule between the cities of St. Gallen and Lausanne with its predicted degree of capacity utilization, which is relevant to determine rolling stock requirements and indicators for financial planning.

Figure 1 *SIMBA Bahn*: Integrated modelling of production and demand in Visum



SIMBA Bahn is a macroscopic model on 2’100 zones. It covers Switzerland and all rail corridors into the neighbouring countries. *SIMBA Bahn* uses the software Visum by PTV for time-table development, route-choice and assignment. The prediction and evaluation system is SBB’s own development. Rail supply is modelled with 1’800 rail stations, 650 lines (a.k.a. “time profiles”) and a timetable of roughly 12’000 train trips. The timetable in the model covers 24 hours, is differentiated for weekday and weekend, and consistently coded for existing and future states. The model applies 24-hour dynamic assignment, using a method in VISUM (Friedrich et al. 2001), while assignment parameters, capacity constraint functions and time distributions have been calibrated by SBB (Lieberherr et al. 2012, Kaeslin et al.

2014). Forecasting of domestic travel demand uses a direct demand model (Scherr, Bützberger 2016), while international intercity demand uses a multimodal approach. The demand model is data-driven, with demand matrices of the existing state derived from on-board OD surveys and permanent passenger counting systems.

2.2 Microscopic preludes

Since 2008, ETH in Zürich and its spin-off senozon maintain a travel model of Switzerland based on the open software MATSim (Meister et al. 2008). MATSim is an open-source software with an agent-based (i.e. microscopic) travel modelling approach (Horni et al. 2016). While this MATSim-based model has been extensively used in research projects, e.g. at ETH, the suitability for applications in real world transportation planning has yet to be shown.

An opportunity of application came up within the scope of the SBB Project "RailFit" in 2016. Using the MATSim-based ETH/senozon model, the aim of the application was to test the impact of cost-cutting strategies on rail passenger flows. While the results of this modelling effort were not used within SBB's corporate planning process, this application has been an important milestone of model development at SBB, as it opened important insights into microscopic travel modelling in the SBB context.

2.3 New assessment of model requirements

Based on the long experience with the macroscopic rail model *SIMBA Bahn* (section 2.1) and on the microscopic experience (section 2.2), an extensive SBB-internal discourse took place in 2016. This discourse established:

1. An assessment of requirements for a new transport modelling system.
2. An assessment of the abilities of various types of models to respond to the requirements. While different types of models were assessed, the focus was on two modelling approaches:
   - *SIMBA Bahn* (rail-only, data-driven, macroscopic), and
   - agent-based modelling with MATSim (multimodal, microscopic).

Before discussing the requirements one by one, the results of the assessments can be summarised in three statements:

- Microscopic modelling has intriguing features that should be integrated in the travel modelling system.
- To get the innovative approach of MATSim ready for SBB's practice, SBB needs to invest in improvements of software and model inputs. With such improvements in place, MATSim could deliver the multimodal functionality needed by SBB.

- The existing macroscopic model *SIMBA Bahn* has important functionality that cannot be replaced by a MATSim-based model.

In Table 1 and the following text , the most important model requirements and the abilities of the two different approaches are explained:

Table 1 Model requirements and model properties

Model requirements	**SIMBA Bahn** **macroscopic** **rail-only**	**MATSim** **microscopic** **multimodal**
Close fit of rail demand in the existing state	☑	☑
Holistic modelling of the rail system (demand, service and production)	☑	☒
Prediction success (rail demand)	☑	☑
Effective feed into financial planning (demand and operations indicators)	☑	☒
High degree of granularity of passenger flows	☒	☑
Door-to-door description of the rail journey (including station access)	☒	☑
Modelling competing travel modes	☑	☑
Possibility to model future transport modes (e.g. autonomous vehicles, sharing modes)	☑	☑
Complex new pricing schemes	☑	☑
Interaction of land use and travel, based on accessibility	☒	☑

The most important model requirements that are not offered by *SIMBA Bahn*:

1. **High degree of granularity of passenger flows**
   As a customer oriented company SBB is aiming to provide mobility which meets the customer needs. Hence, the transport modelling environment should provide insights into individual transport needs and mobility chains, including the respective activities. In addition, sociodemographic changes, coupled with changes in travel behaviour, are expected when looking into the future.

2. **Door-to-door description of the rail journey**
   SIMBA Bahn does not allow for analysis how people access the train. It is key to know how rail customers reach the stations to make sure that also in the future they are well

connected to the rail system. Furthermore SBB plans innovative train access concepts, such as connecting existing and new transport modes at “mobility hubs”.

3. **Modelling competition to rail**
   The passenger transport markets in Switzerland are facing a turning point. The market entry of inland long distance coach companies will affect the railway industry. There is a necessity to predict the effects of competition financially and on the capacity side.

4. **Future transport modes**
   In the more distant future new technologies and modes of transport, such as autonomous cars and sharing concepts, will lead to changes in the transport industry. Uncertainties and risks regarding those technological changes need to be quantified.

5. **Complex new pricing schemes**
   The elaboration of innovative mobility pricing, for individual as well as for public transportation, increases the need to be able to model such concepts and their impacts. It is difficult to include a comprehensive pricing model into a daily mobility model, where some pricing concepts include accumulating travel over several days to determine the price. Still this requirement has been analysed for different modelling options.

6. **Interaction of land use and travel, based on accessibility**
   Switzerland is subject to strong growth rates of the economy and the population. Cities grow and rail demand rises not only in the urban centres but also in areas of intermediate land use. In addition to being a transport company, SBB is also one of the largest real estate companies in Switzerland and it is of high interest to be able to estimate the impact of accessibility changes on future real estate prices.

The most important model requirements that are well delivered by today’s *SIMBA Bahn* and that need to be preserved in the new model are:

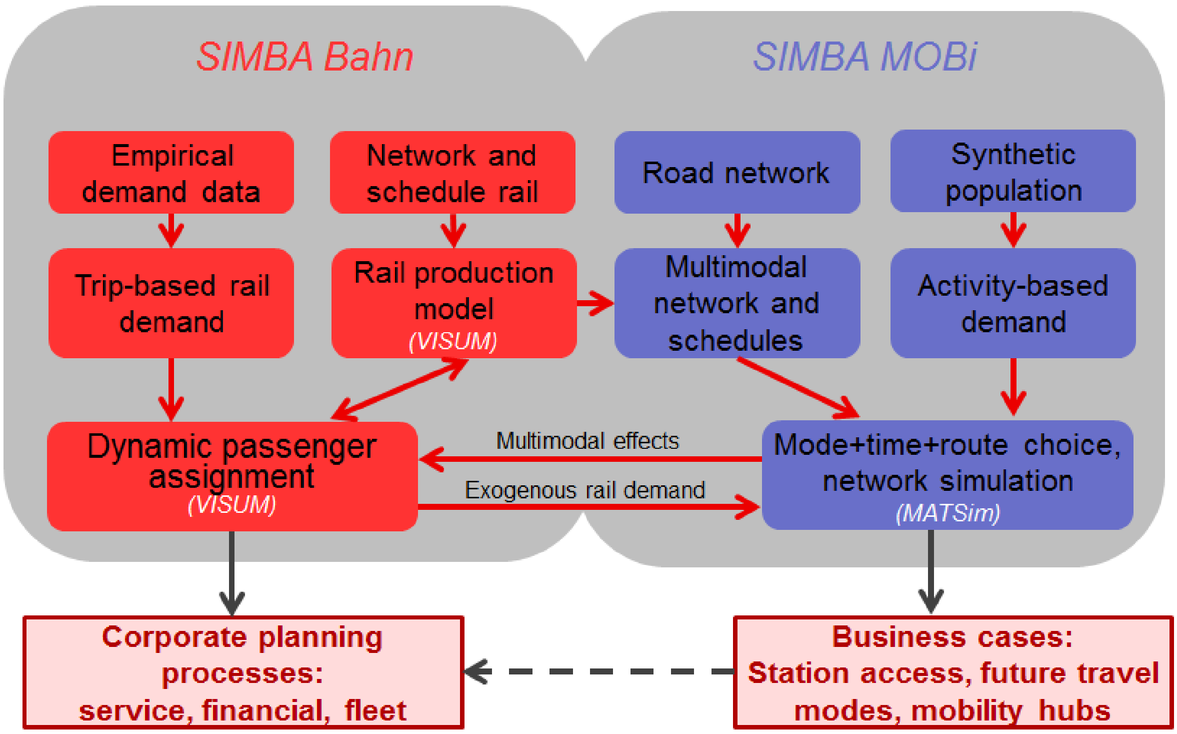
1. A close fit of rail demand in the existing state, which allows for realistic capacity analysis, also in the forecast.
2. A holistic modelling of the rail system, that includes demand, service (schedules), and analysis of operations and production..
3. The prediction success of *SIMBA Bahn’s* demand forecasts, that has been verified and is acknowledged within SBB.
4. The effective feed of model outputs into SBB’s planning processes, that use SIMBA’s demand and operations indicators in mid- and long-range financial forecasting.

3. Design of a new travel model architecture

To respond to the above requirements, it was decided that a combination of macro and micro would best meet all requirements. This combination makes best gains of the respective strengths of the two approaches. It allows to keep the full functionality of the existing *SIMBA Bahn*, while complementing it with microscopic and multimodal functionality.

As a consequence, the new model architecture is built on two pillars: one macroscopic, and one microscopic. Figure 2 visualises the two-pillar architecture.

Figure 2 Future two-pillar architecture of the modelling system SIMBA



The macroscopic pillar is liable for the continuation of *SIMBA Bahn* and includes the preparation of the *SIMBA Bahn* model inputs for the existing state as well as the forecast. The input preparation contains the data processing of the rail count data to the empirical rail origin destination matrix, the maintenance and development of the rail network and the rail schedule in Visum, covering domestic and international travel. These inputs are then used in the dynamic, capacity-constrained passenger assignment in Visum. The results from the passenger assignment are train loads, which are input to the rail operations model. The operations model computes fleet assignment, line blocking and finally train capacities. Passenger model and operations model together deliver a holistic picture of the railway, covering both sides, revenue and cost.

The microscopic pillar includes a MATSim model, which computes mode choice, activity duration, route choice, and network flows for all travel modes in Switzerland. MATSim is complemented with two microscopic models of synthetic population and of the activity-based demand. The microscopic pillar is named *SIMBA MOBi*, where "*MOBi*" stands for "intermodal mobility".

There are **interactions** between the macroscopic *SIMBA Bahn* and the microscopic *SIMBA MOBi*.

Input from *SIMBA Bahn* to MATSim:

- Rail network and schedule, existing state and forecasts – to make sure that the MATSim simulations benefit from *SIMBA Bahn's* precision and operational grounding of rail schedules.
- International demand (existing and forecast) cannot be generated from a synthetic microscopic demand model that replicates only domestic internal travel. Hence, *SIMBA Bahn* delivers these demand segments as exogenous demand ("single-trip agents" in MATSim).
- Further *SIMBA Bahn* will deliver benchmarks for future rail demand to *SIMBA MOBi*.

Input from *SIMBA MOBi*, i.e. MATSim to *SIMBA Bahn*:

- *SIMBA MOBi* shall be responsible or estimating how other modes, demography and new technologies affect rail demand in the future. These effects will be quantified as exogenous effects to *SIMBA Bahn*, in the form of OD-specific growth rates, and find their way into *SIMBA Bahn* applications.

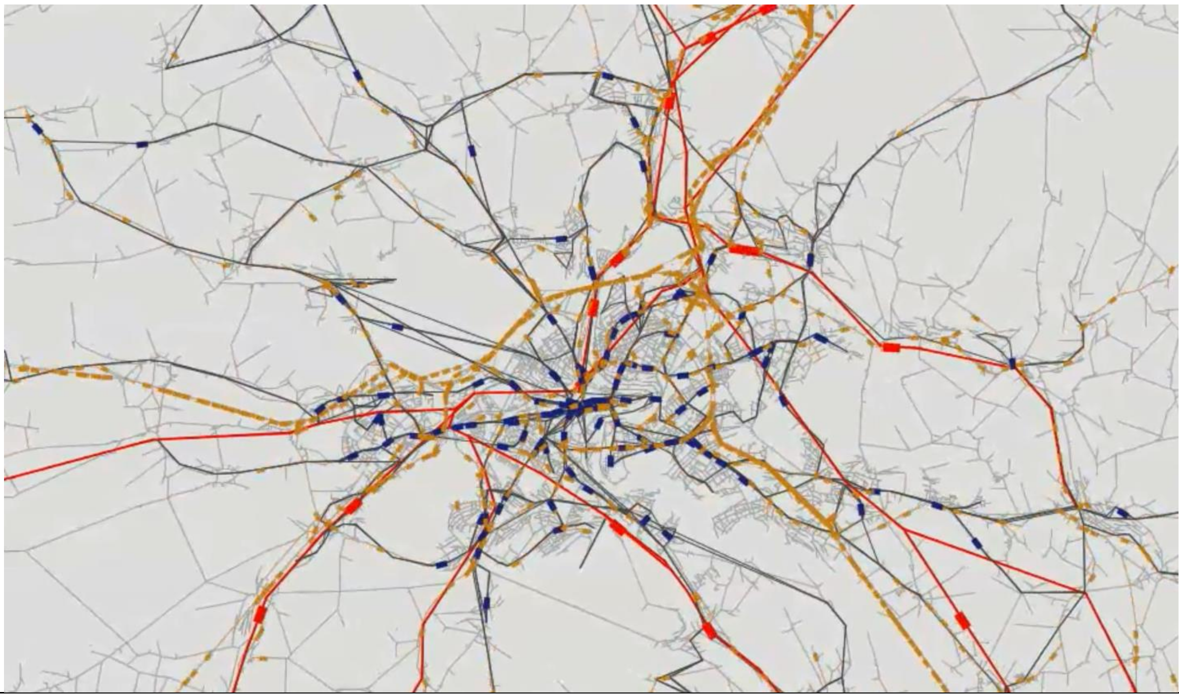
Purpose and fields of applications of the two pillars:

- *SIMBA Bahn* delivers inputs for SBB's financial planning processes. These inputs are standardised and cover short-term, medium-term, and long-term planning processes.
- *SIMBA MOBi* will inform *SIMBA Bahn* how exogenous factors (demography, competition, future mobility) affects rail demand. In addition, it will be used in business case studies that have a focus on intermodal topics, such as train access, mobility hubs, future new modes, and customer composition

4. Development of the new model

Having laid out the model architecture it must now be implemented. The macroscopic pillar is already fully functional in place and needs little investments to maintain and optimize it. On the contrary, the microscopic model has to be developed almost from scratch. The development of such a transport model can be understood as an integrated system of data, mathematical functions and parameters, and the software. This section of the paper describes the current state of the development – after one year of a three-year project.

Figure 3 *SIMBA MOBi*: microscopic picture



4.1 Improvement of model input data

Given the fact that microscopic models are more "data hungry" than macroscopic ones, it is very important not to limit the preparation of input data to the existing state, where many data sources exist. For SBB, it has been very important to develop data sources for the microscopic model covering all of Switzerland that are consistent between the existing state and future scenarios. At this time, two major inputs are finalised: public transportation service data and exogenous demand:

Comprehensive public transport service data

The public transport service data inputs were customised for SBB by integrating existing and forecasted rail schedules from *SIMBA Bahn*. When these data are translated to MATSim, they allow for simulations with a consistent rail schedule between existing, mid-term, and long-term forecasts. For all other public transport modes such as busses, non-forecasted schedules are imported from passenger information systems for the existing state. Bus schedules are adjusted to future rail schedules by coordination heuristics. This integrated schedule of all public transportation in Switzerland is a shared product of the Swiss federal government (UVEK/ARE) and SBB.

Exogenous demand

The MATSim model simulates the domestic travel demand by Swiss residents only. Therefore, exogenous traffic, such as border-crossing travel and domestic traffic made by non-residents (visitors, tourists), has to be supplemented. On the rail side, the source of this supplement are the OD matrices of *SIMBA Bahn* plus other surveys and booking systems. At this stage of model development, an automated interface between *SIMBA Bahn* and MATSim generates the exogenous demand as “single-trip agents” in MATSim format (see Table 2).

Table 2: Exogenous rail demand (number of trips, 2015, average weekday)

Group	*Explanation*	*# of trips*
International long distance travel	Long distance travel across the borders	37’900
Cross-border commuter	Regional travel across the border	41’300
Tourism transport	Domestic travel made by non- residents	17’900
Airport traffic	Travel from and to airports, in order to take international flights	26’500

4.2 Improvement of the MATSim software

In one year of using MATSim, SBB has implemented several improvements to the MATSim software code. The most important ones are summarised here:

Realistic and efficient passenger flow model

With SBB being a public transportation company, the SBB modellers analysed the public transportation model in MATSim with scrutiny, and a need to improve the model in this regard was detected. Two software features developed by SBB are described with more detail in Rieser at al. 2018:

- First, a new router has been developed. It is available as open source to the entire MATSim community, under the name “SwissRailRaptor”. This new router has increased efficiency, by reducing the computation time and also the memory need by orders of magnitude compared to MATSim's previous public transport router. Furthermore, the quality of the routes (i.e. the agents paths that are built based on the schedule data) is improved, as the SwissRailRaptor allows for more sophisticated utility functions.

- The public transportation flow model (in MATSim, the simulation engine "QSim") was extended with deterministic public transport simulation (detPTSim). This new simulator allows that the public transport vehicles follow the network more strictly according to the schedule, hence "deterministic". As a result, the passenger in the simulation depart and arrive according to schedule. This simulating approach is recommended to model rail or other PT modes that operate on dedicated tracks, where the previous PT simulation in MATSim did not produce satisfactory results.

Software extension to improve mode choice utilities

Secondly, SBB wanted to better represent various factors which determine in reality if travellers choose public transportation as a mode:

- A car access time model was added to MATSim. It allows to model that car is less attractive when origin or destination of travel is in an area of increased urban density.
- By default, MATSim uses global utility functions for the entire population or for sub-populations. This concept proved not sufficient, if various socio-economic person attributes, such as mode availability, public transport subscriptions, or income, should be taken into account in agent's utility functions.
  A new software feature developed by SBB allows to diversify utility parameters by all kinds of available person attributes and their values.

Simulation post processing

Standardized model outputs and visualization are key for model development as well as application. For model development it is, for example, crucial to compare different model runs with each other as well as with reference values. SBB programmed a standardized model output that extracts aggregated or disaggregated model results from the MATSim events, which allows a comparison of model results with empirical data. In this context, SBB also developed a two-way interface of MATSim with the software VISUM that allows for in-depth analysis of passenger flows and for data exchange between *SIMBA Bahn* and MATSim. An overview of some examples of these outputs are given in section 0 of this paper.

4.3 Calibration of MATSim utility functions

Calibration of a travel model - according to SBB's definition - means adjustment of parameters and functional relationships in the model, plus improvement of the input data, in order to obtain the maximal fit between empirically observed data and the model output. Important is that the calibration methods preserve the explanatory power of the model, i.e. preserve the ability of the model to make predictions. Hence SBB does not apply automated calibration methods which produce unexplained variations of model output to "force the model into the counts", such as CADYTS (described in Horni et al. 2016).

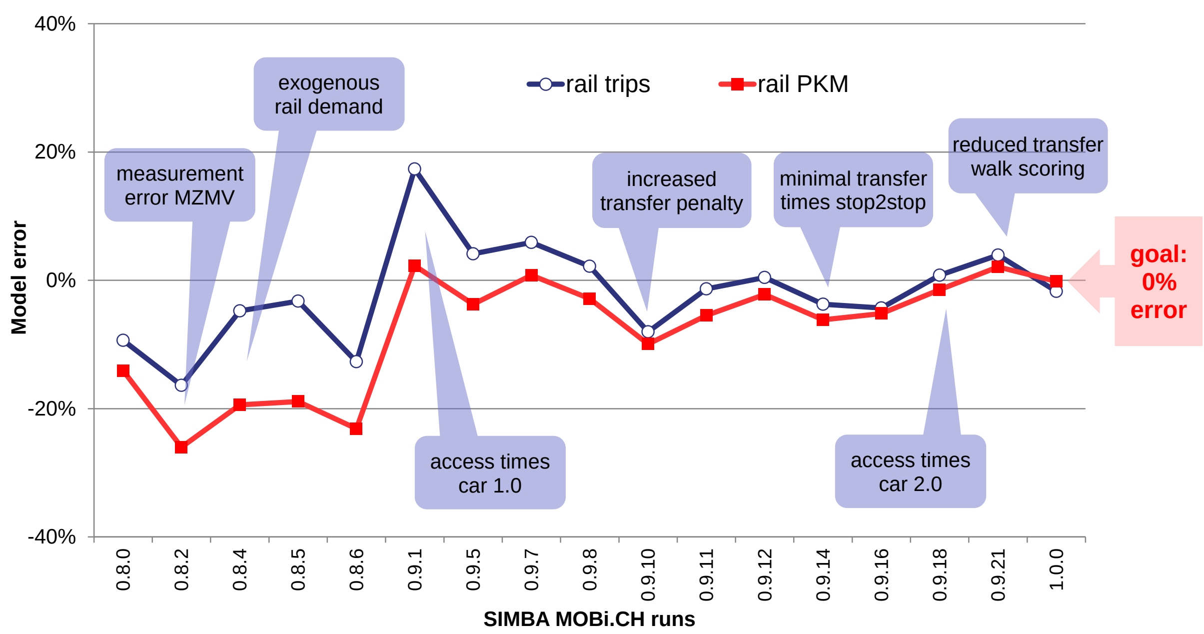
From December 2017 through April 2018, SBB's modelling team performed a calibration of the MATSim model of Switzerland. The process is described in this section of the paper. The core of the efforts has been the calibration of utility parameters of the agents (in MATSim this is called the "scoring parameters"). At this time, there are no statistical methods available to determine MATSim utility parameters from surveys. Hence, the method used was manual calibration, i.e. variation of the parameters while observing and improving the fit to empirically observed data. The initial parameter had been derived from discrete choice models based on a stated-preference-survey (Weis et al. 2017). In addition to the utility parameters, SBB improved input data such as public transportation schedules and exogenous demand (see section 0 of this paper).

In this calibration process SBB did not change the following Inputs, which come from the MATSim model of Switzerland, developed by ETHZ and senozon (Meister et al. 2008):

- The synthetic population (all agents and facilities, described with attributes)
- The agents' plans (activities and their destinations)
- The road network (derived from the Open Street Map)

The following Figure 4 shows the calibration history based on two model fit indicators, which are the percent error of total number of rail passenger trips and of total number of PKM (passenger kilo-meters travelled), on an average weekday. These two global statistics are key performance statistics of railways in Switzerland; they cover SBB and other rail corporations, and are derived from nationwide rail on-board surveys and permanent counting systems. Figure 4 shows 17 MATSim simulations in chronological order – they are a selection out of 40 simulations that were performed over four months of calibration. Also shown are major milestones of input data improvements, first applications of software improvements or major parameter changes. Not surprisingly, these milestones typically are marked by disruptive jumps of the two model fit indicators.

Figure 4 Calibration history – based on two indicators of model fit



Overall, SBB used 46 statistics as calibration criteria:

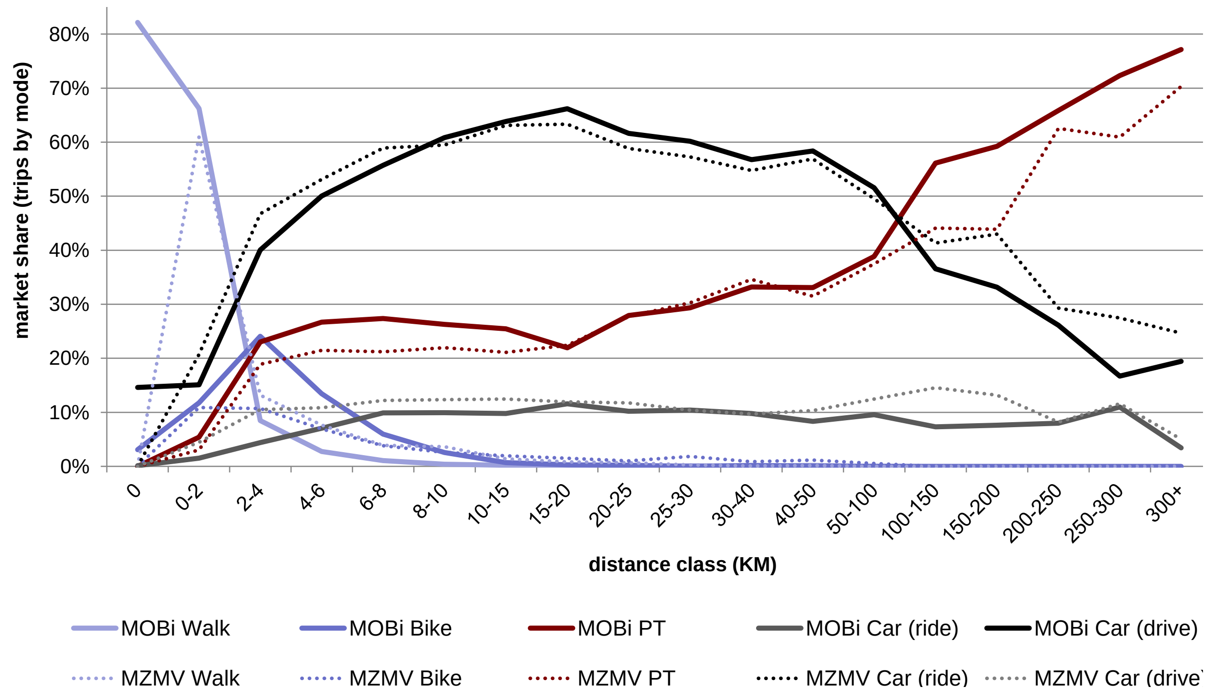
- Source: national travel diary survey («Mikrozensus Mobilität und Verkehr 2015»):
    - Mode shares (km travelled, # trips), global and by person groups
    - Mode shares (# trips) by distance classes
    - Mode shares (# trips) aggregated district-to-district
    - Number of transfers in public transport trips by sub-markets
- Source: Rail demand statistics (HOP[1])
    - Rail demand (km travelled, # trips), global
    - Passenger volumes per station, per link, per OD pair
    - Distributions of demand by LOS (travel time, distance, transfers)
- Source: Road counts ASTRA (national office of roads)
    - Link volume counts on Motorways and other national roads

An important example of a calibration criterion is the statistic of mode shares by trip distance classes (Figure 5). This statistic allows to differentiate different sub-markets of travel: for

[1] HOP stands for "Hochrechnung Personenverkehr" – it is a system to consolidate onboard surveys, plus the manual and automated counts on all trains of several railway companies in Switzerland.

railways it is essential that the public transportation share ("PT") has a good model fit in the distance classes of 15 KM and more.

Figure 5 *SIMBA MOBi*: validation of modal shares by trip distance classes



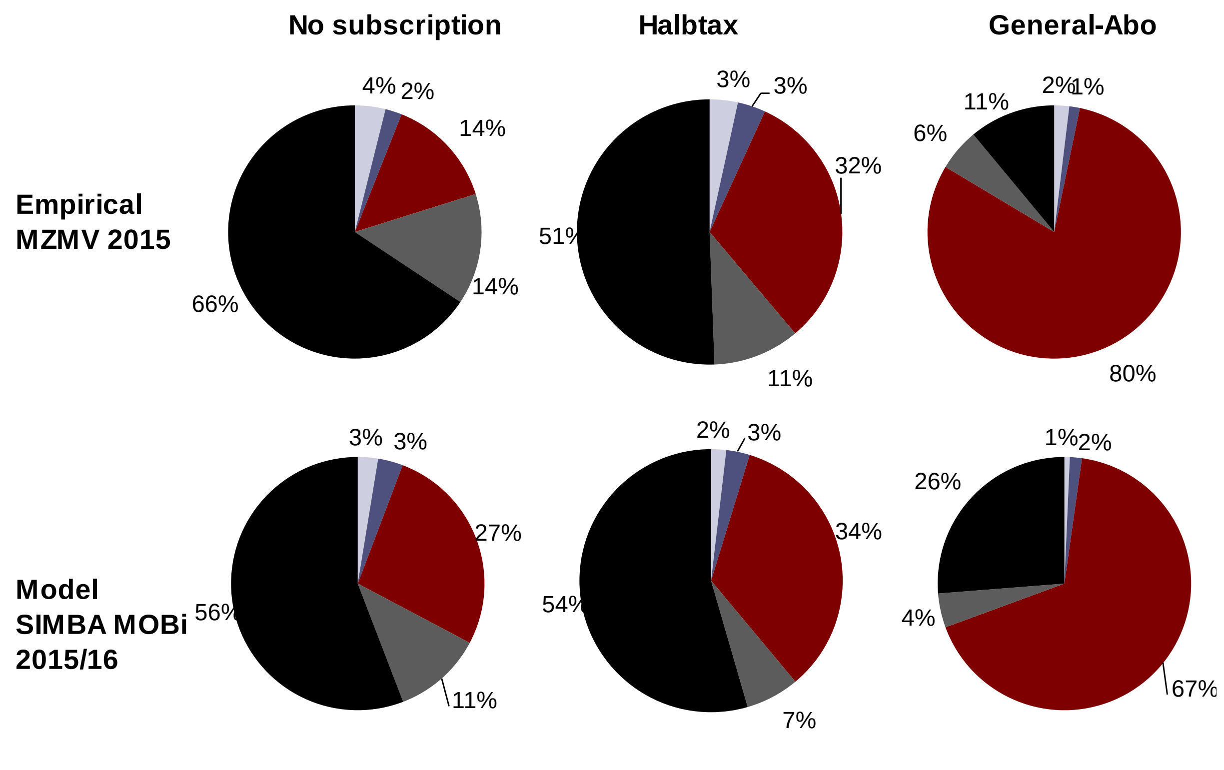
So far, three person-specific attributes are used to diversify the utility functions between agents: public transport subscription, car availability and land use type.

Table 3 implemented person attributes

Person Attribute	*Explanation*
Public transport subscription	Possession of a public transport subscription. Possible products are "General Abonnement", which is a pre-paid year-long full subscription to unlimited use of all public transport services in the country, and "Halbtax", which is a year-long subscription to use public transport for the half fare.
Car availability	A car is considered available if a person does have a driver license and either has a car available all the time or upon arrangement with other household members.
Land use type	The location of the domicile influences mode choice not only by land use type but also regional cultural differences.

The following Figure 6 shows calibration results for modal shares by person attributes, in this case the type of PT subscription: it can be seen that the behaviour is significantly different by person type and that the MATSim scoring parameters in *SIMBA MOBi* have been calibrated to reflect these differences.

Figure 6 *SIMBA MOBi*: validation of modal shares (in PKM) by PT subscription



According to SBB's experience, MATSim can be calibrated in the same way as macroscopic travel models. The need of man power and computer resources is somewhat higher than for a macroscopic model, because of longer computation times and of the time it takes to customize the software and to program post-processing routines for the comparison of aggregated model results with empirical data.

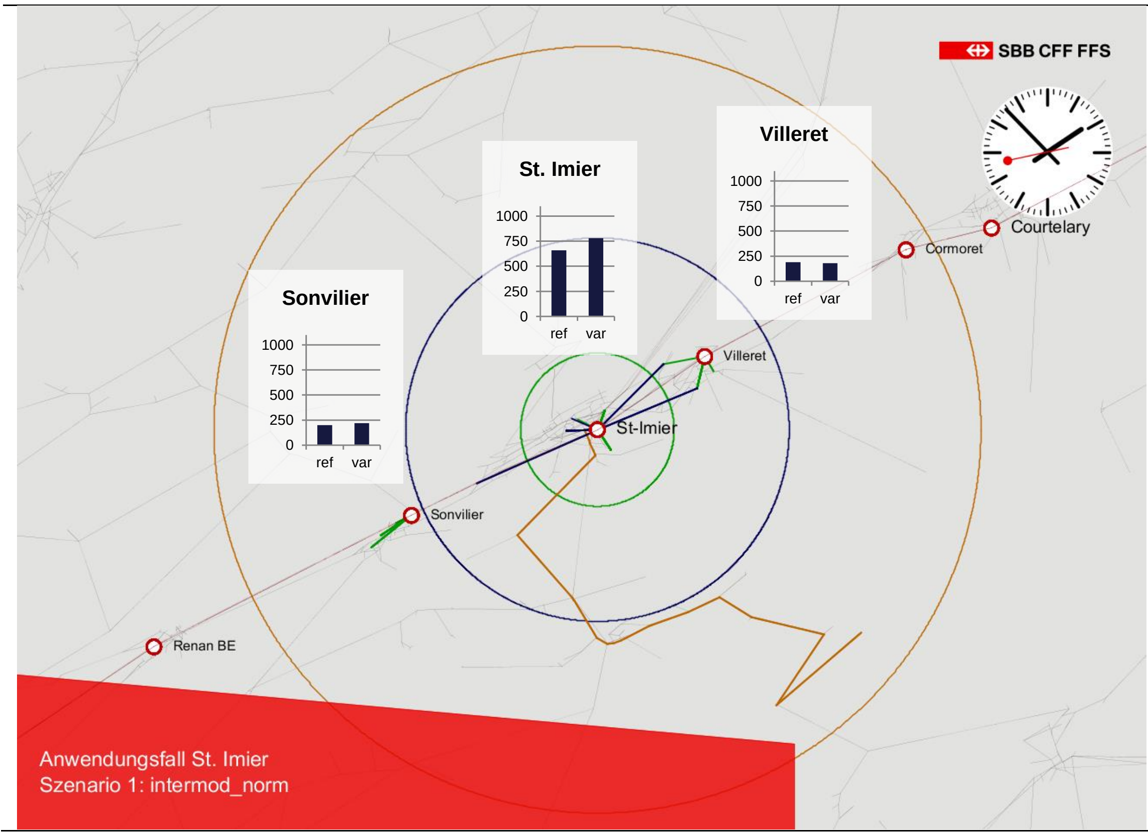
4.4 Reality tests with the MATSim model

As this paper is being published, first preliminary applications (called "reality tests") are performed with the calibrated MATSim model, presented in section 4.3. The goal of these reality tests is to verify the model reactions to changes in transport service ("sensitivity" of the model), but also to examine the usability of the model. A third aspect is to analyse model convergence, which is considered an essential model property. Among the tests SBB performs are:

- Rail service improvements (shorter travel time or increased service frequency),
- Road capacity and speed reductions,
- Replacement of rail services by buses during construction or temporary line closure,
- Competition by long-distance coach lines,
- Intermodal extension of rail service access.

The latter two are applications of advanced MATSim features, that became available with the SwissRailRaptor (see section 4.2 of this paper). The reality test "competition by coach lines" makes use of the possibility to realize differentiated marginal utility of time for different public transport modes. The "intermodal" reality test enables the enlargement of a station's catchment area using additional access modes that are faster than walk, which is the default access mode in MATSim. Figure 7 shows the intermodal extension of rail service access by the example of St. Imier. The circles represent the catchment area by different access modes: The inner circle reaches the rail station by foot. For the middle circle bike is enabled and in the outer circle taxi or kiss&ride is enabled. It can be seen that the reality test is helpful to test intermodal rail access in MATSim and to verify if the remand reaction to the additional choices in station access is realistic.

Figure 7 Intermodal extension of rail service access



4.5 Next steps of model development

Two major developments are in progress: a new synthetic population and an activity-based demand model covering activity generation and destination choice.

Synthetic population *"MOBi.SynPop"*

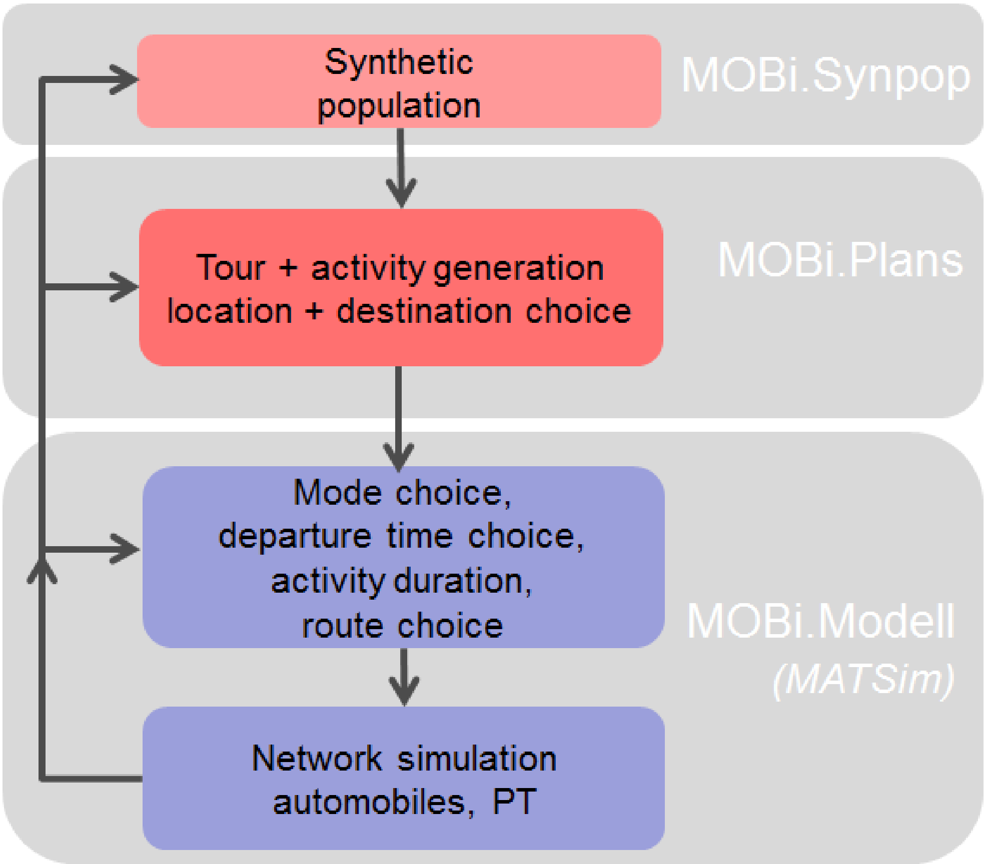
The first applications and analysis of the synthetic population of Switzerland, which was developed by ETH and senozon, showed that some distributions of population attributes do not reflect the latest state of the empirical data and survey results available to SBB. A new synthetic population of Switzerland is currently being developed, using improved input data, with a focus on person attributes that affect mode choice, such as car availability and PT subscriptions. It is designed to be able to forecast future scenarios, including land use, demography and availability of mobility instruments. The result will be the first step in SBB's microscopic model chain and is called "*MOBi.SynPop*" in Figure 8. For this new synthetic population, SBB cooperates with the Swiss federal government (Federal office of land use, "ARE"). The work is performed by consultants who have done previous work on synthetic population and land use modelling in Switzerland (Müller 2017, Bodenmann et al. 2014).

Activity-based demand model "*MOBi.Plans*"

An important input of MATSim models are the agents' plans. In the plans, the daily activity schedule and all destinations are given for each person of the synthetic population. SBB has started to develop an activity-based prediction of agents' activity schedules and their destinations. The model will have components to generate tours, stops on tours, activity choice, location and destination choice, and activity scheduling. The methodology follows the North American practice of activity-based models (e.g. Paz de Araujo and Joshi, 2017).

These two developments, *MOBi.SynPop* and *MOBi.Plans*, will complete the microscopic model chain, where the MATSim model is the third component in the chain (see Figure 8).

Figure 8 Components of the microscopic model pillar



Other developments that are planned by SBB for the next two years:

- Integrated calibration of the entire microscopic chain, once MOBi.SynPop and MOBi.Plans will be operational. This includes re-calibration of the MATSim utility functions (see section 0 of this paper).
- Develop a configuration of MATSim that allows for acceptable model convergence, good enough to be able to test scenarios and evaluate individual transportation projects.
- Explicit modelling of intermodal passenger trips (e.g. taxi – rail, shared AV – rail, ...) in MATSim, based on first experiences shown in section 4.4 of this paper.
- Explicit modelling of autonomous vehicles (AV) and sharing modes as part of future road demand.
- Continuous work flow automation. The major goals here are usability improvements of the microscopic model, automation of the interaction between the two pillars of the model system.

- Continuation of the efforts to simulate complete demand in MATSim. The long term goal is to have not only the resident population as endogenous agents (i.e. agents who can react to changes in travel service), but also other important segments of the demand, such as population living abroad but close to the Swiss border («Grenzgürtel») as well as non-resident populations (tourists and visitors).

In order to speed up model development and to integrate the demands of other divisions of SBB's railway business, another SBB unit, called "LIMA" (long-term integrated mobility and site development), is running a parallel project, which keeps close exchange with the model development presented in this paper. LIMA has launched several proof-of-concept projects to advance modelling methodology in areas such as accessibility, border-crossing demand, intermodal travel and autonomous vehicles.

4.6 Further research need

In this project, SBB staff has identified need for academic research around MATSim in the following areas:

- Convergence of simulation results with the existing agent model
- Agent-based user equilibrium
- Calibration methods that maintain the explanatory power of the model
- Routing, scoring and simulation of intermodal trips
- Future mobility: utility functions that include cost and time for different person types

5. Summary and conclusions

SBB has reached the one-year milestone of a three-year project to develop a new transport model. The architecture of the new modelling framework is based on the assumption that there is not one model that fits all purposes. The strategy integrates two modelling approaches. It combines the macroscopic "*SIMBA Bahn*" with a microscopic, activity-based model ("*SIMBA MOBi*") that makes use of the MATSim software. There are interfaces between the two and a well-defined purpose for each one. With that approach SBB benefits from both, the strength of the established macroscopic tools, as well as the potential of the new microscopic, multimodal model.

SBB considers this an innovative approach in several aspects. On the one hand, SBB developed new algorithms and new methods. On the other hand, there is another kind of innovation involved that consists of the adjustment and application of better solutions to meet new requirements. The new requirements come from SBB's need as a transport corporation to prepare for a future of 2040 and later, when new technologies and new mobility paradigms will change the picture.

After the first year of model development, SBB achieved the following points:

- A consensus has been established across the corporation on the model strategy.
- The modelling capacity within the corporation has been extended by know-how in microscopic and agent-based modelling. SBB has built a functional MATSim modelling team. In terms of IT, SBB acquired additional resources in cloud computing and by putting in place local servers that enable us to run large-scale simulations.
- The MATSim software has been improved with several new methods to enable the realistic simulation of public transportation schedules and passenger flows.
- A first version of a MATSim model covering all of Switzerland has been calibrated and is being tested in reality applications.

The next challenges in model development are laid out and their implementation has been started: a new synthetic population is being developed as well as an activity-based model to determine agents' plans including activity schedules and destinations. Further planned model improvements include an extension of the MATSim model to represent intermodal demand, autonomous cars, and forecasting all the microscopic input data to 2040. A big challenge will be to put all the assumptions of future mobility into numbers, including car possession, PT subscriptions, demography, travel behaviour, cost of travel, etc. The need for further research has been identified.

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