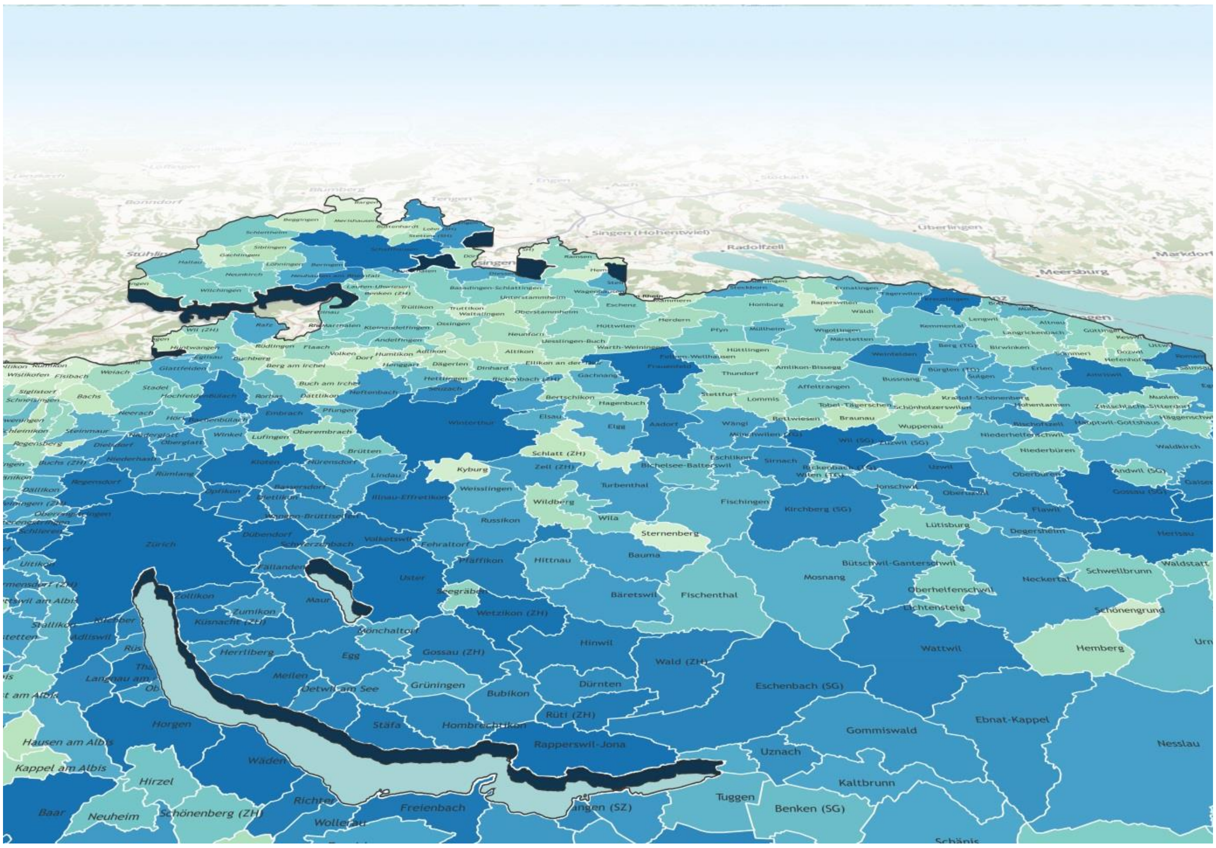

An Integrated Land Use Model for Switzerland

Detailed Description of the FaLC Template

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28/08/2014

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28/08/2014

Abstract

The main goal of the first version of the Swiss Case Study is to test convenience and achievement of the stated objectives for the whole FaLC project. The presented results are an intermediate state of work in progress and refer to the softwares' and models' state in April 2014. FaLC as well as the Swiss Case Study will be further developed.

This report focuses on the different dynamic models that have been implemented in FaLC during the years 2012 and 2013 and is part of the FaLC documentation (comparable to an implementation guide). Those implementations will also serve as a template for further Case Studies.

Preferred citation style

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1 Introduction

1.1 Goals

The first ideas to implement a new integrated Land-Use and Transport Simulation Tool came up more than three years ago. In the course of implementing a Zurich Case Study for an EU-founded project called SustainCity,[1] several partners reasoned that there is a need to have a simple and robust (integrated) Land Use and Transport Simulation Tool (LUTI) for Europe. The main advantages of a redesigned tool are diverse: possibility to use only locally relevant data or models, the integration of widely used transport software such as VISUM[2] or MATSim[3], and less unused code fragments complicating the modelling work. After some presentations of the idea at congresses, FaLC was presented at the Federal Office for Spatial Development (ARE) to ask for support. At the same time, the consortium had the opportunity to integrate FaLC in an EU-founded research project “Smart Urban Adapt” (SUA).[4] The support of ARE as well as the SUA project, led to the start for the implementation of a Swiss Case Study in FaLC in May 2012. In parallel, the FaLC Software has been developed.

The aim of the ARE is to set up a Land Use Model for Switzerland that can be connected with the existing National Passenger Transport Model (NPVM).[5] The Land Use Model shall be capable of answering different research and planning questions; e.g. what are the effects on the (spatial) behaviour of residents, households and business of:

- changing (transport) infrastructure, e.g. new motorway connections,
- decisions of political institutions and authorities, e.g. adjusted land-use policies, and
- changing framework conditions in demography and economy,

About two years later, we are happy to present the first prototype of FaLC and of a land-use model for Switzerland. There is still a lot to do, but the software performs well and runs very stable. The implemented Swiss Case Study shall test the modelling accuracy and achievement of the FaLC project aims. Additionally, a second objective of the Case Study is to give potential users the opportunity to have a template for further work in other regions.

This report focuses on the different dynamic models that have been implemented during the last year. It is meant as the final report of the work done in 2012 and 2013 and additionally

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1 See also www.sustaincity.eu

2 VISUM and VISEVA are (closed source) transport modelling tools of PTV Group; see http://ptvgroup.com

3 Multi Agent Transport Simulation Tool: developed by TU Berlin and ETH Zurich; see www.matsim.org

4 See also http://sua.ethz.ch/

5 Nationales Personenverkehrsmodell (NPVM);
see http://www.are.admin.ch/dienstleistungen/00906/index.html?lang=de

documents the status of the current FaLC implementations. Specifically, the presented results refer to the status of the software and models in April 2014. But, FaLC as well as the Swiss Case Study will be further developed. Therefore, this represents only an intermediate result of a work in progress.

After a short introduction (including workflow) and an overview of the FaLC framework, this report will shortly describe the set-up of the Swiss Case Study and the data used from the FaLC database. In Chapter 3, the different dynamic models are discussed. This includes demographic events models such as birth and death rates, and firmographic events model including business establishment and closing. Chapter 4 presents additional models, such as the Transport Simulation Module. In Chapter 5, results of the validation and calibration model are presented. Chapter 6 summarizes the first results of the implemented Use Cases. Finally the paper closes with the main conclusions and gives an overview of the next steps.

1.2 Modelling concept

Compared to other (integrated) land-use and transport simulation tools, FaLC will focus on the following main objectives:

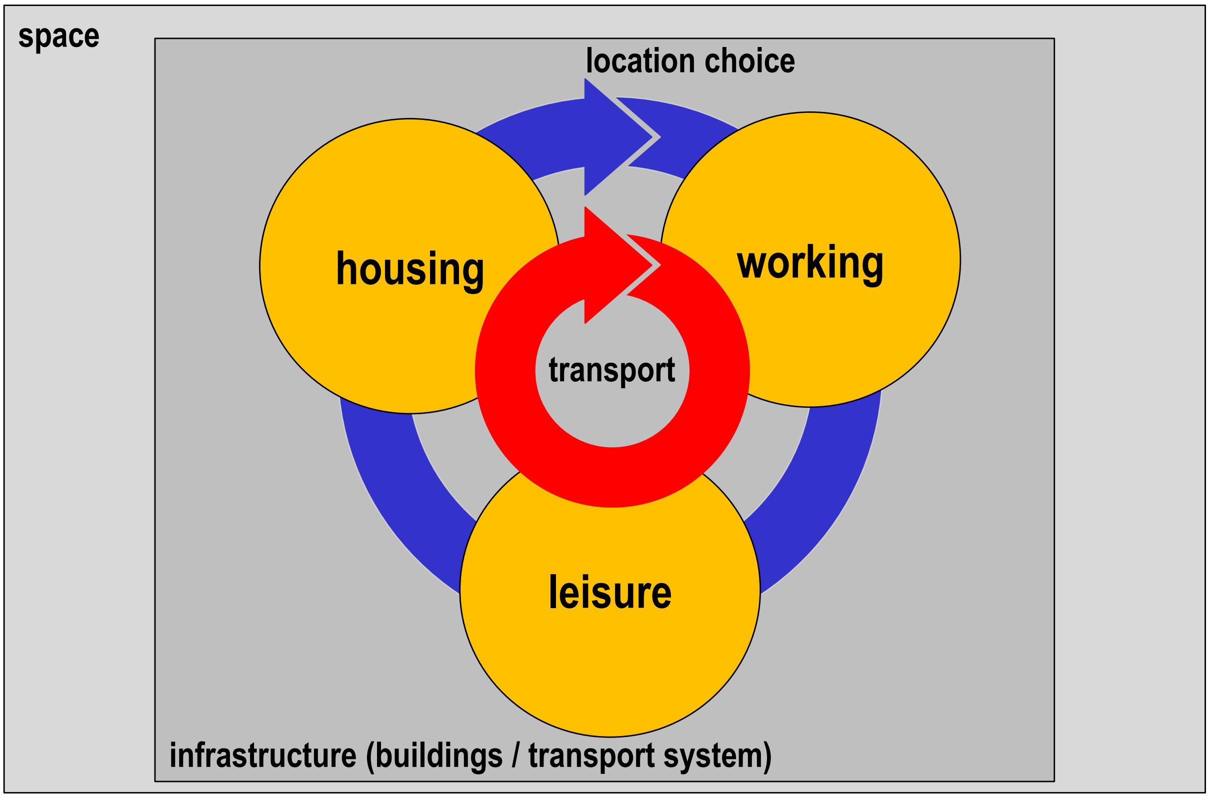
- **Data**: data requirements shall be as low as possible.
- **Spatial resolution**: shall be modular and scalable. At first, a model on the level of municipalities will be implemented.
- **Code**: shall be open source, modular, transparent, stable, and with interfaces to other relevant software.
- **Models**: shall cover all relevant models to explain spatial long-term location decisions (households, firms and people) and related transport activities.
- **Run time**: short run times allow testing multiple scenarios to validate the models and perform multiple runs.
- **Costs**: FaLC shall allow the set-up of a simple land-use and transport model (comparable to the model presented in this report) within 1-2 months.

In parallel to the implementation of the software, the Swiss Case Study is testing achievements of FaLC. Additionally, the implementation of the Swiss Case Study gives the opportunity to have a template for further work in other regions.

Figure 1 shows the idea of the agent based modelling framework implemented in FaLC: agents like households, firms or persons move (or stay) in a certain study area, comparable to a chess board. In this space, agents use different facilities for different purposes like buildings and transport infrastructure (squares on the chessboard). The different activities of these agents (home, work, leisure) are situated in these facilities. In the line with Wegener's land-use transport feedback cycle (Wegener and Fürst, 1999), the agents' movements between these locations are twofold: a) we observe daily movements between home, work and leisure;

and b) we observe long-term decisions where agents live, where they work and where they generally spend their spare time.

Figure 1 Model of agents behaviour in FaLC

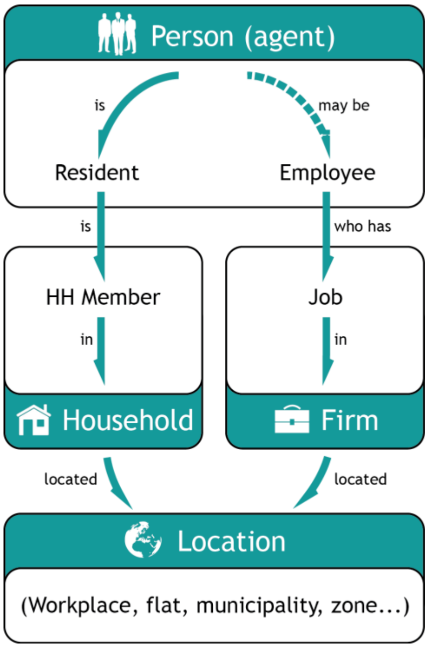


These two cycles are strongly connected and in integrated land-use models consequently modelled in the same framework to consider interdependencies. Indeed, the FaLC project focuses mainly on long-term location and relocation strategies with time steps of generally one year.

The idea of FaLC is to model daily transport movements in two time-aggregation levels, according to the questions to be answered: a) external transport simulation tools such as MATSim or VISUM (and in the case of ARE, NPVM) provide detailed information; and if there is no transport simulation tool available or due to time calculation time constraints b) in an aggregated approach (e.g. the traditional four step approach to model transport), FaLC focusses more on Daily Transport Volumes and average travel times.

Figure 2 shows the modelling structure of the agents in FaLC: every person (or resident) belongs to a household and at the same time, every household is located in a certain location of the study area. In addition, persons are employed/unemployed. And, congruent to households, every firm is situated in a location, too.

Figure 2 Modelling structure of agents in FaLC



The concept of FaLC has been presented in detail at the Swiss Transport Research Conference 2013 in Ascona (Bodenmann et al., 2013). In general, the presented ideas have been implemented accordingly, with small amendments addressed in this report.

1.3 Modelling framework

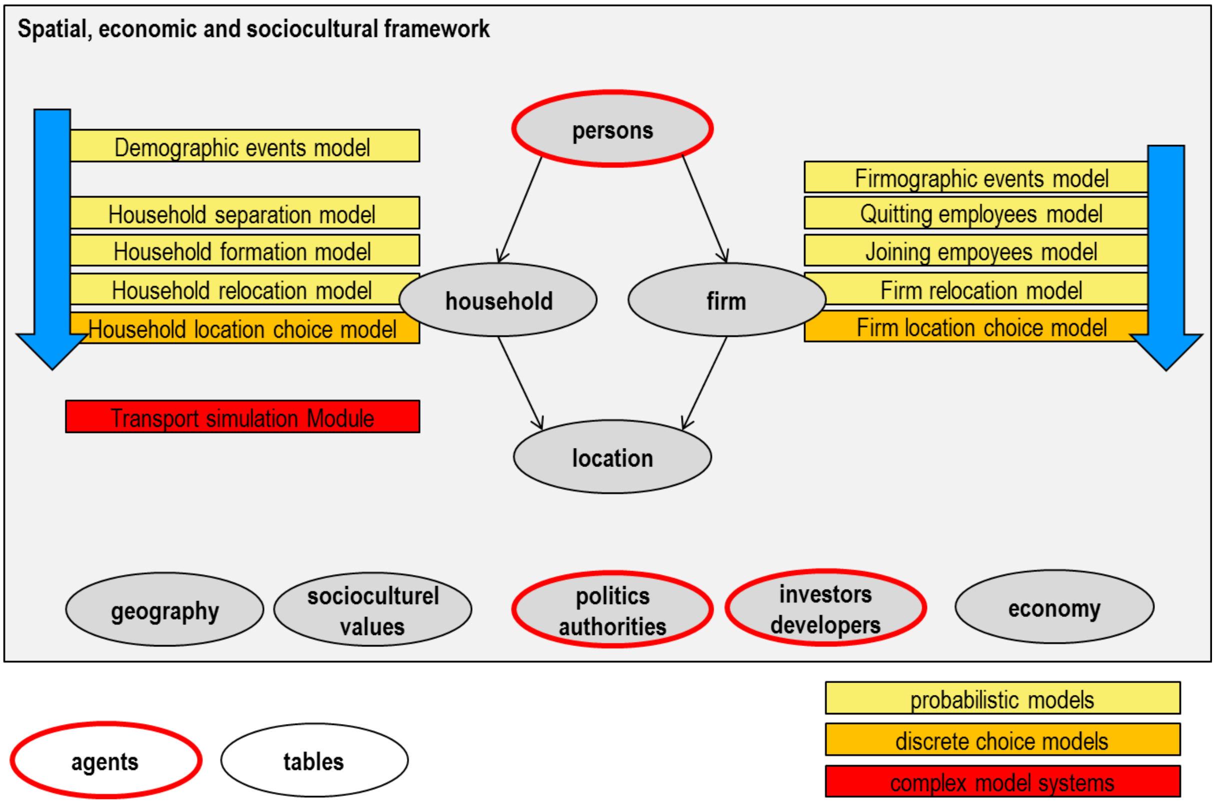
Figure 3 gives an overview of the different models and model types for the implemented Swiss Case Study. In general, three different model types are involved: *probabilistic models* combined with Monte Carlo simulations; *discrete choice models* with, subsequently, also a Monte Carlo simulation; and more *complex model systems* like transport simulations.

Probabilistic models generally use probabilities to dedicate certain events. E.g. a 50 year old man has a certain probability to die, or a 30 year old woman has a certain probability to get pregnant. The probabilities can change by year and may depend on other rules. As we observe that in larger zones households and firms tend to relocate within the zone, according relocation rates to other zones decrease with increasing zone-areas. E.g. probabilities for firm relocation therefore depend on the sector as well as the size of the location zone. Relocation rates and other probabilities are used at different model stages and generally are derived from official statistics.

Discrete choice models are used to model a choice process such as new locations for households or firms. In general, these models consist of different sub-models: a) calculation of the utility of possible alternatives (by a so called “utility function”); b) comparison of the utilities of these alternatives and calculation of the probability of each alternative to be chosen; c) simulation of the choice by using Monte Carlo method. In fact, the last step is similar to the other probabilistic models in FaLC.

Complex model systems consist of different sub-models including probabilistic as well as discrete choice models.

Figure 3 Base models (2013)



Each time step or cycle (usually one year[6]), will pass through different steps containing different models. In a first step, base information regarding the agents and locations have to be updated by running the *demographic events model* (e.g. persons die or give birth to children) and the *transport simulation model* (provides distances and further accessibility variables). The according results may influence the models of the second step: *household* and *job separation models* as well as *household* and *firm formation models*. In the *household and firm relocation model*, this information is needed to designate moving households and firms. Finally, in the *household* and *firm location choice model*, relocating households and firms choose a new location.

[6] Of course, it would be possible to define a cycle of 6 months or 5 years. But, as most of the parameters are calculated for a time period of one year (e.g. relocation rates), they would have to be adapted accordingly.

1.4 Modelling workflow

The aim of FaLC is to implement practical software for planners as well as researchers. Therefore, this chapter focuses on the sequence of steps needed to create a scenario in FaLC, ready to be analysed by the user.

As illustrated in Figure 4, there are three different ways to start a scenario in FaLC:

a. by importing new raw data (input tables) in order to create a synthetic population;
b. by creating a synthetic population from existing raw data; and
c. by using an existing synthetic population in the FaLC database.

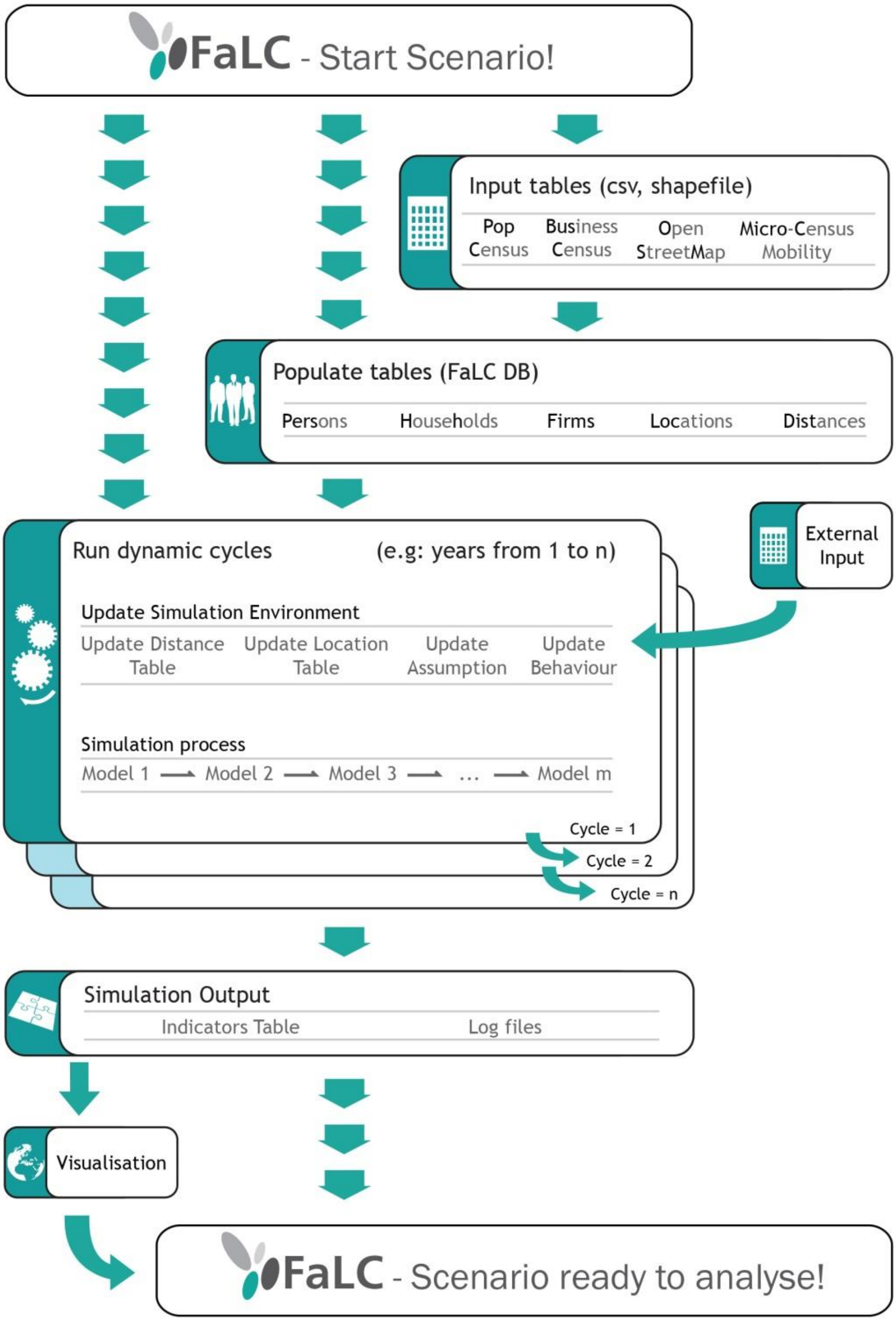
The source database for the generation of a synthetic population is composed primarily by official census data (e.g.: Federal Census of Population or Business Census from FSO) and micro-census on mobility. Thanks to this information, it is possible to generate a synthetic population adapted to the different locations in FaLC database (the current level of detail is municipalities but can be disaggregated in more detail in the future). Additionally, FaLC is based on distance tables (time and/or distance between locations) provided by external transport models (e.g. NPVM) or the simplified FaLC Transport Model.

Following, FaLC starts its core application: the dynamic cycles modelling the yearly dynamics (e.g.: from year 2000 to 2020). The yearly cycle includes demographic models and relocation models, among others. Depending on the scenario, some annual assumptions or conditions will be updated in a first step as external input (e.g. a new motorway segment). In a second step, FaLC simulates the scenario through different models modifying, cycle by cycle, the initial dataset (e.g. people are born, others die, firms are closing, couples move together to form a household, firms and households change their locations,…).

Finally, the results of the simulation are written to different files compatible with SPSS, R, MS-Excel or QGIS/ArcGIS. The user is now ready to visualise/analyse the final scenario. Furthermore, a visualisation module is also included in FaLC and allows the user to visualise maps comparing some important information between any of the cycles predefined in FaLC configuration. For example:

- Population distribution: annual balance of residents.
- Employees distribution: annual balance of employees.
- Population dynamics: Balance of residents since previous run.

Figure 4 FaLC: general workflow



As described above, FaLC creates any scenario by exporting an indicators-file, which allows a large flexibility to adapt/integrate it to any other specific software. Figure 5 illustrates a possible workflow to analyse and visualize this indicators-file.

FaLC writes the indicator file including property and log file in a Dropbox folder.[7] The advantage of this procedure is that different persons can run FaLC on different computers, but all members of the FaLC project have the possibility to check results and log files.

Figure 5 FaLC: workflow analysis/visualisation of results

Supported e.g. by a MS-Excel application for the analysis of the resulting indicators, the user is able to import the FaLC indicators-file and analyse the results by comparing them with other database, creating evolution diagrams or generating statistical reports.

In the same way, the indicator file can also be loaded as database in a powerful GIS software like QuantumGIS directly or by modifying the structure or adding information to the database via MS-Excel.

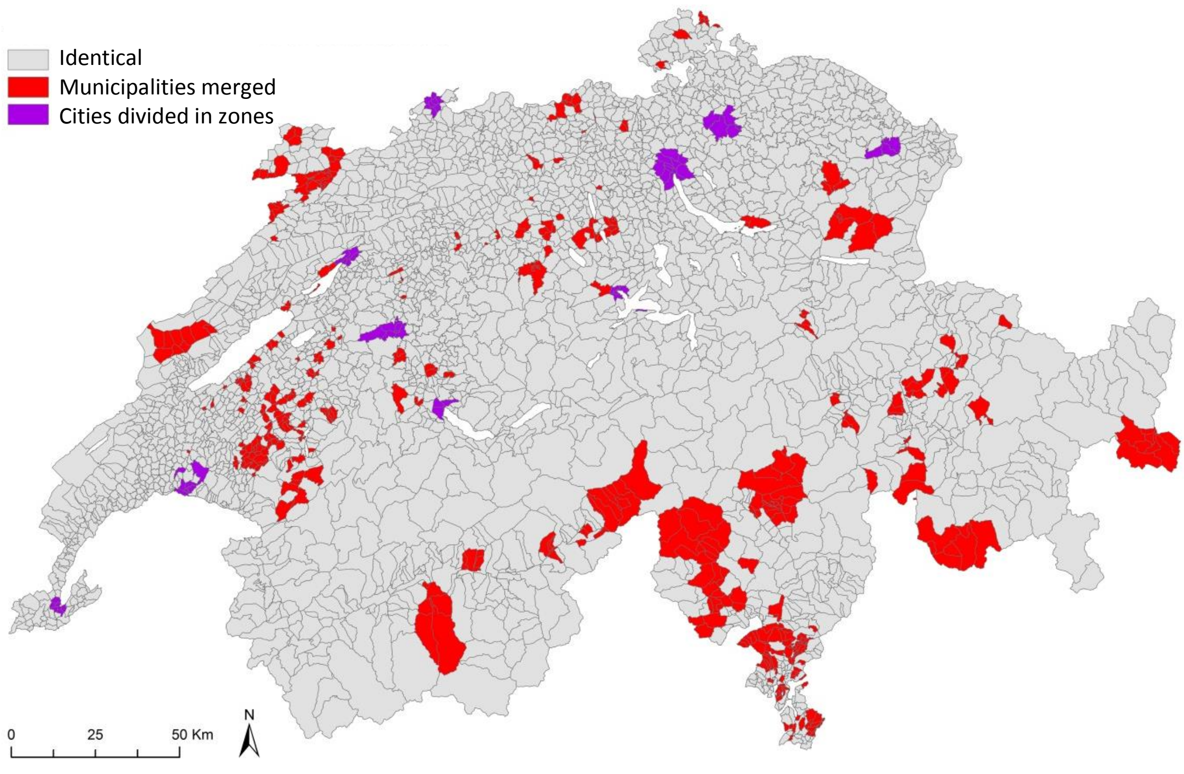
7 Using Dropbox is for users optional; to work in a team, this can be a folder in a local network (e.g. NAS, server) or a FTP-Server.

2 Swiss Case Study

2.1 Area and aggregation level

The Swiss Case Study 2013 covers the whole area of Switzerland on a spatial scale of municipalities as of the year of 2000. Additionally, five cities with airports and the ten largest cities like Zurich, Bern, Basel, Geneva, or St. Gallen have been divided in further subzones (in total 2949 analysis zones). These zones correspond to the zoning level of the National Passenger Transport Model (NPVM). Therefore, the zoning used for the Swiss Case Study is slightly more detailed as the actual official municipalities (see Figure 6).

Figure 6 Differences between NPVM zones and official municipalities 2010



For visualization and to separate base data for the specific airports, its perimeter have been digitalised by using land use perimeters from CORINE Land Cover[8] 2006 data, and the official perimeter[9] in the specific case of Zurich airport.

[8] The European Environment Agency (EEA)

[9] Kantonaler Richtplan (Beschluss des Kantonsrates (Festsetzung) Stand: 24. März 2014) http://maps.zh.ch/

2.2 Data

As base input, various publicly available datasets of the Swiss Federal Statistical Office (FSO) are used, as well as a database including information of different sources describing municipalities (Bodenmann, 2011). The main datasets are listed in Table 1.

Table 1 Datasets used

Dataset	Source	Costs	Purpose
Swiss Federal Population Census 2000 (PopC)	FSO	Included in proAbo (CHF 800.-)	Synthetic persons and households
Swiss Federal Business Census 2001 (BusC)	FSO	Included in proAbo (CHF 800.-)	Synthetic businesses
Micro-Census Mobility and Transport 2010	FSO	Free* (aggregated Data)	Parameter estimation for the creation of a synthetic population
Variables of municipali-ties	different sources (Bodenmann, 2011)	Free* (aggregated Data)	Utility functions (e.g. taxes)
Level of service matrices (time, distance)	NPVM (ARE)	-- (Contract needed)	Distances, travel times
OpenStreetMap (OSM)	Openstreetmap.org	--	Distances, travel times

* data available directly in the provided FaLC-Database of this Template

Service matrices (in this report, generally referred to as distance tables of ARE) are used for simulations as well as for testing the interaction with external transport models. Additionally, generated distances from OpenStreetMap are used to test the impact of potential infrastructure projects such as new motor ways.

Since nearly no micro level data is available and especially since, when available it is very sensitive, a synthetic population of persons, households and businesses has to be built. In a first step, simplified synthetic data is used. This synthetic population can be provided as a template for further case study areas in Switzerland. Later, this data will be replaced by more appropriate synthetic data calculated at IVT Zurich (Müller and Axhausen, 2012a). Alternatively, the synthetisation module could be further developed.

A detailed description of the underlying processes to create the synthetic population, as well as further data used for the Swiss Case Study 2013, is the subject of an according whitepaper of the FaLC documentation (Bodenmann et al., 2014). Information regarding data sources is also mentioned in the meta-data-files to the according input dataset.

3 Dynamic Models

In this chapter, the different dynamic models are discussed. This includes a) demographic events models such as birth and death rates, and b) firmographic events model including business establishment and closing.

3.1 Demographic events

Demographic events model

model type	**probabilistic model**
sources	**Indikatoren der Fruchtbarkeit in der Schweiz, 1950-2050** **Sterberaten nach Alter und Geschlecht 2000-2050** **FSO (BEVNAT, ESPOP), Bodenmann et al. (2009)**
FaLC implementation	**.agentmodel.service.methods.LDMethodsNew_Impl_1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **demographyOn = true**
FaLC tables in DB	**deathtable** **birthtable**
Parameters	**probability of death for old people = 0.33** **age limit for death.probability parameter = 93** Parameters are used to define probability of death for people with age older than ages stored in deathtable. The values above define that mortality of persons with age of 93 and older is 33% (per year).

Depending on the different attributes (like age or civil status) of a person the probability to die or giving birth to a child within a certain period of time differs. Knowing these probabilities for all persons in a certain region, a new number of persons can be estimated for the end of the time period.

After a Monte Carlo Simulation, the model selects persons that will die, or not. In a second step, an additional Monte Carlo Simulation denotes (not died) women giving birth to children in the according period (with probability depending on age of the mother).

input	output
persons in t	persons in t+1
probability of death	
probability of birth	

Please note that the demographic events model directly changes the composition of the according household.

Immigration model

model type	**probabilistic model**
sources	**-**
FaLC implementation	**.agentmodel.service.methods.EWMethodsImpl_1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **immigrationOn = false**

Currently, this model is switched off. It calculates numbers of immigrants and generates households for them with status immigrants.

Household separation model

model type	**probabilistic model**
sources	**Population Census 2000 (FSO)** **Beige (2008)** **Bodenmann et al. (2009)**
FaLC implementation	**.agentmodel.service.methods.HHSeparationMethodsImpl_1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **hhSeparationOn= true**
FaLC DB tables	**umzugsraten_n_alter** (rate of children that leave home) **scheidung_n_jahr** (divorce rates)

Considering a household, the probability of changes depends on the persons (and respectively their attributes) living in this household. The household separation model includes two processes:

Children leaving their parental household.
Regarding a household consisting of a young adult (i.e. 20 years old) and his parents, the probability that the young adult leaves the parental home is very high. On the one hand such an event would cause a new single-person household and on the other hand the parental household type would change from “3 person family” to “couple”. FaLC calculates for each person in a household with ‘child’ status according to their current age (the probability that children will leave the household and create a new one increases with age).

Couples divorce.
Other separation events that could occur in households are divorces. Knowing the probability of this change for all households makes it possible to estimate the new number as well as the new structures of the households in a region. FaLC calculates the lifespan for each household of couples according to: depending on the duration of couples living together and the probability of their separation, couples divorce; as consequence, the according household is “closed” and two new (single-person) households generated.

input	output
households in t	households in t+1
probability of exit of household	single persons changing household t+1

The new single households are important, as they potentially form new households (couples) in a next step (see household formation model).

Household formation model

model type	**Discrete choice model**
sources	**Beige 2008** **(see also Killer and Axhausen, 2012)**
FaLC implementation	**.agentmodel.service.methods.HHFormationMethodsImpl_1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **hhFormationOn= true**
Parameters	**mate probability = 0.1** (probability that a single-person gets in relation to another person) **minimal distance = 2 [km]** (distances of less than 2km are set to 2 km)

In the event of a couple deciding to move in together, a new household must be chosen. So either one of the partners moves into the other's household or the couple is allocated to a new household. To model this choice, push and pull factors for all opportunities should be known (or estimated) to select the most likely household.

In the current implementation, this process was simplified. First, FaLC generates probability intervals for locations of the new household according to the number of households and distances to the locations with potential household members. In a second step, for each male person looking for a partner (a certain percentage of males living in single households) the model looks to find a female partner. As default values, 10% of men in single households are looking for a new partner.

input	output
households in t+1	households in t+1
single persons changing household t+1	
different variables	

Currently, size of the household does not have any influence in the relocation process. Therefore, the number of households and household size haven't been calibrated yet. In one of the next steps, demographic changes will be addressed and revised. The calibration of household types will be the subject of this future research work.

Household relocation model

model type	**probabilistic model**
sources	**Population Census 2000 (FSO)** **(Bodenmann et al., 2009)**
FaLC implementation	**.agentmodel.utility.UtilityMoveSwiss_2_weighted1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **utilitiesOn = true**
FaLC property files	**umzugsraten_n_alter** (migration rates)

In Switzerland about 5% of all households decide to move per year, but the probability to move is not equally distributed among the households. The household composition, structure and the characteristics of the persons living in a household are decisive for the probability to move.

In the current implementation, for each household FaLC calculates the average age from all earners. According to the average age, the probabilities are used to define whether a household will move or not.

input	output
households in t+1	staying households in t+1
probability to move	moving households in t+1

In fact, to select a moving household, all factors like size and jobs of household members of a certain household should be taken into account. The implementation of a more adequate relocation model considering household types will be subject of future work.

Household location choice model

model type	**discrete choice model**
sources	**Schirmer et al. (2011)**
FaLC implementation	**.agentmodel.utility.UtilityMoveSwiss_2_weighted1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **utilitiesOn = true**

Once a household has decided to move, the next step is to choose its new location. Doing so, all household members have their own preferences depending on factors like distance to work/school, distance to leisure or shopping facilities, socio-cultural aspects, rental price, accessibility, etc. The choice of the new location must consider the preferences (in terms of utility functions) of all household members. Considering all the factors that influence the location choice, a utility function can be defined as the sum of the utilities of all household members. Indeed, to keep things simple, the current implementation of FaLC calculates the utility function for only one person, the head of the household. The head of the household is always an adult person, ideally with a job. If there are several persons in a household possible as head of the household, the head is randomly chosen out of the possible persons.

The following table shows the parameters used in the Swiss Case Study 2013. In general, increasing distances to workplace and last location have a (strongly) negative impact on the attractiveness of a location. In contrast, accessibility has a positive impact.

Parameter	assumed β
Distance to last location [km]	-1.590
Distance to workplace [km]	-1.590
Portion of households of the same size (within same zone)	0.016
Accessibility of Public Transport (logarithm)	0.056
Accessibility of Private Vehicular Transport (logarithm)	0.056

Parameters for the utility function are based upon the final model proposed by Schirmer et al. (2011), but due to a lack of data, the parameters had to be adapted for FaLC: a) the impact of the distance to the last location is assumed to be equal as the impact of the distance to the workplace; b) the estimated results for the accessibility variables have to be in common sense positive values, as Schirmer et al. (2011) has a negative value for private vehicular transport, the impact of both variables is assumed to be the mean value of Schirmers results.[10]

Accessibility variables are calculated based on the potential approach. In this approach, the activity points are weighted according to their attractiveness (travel time to reach the activity points). The weighting follows over increasing distance or travel time a negative exponential function:[11].so that activities in the immediate vicinity of the observed point are more strongly weighted than points at a larger distance (see Bodenmann, 2011).

input	output
moving households in t+1	location of households in t+1
different variables	

In a second phase of the project, FaLC aims to also include housing markets and the processes of renting flats and houses. Indeed, there is some research needed, and the concept to integrate markets has to be developed.

10 We assume that, due to the strong connection between the accessibility variables, there are strong interdependences between the estimated parameters resulting in biased results. Therefore, to keep the overall impact of accessibility constant, the mean value of the estimated parameter has been used.

11 $A_i = \sum_m \sum_j O_j \times e^{\beta \times t}$, with A_i = accessibility in municipality i; j = locations in the Case Study Area, m = means of transport (car, public transport), O_j = number of opportunities in j (e.g. residents or employees), t = travel time (generalized costs) with modus m between i and j [min.], β= 0.20.

3.2 Firmographic events

Economic development model

model type	**probabilistic model**
sources	**FSO, seco, Bodenmann 2006**
FaLC implementation	**.agentmodel.service.methods.BusinessEconomicDevImpl**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **firmographyOn= true** **firmography.properties**

Based on (exogenous global) economic indicators, business growth, establishments, and closures are modelled (see following model description). This model is an intermediate step that calculates expected control totals needed in the sub-model for the firmographic events. The results are the number of firms and workplaces provided per economic sector.

Main source for the exogenous economic indicators is the employment statistics of BFS. For the future, a unemployment rate of 3.3% has been assumed. Based on the predicted active population in the future (BFS scenario “mean” for the population of Switzerland 2010-2060) control totals for employees can be assumed for the same period. Hence, in the current FaLC version, the development of firms and employees are related to the (future) development of the residents.

input	output
workplaces in t	workplaces in t+1
firms in t	firms in t+1
economic development	

The assumption of the future number of employees is a very rough assumption. Indeed, at this stage, a more reliable concept is missing and has to be set up with according specialists. The proposed approach is based on the assumed future development of residents and persons in working age. In general, this is certainly the right base for this model.

Firmographic events model

model type	**probabilistic model**
sources	**FSO, seco, Bodenmann 2006**
FaLC implementation	**.agentmodel.service.methods.BusinessEconomicDevImpl**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **firmographyOn= true** **firmography.properties**
FaLC DB table	**closures_migration**

Based on economic development defined in the previous model, business establishments and closures are modelled. FaLC calculates for each business a duration of existence. According to duration and a probability table, businesses are closed or not. If a business is closed, all employees become unemployed.

Sector in FaLC		Probability to close
1	agriculture	3.63%
2	production	3.74%
3	wholesale	5.09%
4	retail	5.67%
5	gastronomy	8.41%
6	finance	4.39%
7	services fC (for companies)	4.39%
8	other services	4.39%
9	others	4.80%
10	non movers (authorities, schools, etc.)	4.80%

Then, for each sector and assumed future number of companies, FaLC generates new companies until the control total prepared in the economic development model is reached.

input	output
workplaces in firms in t	workplaces in firms in t+1
distribution of firm types/growth	

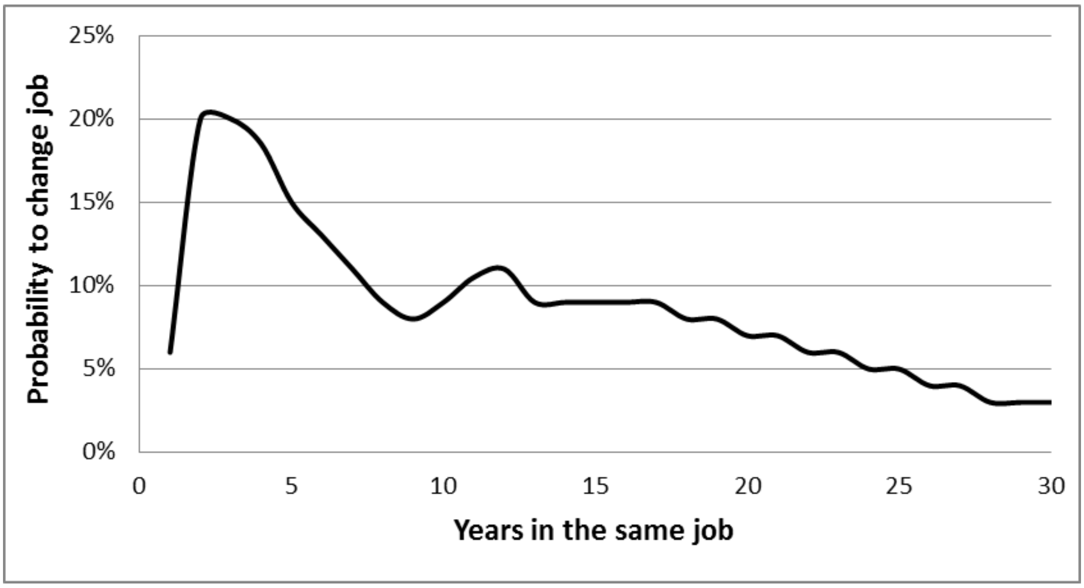
Quitting employees model

model type	**probabilistic model**
sources	**Beige 2008**
FaLC implementation	**.agentmodel.service.methods.BusinessQuittingEmpImpl**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **quittingEmplOn= true** **firmography.properties**
FaLC DB table	**employement_durations**

Since it is very unlikely that a person conducts the same job (in the same position) for the duration of the entire working life, estimated probabilities of job changes are necessary. This allows the reasonable representation of employee-flows between firms and respectively the number of vacancies and unemployed persons. Job changes also occur when a young person coming from school starts the professional life.

The following diagram shows the assumed development of the probability to leave a firm depending on the duration that an employee was working in this firm.

Figure 7 Probability to change the job



Source: Beige (2008)

For each employee, age and job duration is calculated. If the age of an employee reaches a certain maximum age (now 65), the employee automatically quits the job. All other employees quit their job according to the probability based on the job duration.

input	output
job of persons in t	persons keeping their job in t+1
probability of job changes	persons looking for new job in t+1

Joining employees model

model type	**discrete choice model**
sources	**Beige 2008** **(see also Killer and Axhausen 2012)**
FaLC implementation	**.agentmodel.service.methods.BusinessJoiningEmpImpl**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **joiningEmplOn= true** **firmography.properties**
Parameters	**EMPLOYEE = 2** **CEO = 1** **MAX_LEVEL_EMPL = 0.95**

The choice of a workplace mutually depends on factors like education and position of a person, the distance to workplace or the wage level of the business. Considering these factors the probability of choosing a certain workplace can be estimated, and for every person an appropriate workplace can be assigned. In absence of specific parameters, at this stage, FaLC only uses the potential commuting distance to allocate jobs. Based on the results of Beige (2008), the distance is weighted as an exponential function with $\beta=0.1$.

First, FaLC generates a list with empty workplaces for all locations. Second, the calculation goes randomly through all locations and for each business in each location, it tries to allocate workers for all free jobs. FaLC distinguishes between employees (2) and CEO (1), this gives the opportunity (in a later step of FaLC) to introduce variables of the owner of person driven firms.

The joining employees model needs an additional specification for the case that in the Case Study Area are not enough persons available to cover all jobs with employees. In this case, we assume that an according percentage of the jobs will remain unstaffed. Additionally, it is implausible that in extremis all residents have a job. In consequence, an additional parameter for the maximum level of employment *MLE* (MAX_LEVEL_EMPL) has been introduced.

FaLC calculates first the level of employment LE in the case Study Area based on the number of jobs J and the number of residents R_{wa} in the working age:

$$LE = \frac{J}{R_{wa}}$$

if $LE \leqq MLE$ then all free jobs will be filled

if $LE > MLE$ then the free jobs will be filled with a certain probability P_E

$$P_E = \frac{(R_{wa} \times MLE) - E}{J - E}$$

With

J	Sum of jobs in the Case Study Area
E	Sum of employees in the Case Study Area
R_{wa}	Sum of residents R_{wa} in the working age (18 years - 64 years)
LE	Level of Employment
MLE	Maximum Level of Employment (defined by parameter MAX_LEVEL_EMPL)
P_E	Probability that a free job will be chosen by a new employee (range 0%-100%)

As soon as FaLC discovers that in the Case Study Area are not enough persons available to cover all jobs with employees, the free jobs will be filled only with a certain probability P_E by using a Monte Carlo Simulation. As in this status of the project FaLC does not consider immigration, the maximum level of employment has been fixed to a very high rate of 95%.

input	output
unoccupied workplaces in businesses in t+1	occupation of workplaces in t+1
persons looking for new job in t+1	
different variables	

In a second phase of the project, FaLC aims to include in the Workplace Choice Model, also a model of the labour market. Indeed, there is some research needed and the according concept to integrate markets has to be developed.

Firm relocation model

model type	**probabilistic model**
sources	**Bodenmann 2011**
FaLC implementation	**.agentmodel.utility.UtilityMoveSwiss_2_weighted1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **utilitiesOn = true**

In Switzerland, an approximate total of 3% of all firms decide to move per year. Similar to the household relocation, the probability to move is not equally distributed among the businesses. Factors like sector, business and market size, available employees, etc. influence the probability of relocating.

In the current implementation, the probability for a firm to move depends only on its sector. The following table shows the yearly probability of moving:

Sector in FaLC		Probability to move RR_S
1	agriculture	0%
2	production	1.35%
3	wholesale	2.22%
4	retail	1.40%
5	gastronomy	1.14%
6	finance	2.26%
7	services for companies (fC)	2.26%
8	other services	2.26%
9	others	1.77%
10	non movers (authorities, schools, etc.)	0%

The probability for agriculture to move is a special case. We assume that this sector remains relatively static. Therefore, in this state of FaLC, this sector will generally not be modelled. The according probability to move was therefore set to zero.

input	output
firms in t+1	staying firms in t+1
probability to move	moving firms in t+1

Firm location choice model

model type	**discrete choice model**
sources	**Bodenmann (2011)**
FaLC implementation	**.agentmodel.utility.UtilityMoveSwiss_2_weighted1**
FaLC property files	**app-config.xml** **org.falcsim.agentmodel.app.domain.RunParameters** **utilitiesOn = true**

For all moving firms, this model allocates a new location considering sector, size, age and other firm specific variables. In a later project phase, the location choice process may also include preferences of the owner(s) and business. Especially for (small) person driven firms, these factors cannot be neglected (Bodenmann, 2011).

The following table shows the parameters for the utility function based on estimation results published in Bodenmann (2011).

Parameter	assumed β by sector							
	2	3	4	5	6	7	8	rest
Distance (Lambda)	-0.081	-0.080	-0.074	-0.061	-0.122	-0.068	-0.099	-0.076
Distance (BETA)	0.633	0.352	0.331	0.987	1.480	0.752	2.050	0.606
Land price for residential use	-0.015	-0.011	0.000	-0.003	-0.084	-0.012	-0.076	-0.014
Density in Building Zones	-0.022	-0.015	-0.003	-0.018	-0.040	-0.032	-0.094	-0.025
Quote of persons with higher degree	0.037	0.009	0.028	0.160	0.115	0.086	0.066	0.056
Large or intermediate city	0.126	0.109	0.074	0.366	0.513	0.287	0.721	0.194
Rate of employees within same sector	0.022	0.009	0.006	0.041	0.058	0.024	-0.015	0.016
Index of diversity of sectors	0.075	0.030	0.026	0.045	0.274	0.086	0.076	0.060
Tax burden for holding companies								-0.287
Tax burden for partnerships	-0.041	-0.033	-0.031	0.008	-0.159	-0.073	-0.077	-0.041
Tax burden for joint stock companies	-0.095	-0.071	-0.030	-0.204	-0.388	-0.152	-0.230	-0.106
Motorway connection	0.025	0.045	0.016	0.033	0.101	0.064	0.149	0.049
Rail connection	0.052	0.048	0.032	0.179	0.122	0.069	0.295	0.061
Accessibility to employees	0.030	0.018	0.017	0.028	0.095	0.040	0.171	0.033
Cantonal business development	0.136	0.083	0.065	0.215	0.281	0.157	0.345	0.119

sectors: 1 agriculture, 2 production, 3 wholesale, 4 retail, 5 gastronomy, 6 finance
7 services-fC, 8 other services

The largest impact of the variables has the distance to the last location of the firm. With increasing distance, potential locations loose considerably on attractiveness. Additionally, strong positive impacts have alternatives representing cities and business development. Detailed information regarding the parameters and their ranking are available in Bodenmann (2011).

input	output
moving firms in t+1	location of firms in t+1
different variables	

In a second phase of the project, FaLC aims to include housing markets. Indeed, there is some research needed and the according concept to integrate markets has to be developed.

4 Special Modules

Additionally to the core functionality of FaLC – the dynamic (yearly) cycles – the FaLC software offers different other functionalities. The models used for the Swiss Case Study and its assumptions are described in the following. These modules involve transport simulation possibilities, use of subset of locations, land use restrictions, and growth limitation.

4.1 Transport Simulation Module

The internal Transport Simulation Tool provides data for the calculation of values assessed by the utility functions of different choice models. First and foremost, accessibility variables and distance variables (measured in length on transport network or travel time). Initially, the focus will lie on macroscopic private car transport network as well as pedestrians.

Additionally, due to the fact that most partners in the consortium use MATSim (MATSim development team, 2007) and/or VISUM (PTV, 2011), interfaces to these two transport modelling systems are implemented.

ARE implementation generally uses data of the Swiss National Passenger Transport Model (NPVM). The integration of these data is done by a module that allows to import distance and time tables from NPVM. All calibration tests base on distances and travel times from NPVM (for private as well as public transport).

The internal transport simulation tool, consisting of a shortest path algorithm to update distances and travel times between locations, and to calculate accessibility variables for each location, is documented in an implementation guide (Zeiler et al., 2014).

Additionally, the current version of FaLC includes the possibility to choose the distances used in FaLC models. This allowed the impact of new transport infrastructure to be tested (see scenario 1 in chapter 6).

4.2 Subset of relevant locations

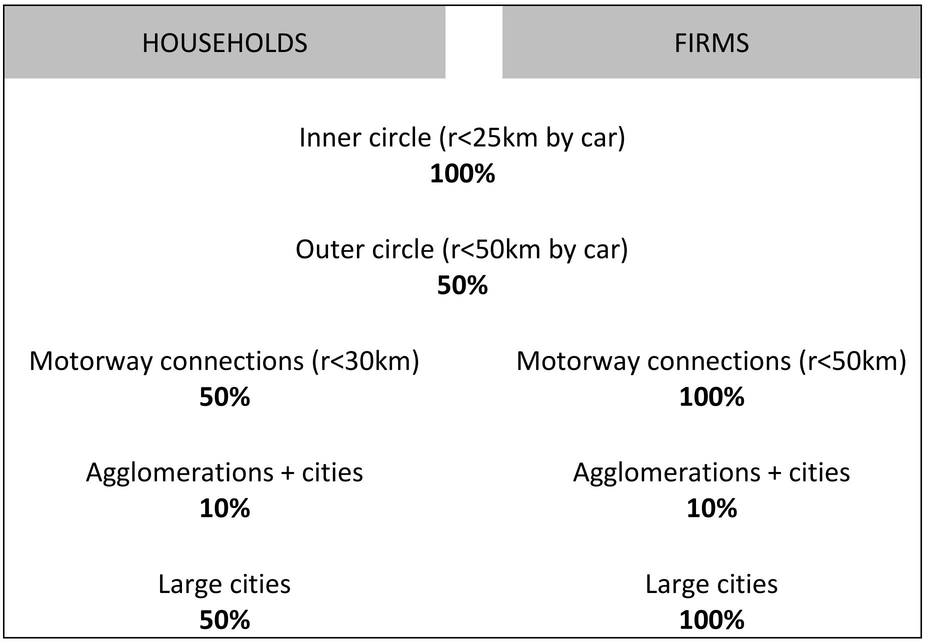
In order to perform the simulation process and reduce the number of calculations as well as the global running time, FaLC generates for each yearly cycle different subset of locations by applying a series of conditions for important locations in the relocation module.

The potential locations where any household or firm located in “A” could be relocated are influenced by a series of conditions, following the Monte Carlo methodology.

FaLC uses the official classification of FSO for large cities and agglomerations. Motorway connections were however in advance calculated and added to the location table through GIS analysis. The conditions used for this purpose are represented in Figure 8.

The set of alternatives is implemented by default in order to perform the simulation process and reduce the number of calculations as well as the global running time. Nevertheless, this module can be activated/deactivated by the user in the FaLC parameter file (run.properties).

Figure 8 Implement conditions for relevant locations



In order to avoid white noise effects due to different sets of alternatives in the multiple runs (chapter 5.6), the current implementation of FaLC can save the sets of precalculated sublocations by year. These sets are stored in the database and FaLC and are used congruently in all following runs.

Figure 9 Set of alternative locations to relocate firms from Luzern (example)

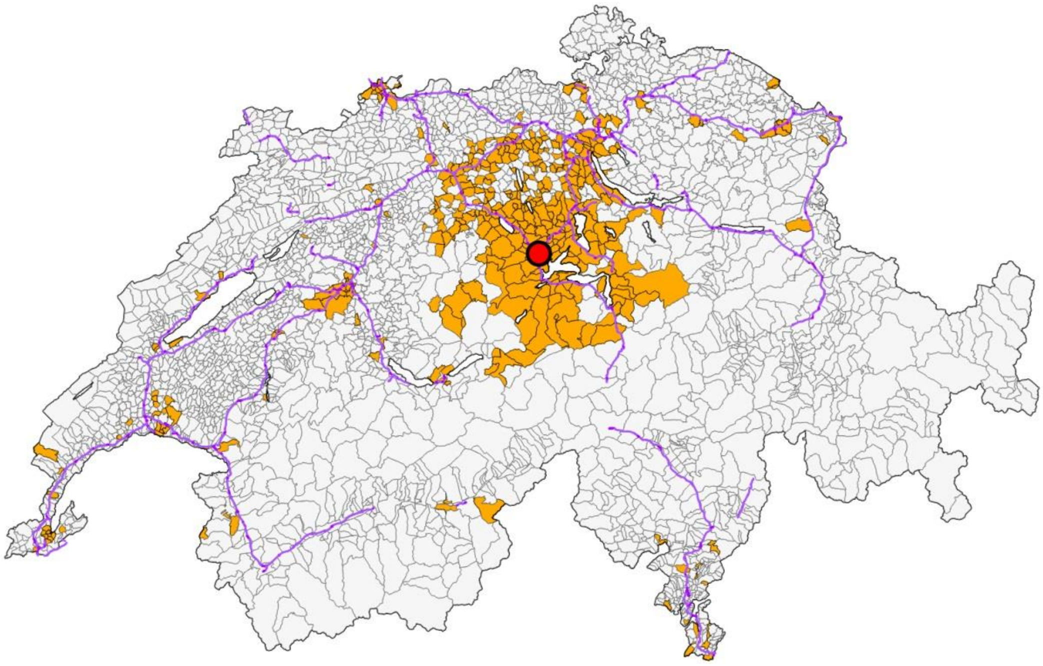


Figure 9 presents an example of the set of alternatives (orange locations) which will potentially allocate firms moving from Luzern Innenstadt (red circle). As we can see, the big cities in Switzerland as well as all the motorway connections (purple lines) in less than 50 kilometres from Luzern Innenstadt are considered.

The average number of subset alternatives in each calculation is around 350 for firms and households (instead of 2949 locations in the whole Case Study Area). This results in considerably faster simulation times of a factor 10.

4.3 Limitations based on land use restrictions

In reality, land-use regulations and territorial restrictions limit the number of residents (households) and jobs (firms) in a location, especially; this holds for cities and airport zones. An absence of according limitations can lead to unlimited growth in these locations. Therefore, an according indicator has been introduced in FaLC. This indicator can be used as a hard limit (a household can or cannot choose this zone as an alternative in the relocation process), or the indicator can just be used to decelerate migrations in a given zone.

FaLC compares each year the floor area which is occupied by the FaLC population with the maximum floor area that can be built in the zone (or municipality). In the event that the occupied floor area reaches the maximum floor area, no additional persons can move in the zone.

The current implementation of FaLC distinguishes two user types u: residents (r) and jobs (j). Therefore FaLC will control the following rule for each location for different user types:

$$occFA(\ell,u) \quad <= \quad \Sigma z \; maxFA(\ell,u,z)$$

1) for $u=r$
2) for $u=j$
3) for $u=r+j$

with:

$occFA()$	occupied Floor Area (by location ℓ and use type u)
$maxFA()$	maximum Floor Area (by location ℓ, use type u, zone type z)
ℓ	locations in the Case Study Area
z	zone types (see table 1)
u	user types: r = residents, j = jobs

The Floor Area occupied (occAF) by the users r and j is calculated by

$$occFA(u=r) \quad = R * FApp(u=r)$$
$$occFA(u=j) \quad = J * FApp(u=j)$$

with:

R	sum of residents in the location (municipality)
J	sum of jobs in the location (municipality)
$FApp(u)$	Floor Area per person [m2 per Person]

The Floor Area per person ($FApp$) reflects the gross floor area that a person (as a resident or a worker) usually occupies. The assumed $FApp$ are generally derived from data of BFS[12] (Altwegg et al., 2003), Gilgen (2001), Huber (1992). Although some additional assumptions have

[12] Monet indicator, see www.bfs.admin.ch/bfs/portal/fr/index/themen/21/02/ind32.indicator.70401.3212.html

been made: e.g., in Gastronomy, we assume 30 m2 per room and 0.46 jobs per room[13]. This results in about 65 m2 gross floor area per job (taking into consideration the hotel room as well as additional areas for restaurant, reception, and so on).

Table 1 Assumed Floor Area per person (*FApp*) by simulation year

entity	sector in FaLC	Assumed Floor Area per person [m2/Person], by year 2000	2010	2020	2030	2040	2050
residents in city	91	39	44	46.5	49	50	51
residents in agglomeration	92	44	49	51.5	54	55	56
residents in small cities	93	44	49	51.5	54	55	56
residents countryside	94	49	54	56.5	59	60	61
job agriculture	1	10	10	10	10	10	10
job production	2	75	75	75	75	75	75
job wholesale	3	120	120	120	120	120	120
job retail	4	80	80	80	80	80	80
job gastronomy	5	65	65	65	65	65	65
job finances	6	40	40	40	40	40	40
job services for companies	7	35	35	35	35	35	35
job other services	8	45	45	45	45	45	45
job others	9	50	50	50	50	50	50
job non movers	10	10	10	10	10	10	10

Assumptions based on Gilgen (2001), Huber (1992)

The Monet indicators of BFS (Altwegg et al., 2003) show that the occupied floor area per person significantly increased over time. Monet indicators state between 1980 and 2000 a constant augmentation in the occupied floor area of 5m^2 per decade. In 1980, each resident occupied 34m^2; two decades later, in 2000, residents occupied 44 m^2 per person. In FaLC, the same growth is considered till 2020. After 2020, a smaller growth is assumed (2.5 m^2 per decade).

The maximum Floor Area (*maxFA*) is calculated by multiplying the area A of zone type z with the maximum Utilization Factor (UF) and the maximum share of the user type:

$$maxFA(u{=}r,z) = A(z) * UF(z) * ms(u,z)$$
$$maxFA(u{=}j,z) = A(z) * UF(z) * ms(u,z)$$
$$maxFA(u{=}r{+}j,z) = A(z) * UF(z) * 1$$

13 Referring to data from Steigenberger Hotel Group for 2007 (www.steigenbergerhotelgroup.com) and Hotelfachschule Thun (www.hfthun.ch).

with:

maxFA()	maximum Floor Area (by use type, zone type)
A(z)	Area of zone type *z*
UF(z)	maximum Utilization Factor in zone *z*
ms()	maximum share that a certain user type can achieve in zone type *z*
u	user types: r = residents, j = jobs

Table 2 Assumed Utilization Factors (UF) per building zone type (ARE)

code **	zone type	max. UF	usual share of use resident.	work		maximum share of use Resident. u = r	Jobs u = j
z		UF(z)				ms(u,z)	ms(u,z)
11	Zone for residential use (Wohnzone)	0.43	94%	6%		100%	10%
12	Zone for commercial and industrial use (Gewerbe und Industrie)	1.00	5%	95%		10%	100%
13	Zone for commercial and residential use (Gewerbezone mit Wohnen)	1.00	50%	50%		75%	100%
14	Core zone development (Kernzone Entwicklung)	1.00	50%	50%		90%	90%
15	Zone for public buildings (Zone für öffentl. Bauten und Anlagen)	0.05	0%	100%	*	0%	100%
16	Protected areas (e.g: Green zones) (eingeschränkte Bauzonen)	0.00	0%	0%		0%	0%
17	Tourism and leisure zone (Tourismus und FreizeitZone)	0.05	0%	100%		0%	100%
18	Zone for transport activities (Verkehrszonen)	0.05	0%	100%	*	0%	100%
19	Special use (weitere Bauzonen)	0.05	0%	100%	*	0%	100%

Assumptions based on calculations for Kt. Solothurn, Appenzell I.Rh., St. Gallen, Zurich
* assumed, as 0 will not reflect reality
** code used in data "Bauzonenstatistik Schweiz" (see ARE, 2012)

The maximum Utilization Factor (UF)[14] is a widely used instrument in Swiss Urban Planning to limit building densities. Assumptions are based on land use regulations in the Cantons of Solothurn, Appenzell I.Rh., St. Gallen, and Zurich. However, as the building zone types are very generalized, large deviations can occur. FaLC can easily integrate additional zone types

[14] In German: Ausnützungsziffer AZ

with information for individual municipalities, cities and regions with more coherent data. Table 2 shows the assumptions that have been made for the current implementation.

Exceptions: higher occupied Floor Area than maximum Floor Area in starting year
The assumptions in Table 2 showed to be too low in large cities (where land use regulation tend to allow more dense settlement) and in agricultural villages (with a relatively large number of residents and employees located outside the officially designated building zones. Generally, this leads already in the starting year to a higher occupied Floor Area than the maximum Floor Area allowed in the zone. In the following years, these locations loose year by year households and firms. To handle this, the three rules have been amended by an additional Floor Area representing the floor area not covered by the zoning plan (and the according assumptions in FaLC):

$$occFA(\ell,u) \quad <= \quad \Sigma z \; maxFA(\ell,u,z) + obzFA(\ell,u)$$

1) for $u=r$
2) for $u=j$
3) for $u=r+j$

with:

$occFA()$	occupied Floor Area (by location ℓ and use type u)
$maxFA()$	maximum Floor Area (by location ℓ, use type u, zone type z)
$obzFA()$	Floor Area outside the considered zoning plan (by location ℓ, use type u)
ℓ	locations in the Case Study Area
z	zone types (see table 1)
u	user types: r = residents, j = jobs

The values for $obzFA(\ell,u)$ are calculated or estimated in advanced and stored in the data base in table obzFA. In the current implementation, $obzFA(\ell,u)$ was calculated based on the status in 2000.[15]

Additionally, we assumed that the maximum Floor Area is at least 10% higher than the occupied Floor Area in year 2000.

In the current implementation, a total of 147 locations are being affected by this rule. They correspond to an important part of Swiss big cities and agglomerations as well as several small locations where an important number are located in the cantons of Bern and Ticino.

This selection of locations are consequently taking benefits of the floor area not covered by the zoning plan (obzFA) designed by regioConcept.

A table containing the 147 locations could be find on FaLC DB chapters (page 73).

[15] $x = (occFA(\ell,u) \times 1.10) - \Sigma z \; maxFA(\ell,u,z)$; if $x > 0$: $obzFA(\ell,u) = x$; if $x \leqq 0$: $obzFA(\ell,u) = 0$;

4.4 Growth limitation

To prevent in rare cases uncontrolled growth in locations over short time periods, a maximum yearly growth in number of residents and employees has been implemented in FaLC. Maximum growth is defined as percentage value. Based on revealed maximum growth in municipalities in Switzerland between 2000 and 2010, values are set to 4% for residents and 25% for employees. Indeed, these values can be changed in the FaLC property file.

At the beginning of the year, FaLC calculates maximum future number of residents and employees for each zone. After all demography and firmography models are processed, FaLC counts current numbers of residents and employees. During relocation, current numbers are updated after each move. In the case that the maximum number of residents for current year is reached, no additional residents can move in the zone. The same rule is checked for employees.

5 Validation of FaLC modules

The validation of results is made by comparing FaLC simulation results with official values from the Federal Statistical Office, FSO (Population Census 2010, Business Census 2008). The following chapters will explain the different steps necessary to validate and calibrate FaLC.

As in the current version of FaLC, assumptions for the models of firms and households are on a very simplified level, the validation of FaLC focuses for the time being on the number of residents and employees in the municipalities.

5.1 General statistics

The according analysis can be understood as a degree of achievement where 100% means "zero differences" or "100% fit" to the public statistics. In the following, two different approaches are used: "Difference by Relative Weight" and the more common "R^2- coefficient of determination".

Validation by Relative Weight

This approach calculates the fit by comparing the sum of relative weights (for inhabitants, employees and firms) of FaLC and FSO (Statistical data for inhabitants in 2010 and Swiss Business Census 2008). The relative weight coefficient shows the main differences between both data sources, taking into consideration the importance of each location related to the whole study area.

$$\mathrm{RW} = 1 - \sum_{i=1}^{n} \mathrm{ABS}\left(\frac{\hat{Y}_i}{\sum_{j=1}^{n} \hat{Y}_j} - \frac{Y_i}{\sum_{j=1}^{n} Y_j}\right)$$

with:

n number of municipalities i and j

Y_i number of residents or employees in municipality j (BFS)

$\hat{Y}_i$ estimated number of residents or employees in municipality j by FaLC

Validation by R2 (coefficient of determination)

The advantage of validation by relative weight is that this approach takes into account the fact that a fit of a large municipality is more important than that of smaller municipalities. Indeed, as most scientific analyses work with the coefficient of determination, we also calculated this more common coefficient.

The coefficient of determination indicates between 0 and 100%, how well data points fit a statistical model by following the adapted equation below:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i \right)^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}$$

with:

n number of municipalities i

R^2 r2 for a certain indicator of a certain run

Y_i result of FaLC for municipality i

Y_i average value of all Y_i for i = 1-3000

$\hat{Y}_i$ average result of all runs for Y_i (usually estimated result of the regression)

$Y_i - \hat{Y}_i$ variation of residuals

$Y_i - \bar{Y}$ variation of Y_i

Overall validation statistics

With a high level of achievement, both, Relative Weight indicator and R^2 show that FaLC fits quite well for residents and especially well for employees. Generally, the values of the Relative Weight Statistics are lower as the ordinary R^2. The fit of the estimated residents and employees is very high with achieving an R^2 of 0.97 and 0.96.

Figure 10 Validation for residents (2000-2010) and for employees (2000-2008)[16]

Relative weight correlation (FaLC - BFS)		
RW_Residents 2010	RW_Employees 2008	RW_AVERAGE
77.0%	**87.1%**	**82.1%**
Coefficient of Correlation		
R2_Residents 2010	R2_Employees 2008	R2_AVERAGE
0.97	**0.96**	**0.96**

Indeed, it has to be mentioned that due to the absence of international migration in the current version of FaLC, the number of residents always will be lower than the observed residents in reality. Despite this constraint, the results are outstandingly good – this was also the reason why the implementation of international migration has been postponed to a later project phase.

[16] Reference run: "2014-04-24-20-33_ARE_0A_10x_2000-2010_run_average" (ARE Network 2005)

5.2 Fit of absolute values by agent groups

The following set of diagrams compares the number of residents and employees predicted by FaLC with FSO official data for the year 2010 and 2008, as well as their classification by ages or sectors of activity. For each group, a related degree of achievement (difference by relative weight or R^2) is also represented.

The double entry diagrams contain a series of dots that represent the number of residents or employees for each municipality (FaLC indicators in the "y" axis and FSO official data in the "x" axis). In the case FaLC export the same value as the official data, the dot is automatically located over the "equal" line.

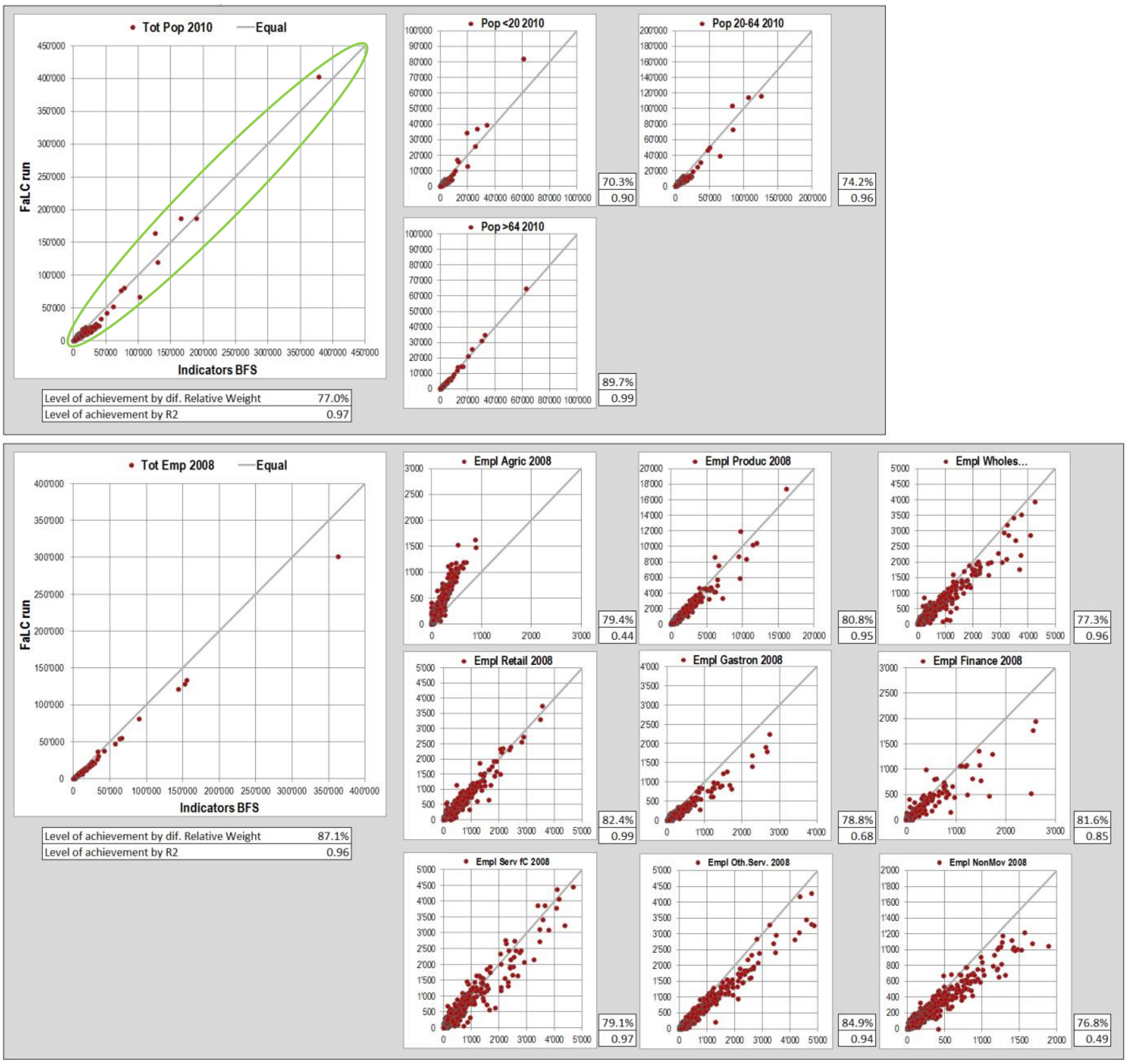
As the green circle in the figure below shows, the more the dots are close to the "equal" line, the better FaLC results fit to reality.

Residents as well as employees show also graphically a good fit. Indeed, also after some calibration processes (see Chapter 5.7), the number of employees still shows a bias between large and small municipalities. Generally, we have systematically too many companies leaving/moving out of the large cities. This has to be corrected in the next months by reducing the relocating firms leaving cities. An according concept is already implemented in FaLC but is currently not used.

Additionally, we observe a very biased fit for the employees in sector 1 (agriculture) and sector 9 (non movers). The sector of gastronomy and hotels (sector 5) shows also too many firms leaving large cities – as restaurants and hotels generally avoid to relocate.

The assumption that these sectors do not move at all may is too restricted and has to be revised in the next steps.

Figure 11 FaLC indicators vs FSO official data for residents (2010) and employees (2008)[17]



[17] Reference run: "2014-04-24-20-33_ARE_0A_10x_2000-2010_run_average" (ARE Network 2005)

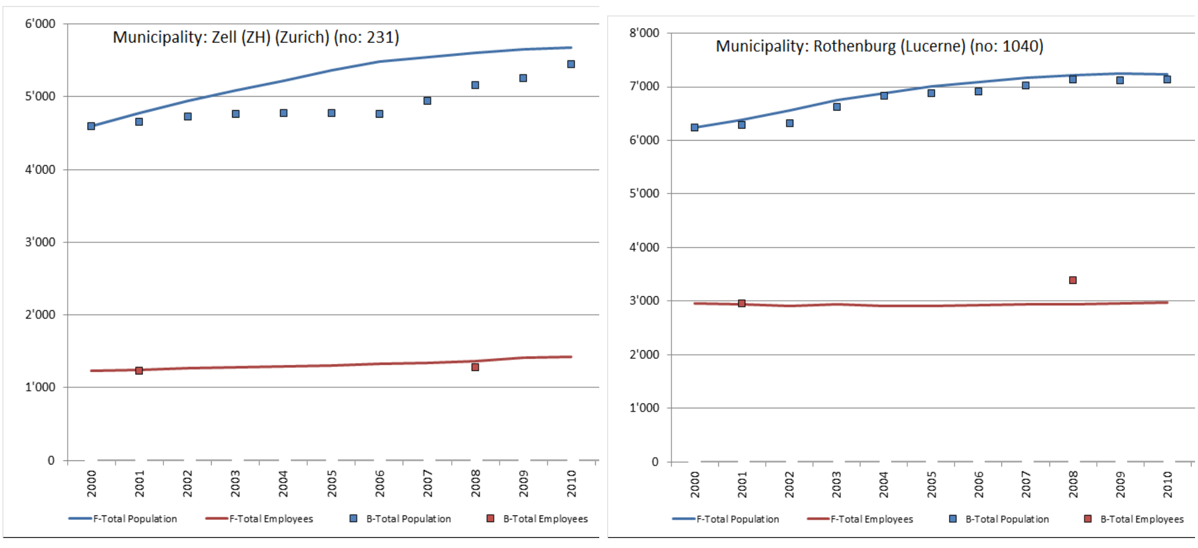
5.3 Validation by municipality

The next figures present a yearly comparison between FaLC indicators (lines) and FSO official data over 10 years (squares) for residents (blue) and employees (red) in six representative municipalities, sorted by number of residents (from 6’000 to 350’000)

In small municipalities (Zell, ZH and Rothenburg, LU) the simulation results fit almost completely with the official data for residents and employees, being less correspondent in the cases of St.Gallen, Luzern, Lausanne and Basel where FaLC slighlty underestimates the number of residents (certainly also because FaLC does not currently apply the immigrants).

Nevertheless, as we can observe in the cases of the cities of Bern and Zurich, where the suburban areas – due to the short distance to the centre and its work places – play a crucial role in the households and firms distribution (e.g: Oerlikon), FaLC results for employees appears underestimated in comparison to the reality in large cities and need to be reviewed. Most important reason for this is the above mentioned relocation rate that is too large for cities. Additionally, it should be noted that talking about the cantonal level, as we will see in the next chapter, FaLC values for Zurich fit quite well with the reality.

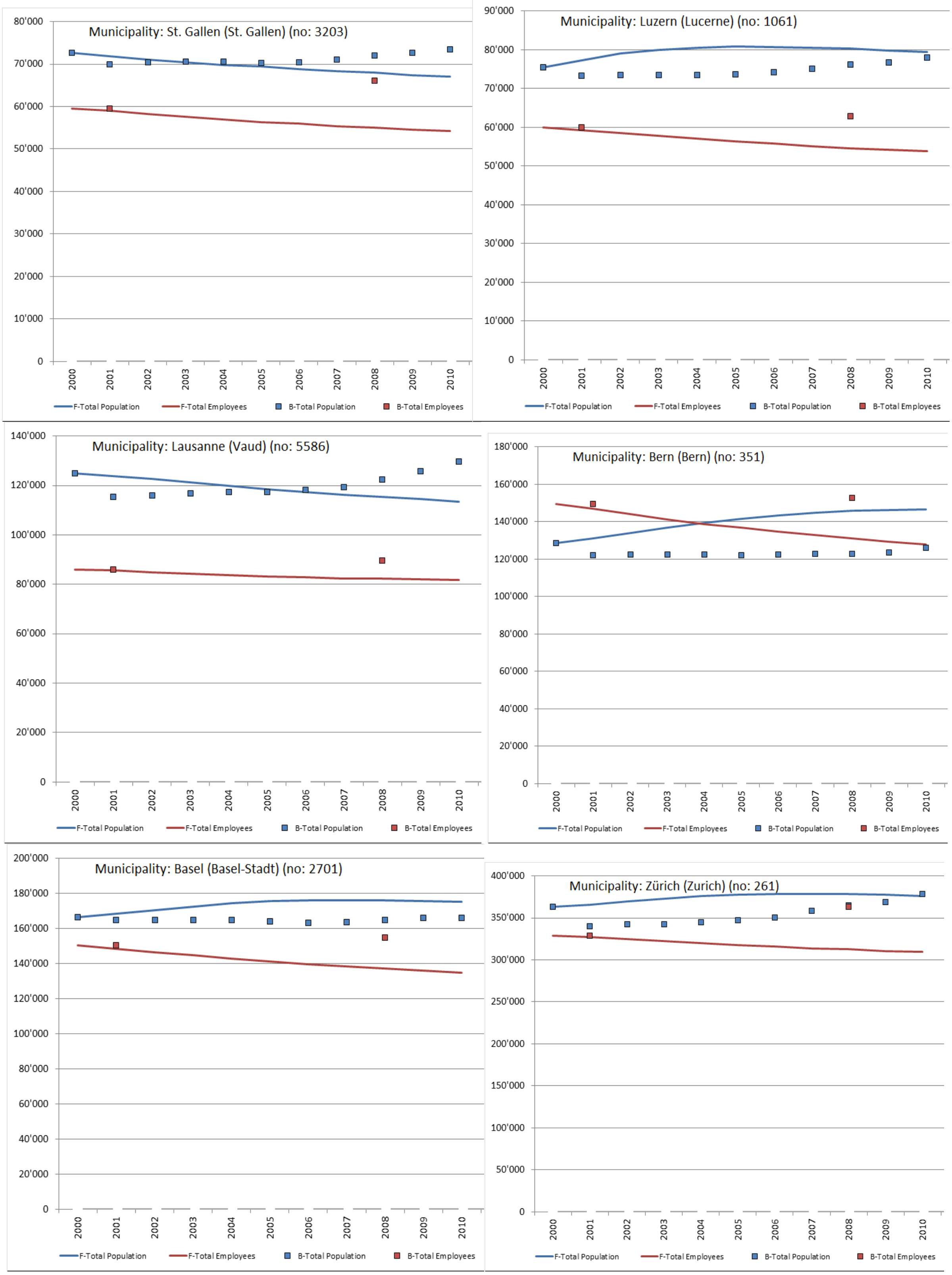
Figure 12   FaLC indicators evolution 2000-2010 in villages



Simulation tools like FaLC hardly can model unexpected and strong increases or decreases due to specific reasons (e.g: new settlements of a large firm). Especially, as the specific reasons for these anomalies often can’t be specified and therefore can’t be implemented in the model.

In general, we state that to advance the models of FaLC, focus has to lie on cities and its interdependences with its surroundings.

Figure 13 FaLC indicators evolution 2000-2010 in cities

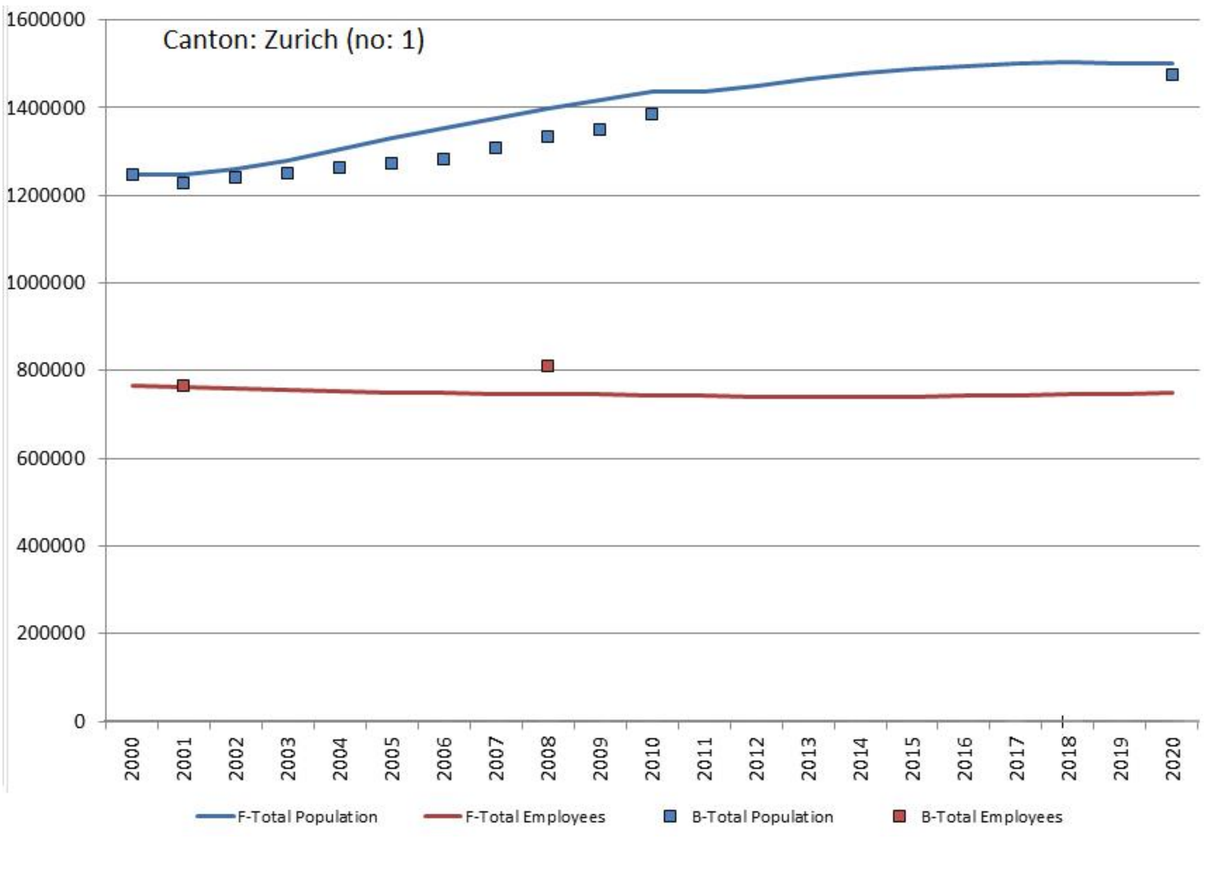


5.4 Validation by canton

On a cantonal and hence, more aggregated level, where the strong interaction effects of "city centre – suburbia" are avoided, we can observe that in general, the indicators fit quite well with reality. In the following diagram, the case of the Zurich canton, match almost perfectly with the reality.

Concerning the year 2020, it should be noted that FaLC fits almost perfectly to the FSO prospective for the future. This holds not only for the Canton of Zurich, but also for most of the other Cantons.

Figure 14 FaLC indicators evolution 2000-2020 for the Canton of Zurich



This result is conform to the common sense that predicting future development of municipalities is nearly impossible – whereas according estimations on the level of regions are much more reliable.

5.5 Spatial distribution of FaLC results

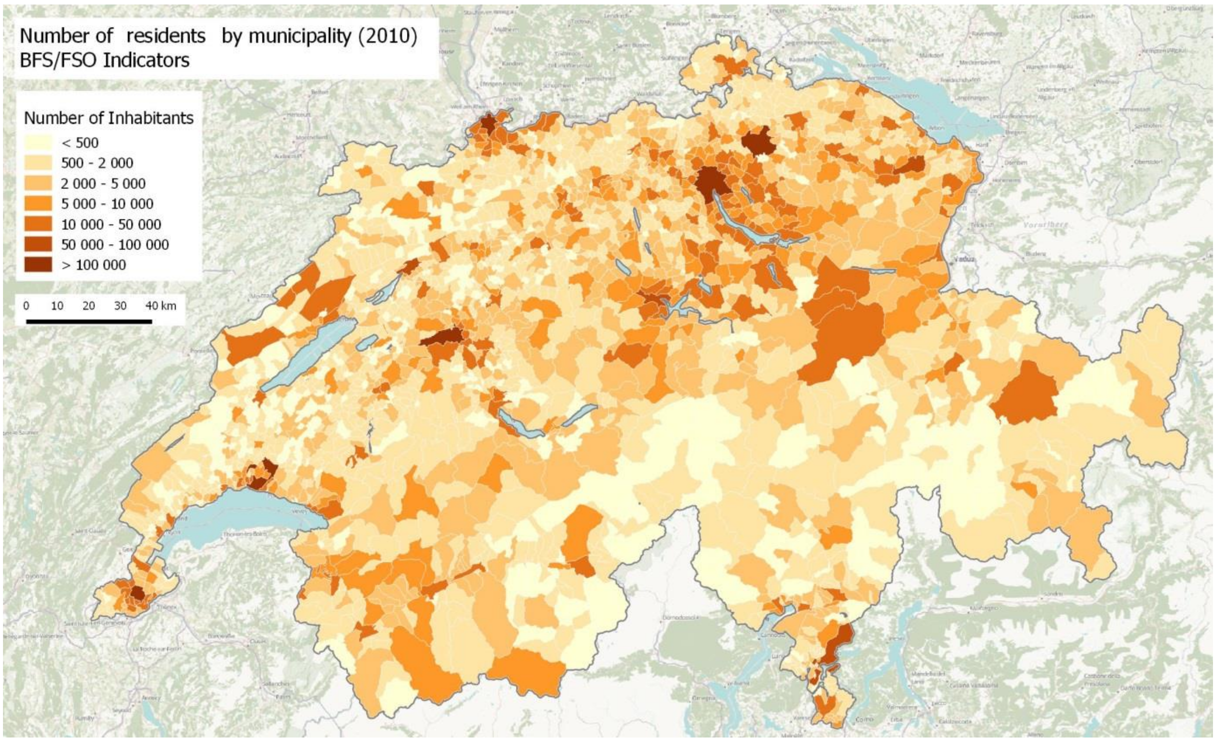
The next four maps (Figure 15 and Figure 16) were created in order to visualise the distribution of inhabitants and employees for the time steps 2008 and 2010 estimated by FaLC and contrasted with the values of the FSO.

The spatial distribution is an important validation instrument to check regionally biased errors. Aim of the simulation results are not only a good fit, but also to avoid regional dependent biases. This can be tested easily by according maps.

As we can observe at first sight, the general spatial distribution of FaLC in both cases are not very distant from the official data (FSO). There are no new centres growing in the surrounding area and there are also no obvious areas with spatial correlated errors. However, in the current status of FaLC, we detect a general relocation of firms and households, and consequently, employees and inhabitants, from the rural areas to the urban zones near cities – but not in the cities. The reason, why cities are not growing is that they (generally) already reached their maximal capacity. In contrast, municipalities near the centre often have also good ratings in the relocation processes and offer free space to live and work.

Nevertheless, some further applications/modifications in the FaLC process have to be implemented to reach a better fit of the simulation results: e.g. more appropriate land-use limitations and market mechanisms. Especially in agglomeration, market effects will be relevant and – supposedly – will lead to less increase of population. In any case, the spatial distribution shows that the urban mechanisms in agglomeration have to be focused in a next modelling step.

Figure 15 Distribution of residents by municipality in 2010. FaLC & FSO



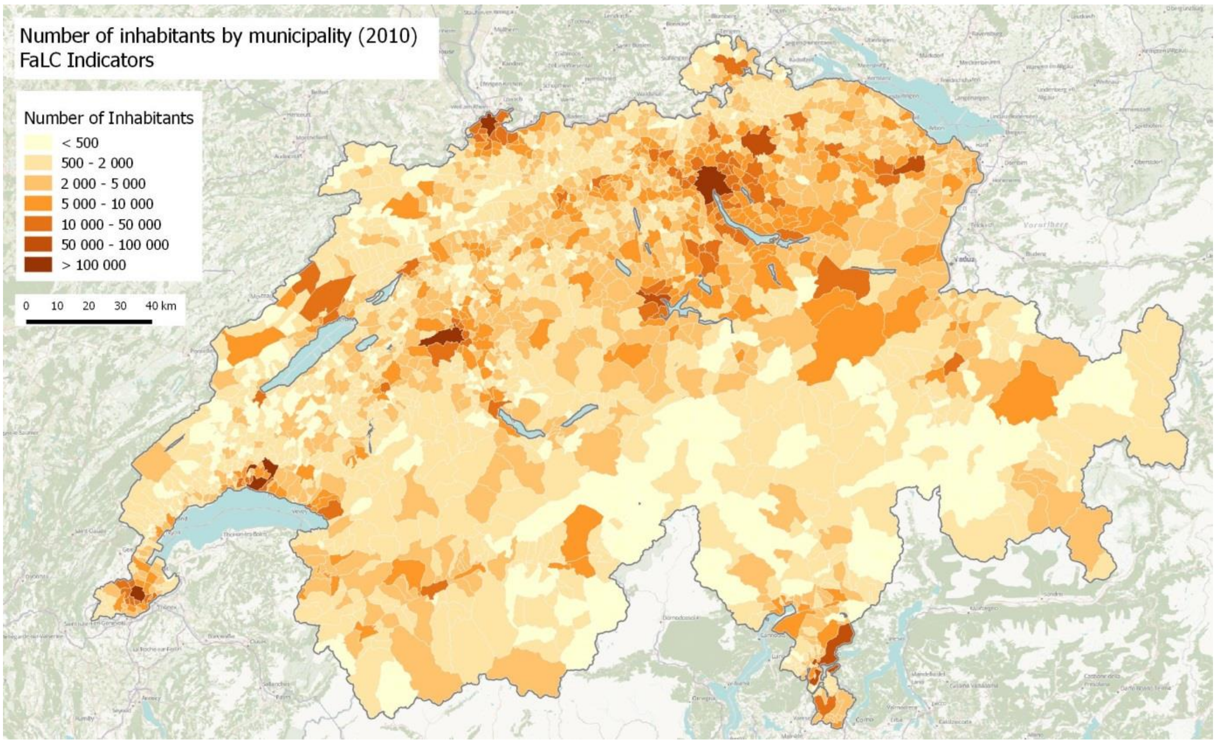
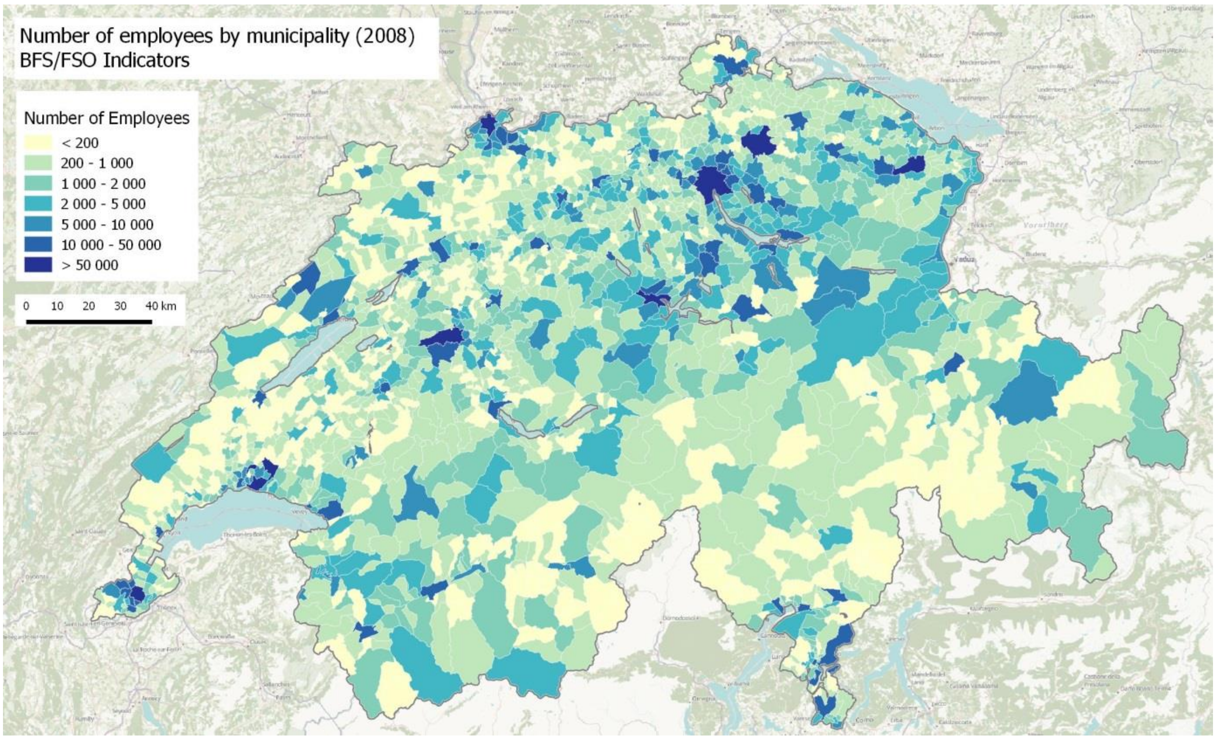
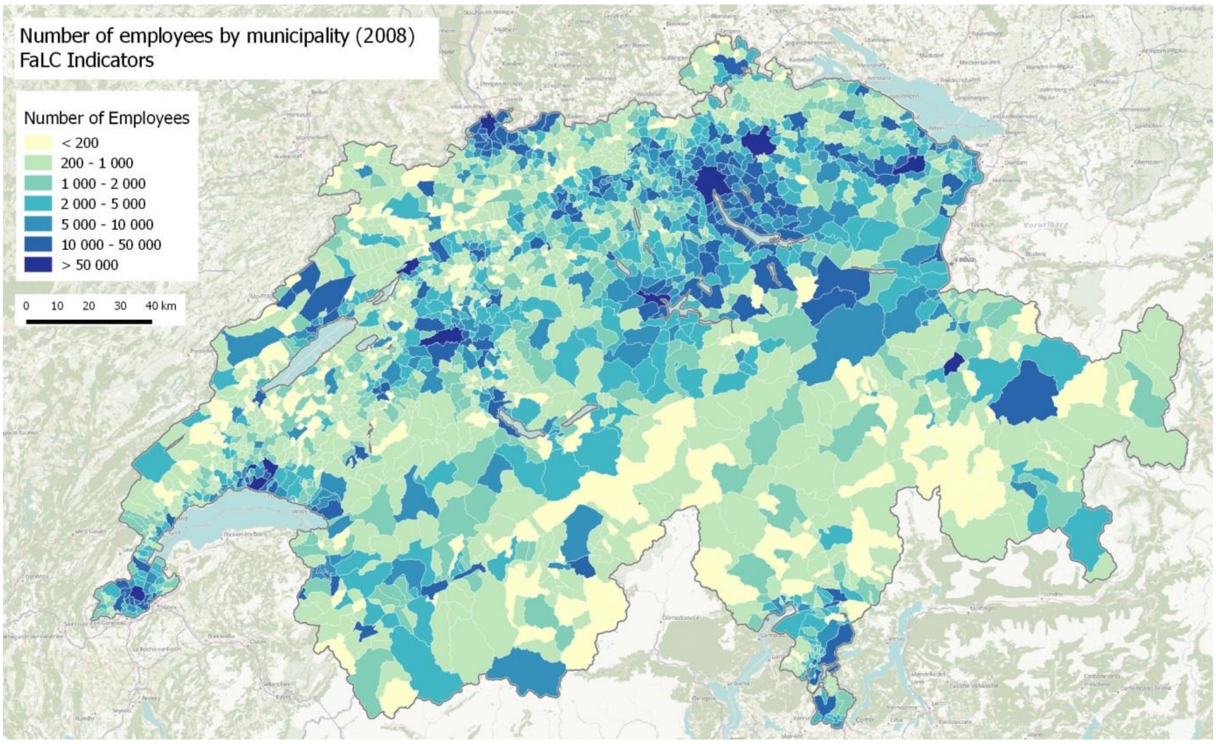


Figure 16 Distribution of employees by municipality in 2008. FaLC & FSO





In order to understand and analyse these differences as well as detect how close FaLC fits to reality, a comparative methodology called "differences of relative weight" is proposed. This concept (as explained in the beginning of this chapter, see Chapter 5.1.1) centralizes the representation of the main differences taking into consideration the importance of each location related to the whole study area.

$$\Delta \mathrm{RW}_i = \frac{\hat{\mathrm{Y}}_\mathrm{i}}{\sum_{\mathrm{j}=1}^{\mathrm{n}} \hat{\mathrm{Y}}_\mathrm{j}} - \frac{\mathrm{Y}_\mathrm{i}}{\sum_{\mathrm{j}=1}^{\mathrm{n}} \mathrm{Y}_\mathrm{j}}$$

with:

$\Delta \mathrm{RW}_i$ Difference of Relative Weight in Location i

n number of municipalities i

Y_i number of residents or employees in municipality i (BFS)

$\hat{Y}_i$ estimated number of residents or employees by FaLC

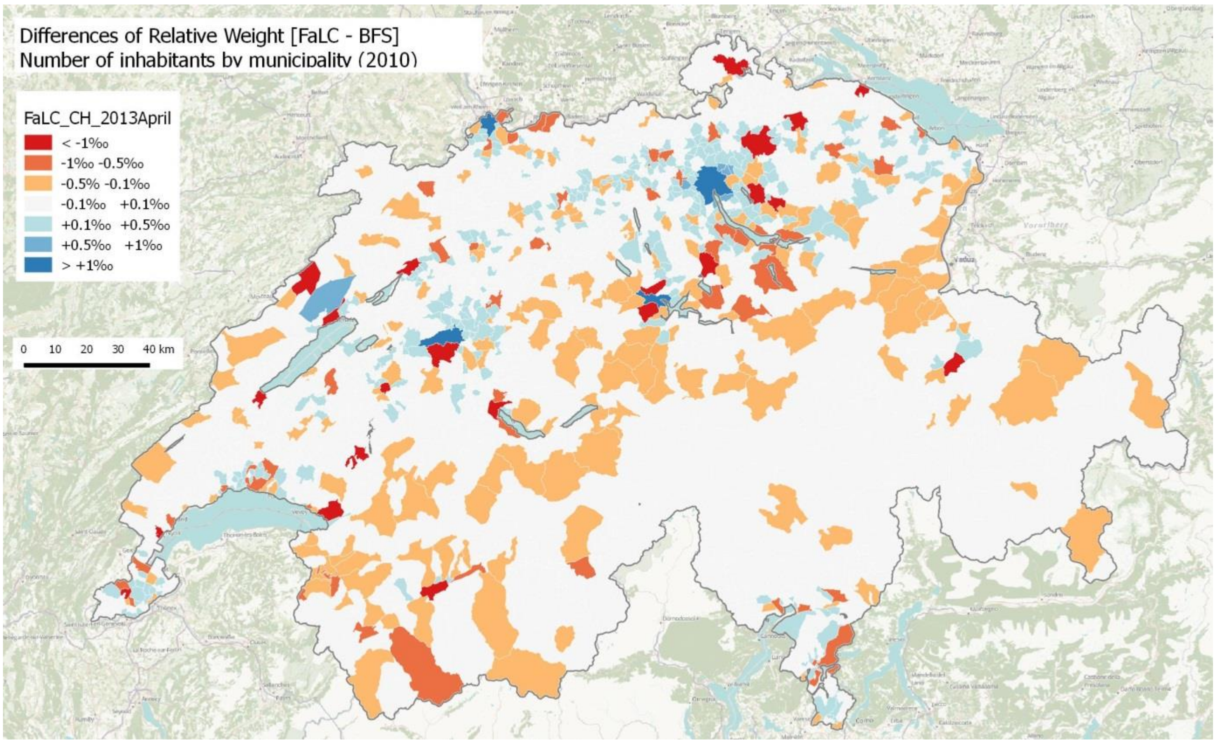
The following maps in Figure 17 show the distribution differences between FaLC and FSO by applying this concept.

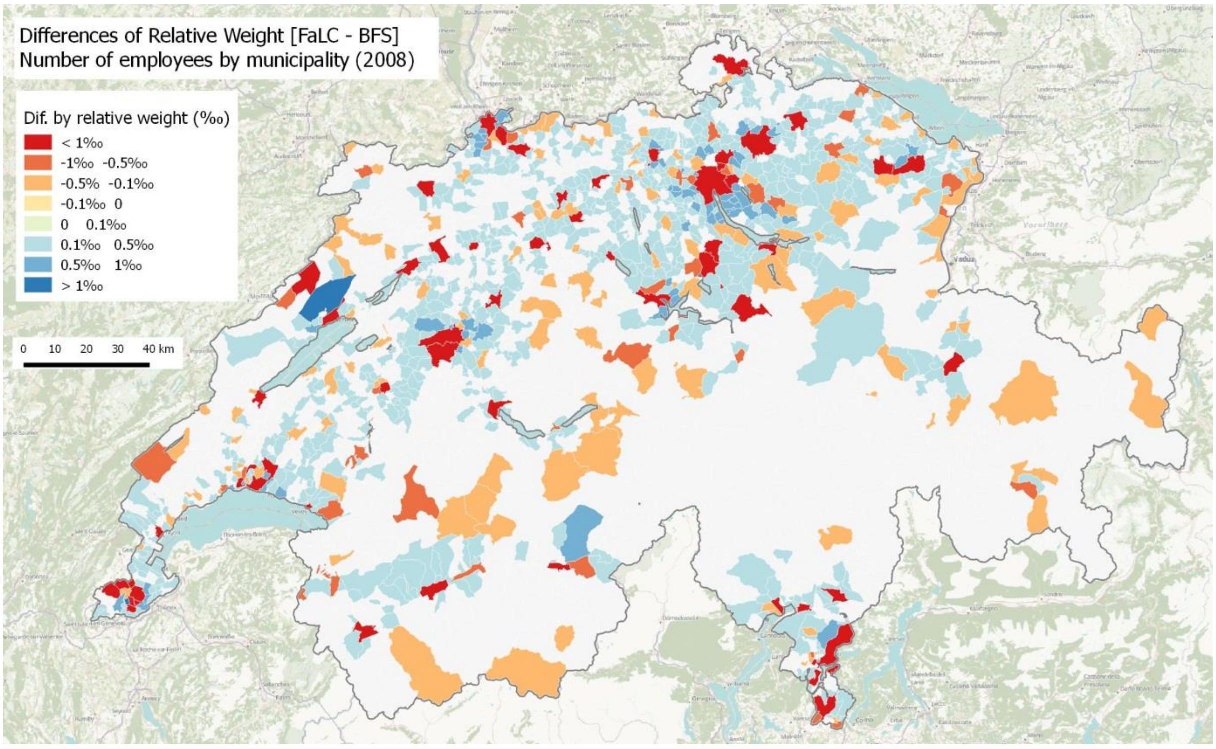
Due to the large quantity of locations analysed in this case study (every value has to be divided by the sum of the 3000 values of all municipalities in the Case Study Area), the map units are consequently very small (0.01‰, 0.5‰ etc).

Having a look at the following maps, the red colour means that FaLC is underestimating the number of residents and employees (e.g: less employees in Zürich, Basel, St.Gallen). On the other hand, the blue colour means that FaLC is overestimating the values (e.g: more inhabitants in Geneva).

In general, the missing migration from outside Switzerland results in a general underestimation of the values. Additionally, white noise effects lead to differences in certain municipalities. Additionally, the maps show an overestimation in FaLC of residents in cities, and in contrast, a general underestimation of firms in cities. One reason for this may is an incoherent modelling of the market mechanisms between households and firms. In the next steps, this issue is to be addressed.

Figure 17 Differences of Relative Weight between FaLC and FSO for Residents in 2010 (top) and Employees in 2008 (bottom)

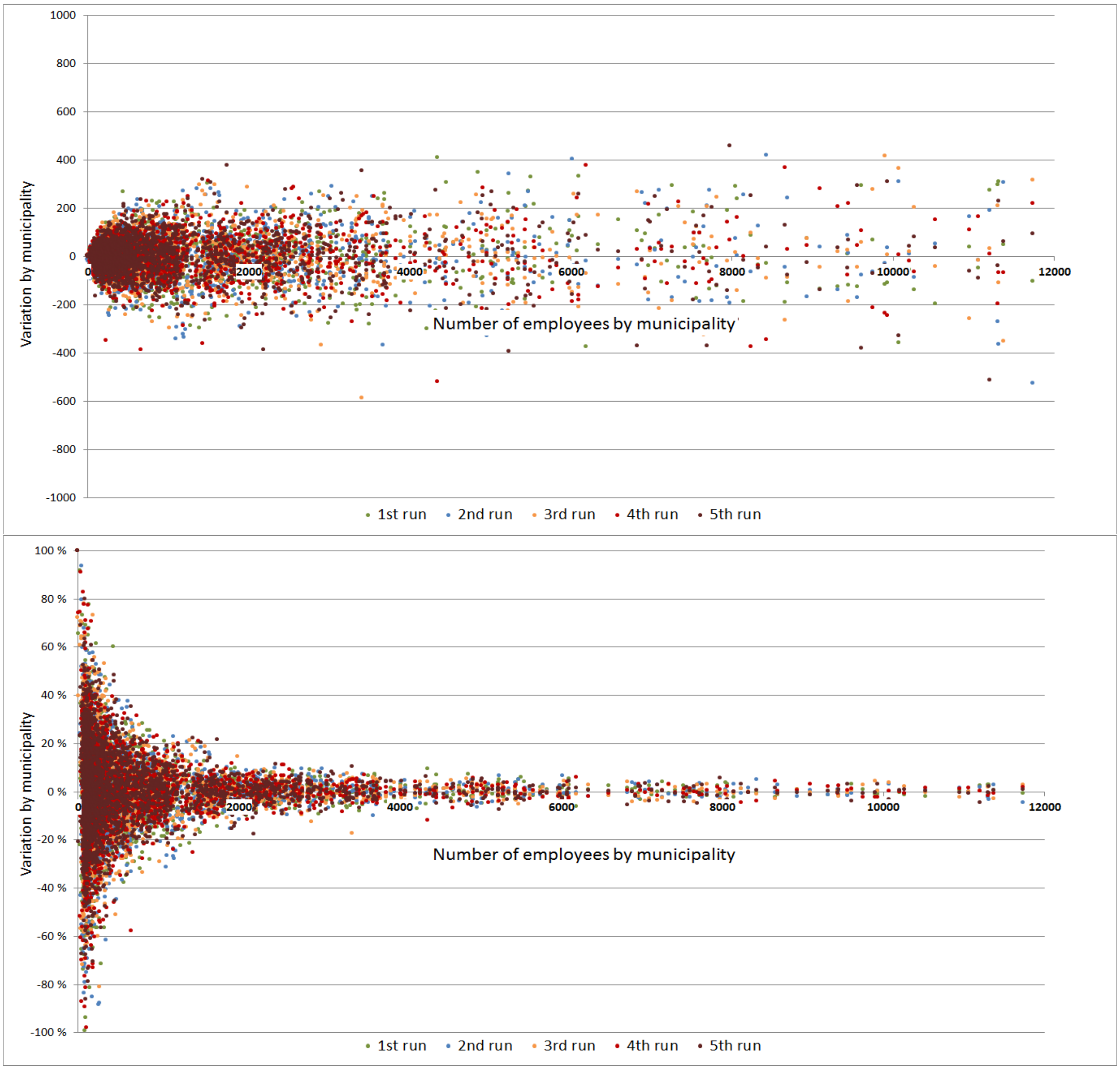




5.6 White noise

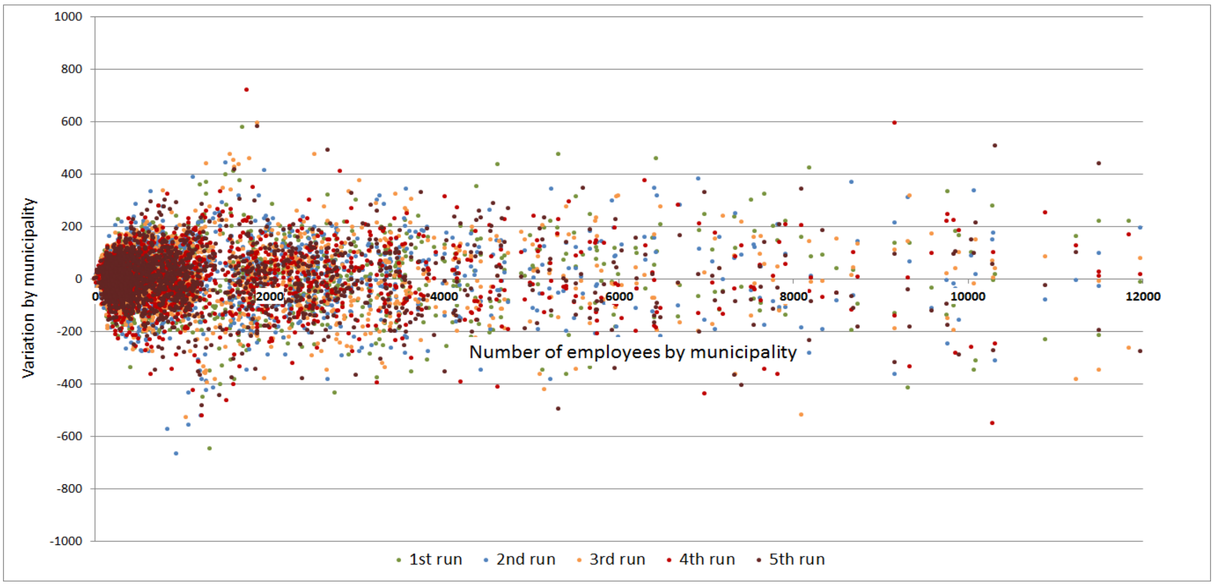
Unfortunately, the outputs of scenarios often do not show unambiguous effects. Comparing the results of the different scenarios, we note that the larger expected effects of a scenario are, the better the results are. Despite the good validation results, we therefore state that effects have to reach a certain level to be visible. In fact, this is perfectly in line with results of Geiger (2007) and Bodenmann (2011). One very important reason for this observation is white noise due to the various Monte Carlo Simulations in different models. The following figures show the variation, or white noise, comparing five identical FaLC runs with the mean value of these runs. Above in absolute and below in relative values, at first sight, we note a relatively high white noise, especially for small municipalities.

Figure 18 White noise for employees after 10 years (5 runs)



Comparing the observed white noise after 10 years (Figure 18) with those after 20 years (Figure 19), we note a much larger noise after 20 years. This is reasonable, as with each Monte Carlo Simulation processed in the model, white noise will increase. White noise seems to grow at least 50% and especially the number of very extreme outliners increased considerably.

Figure 19 White noise for employees after 20 years (5 runs)



As most of the scenarios only have an impact of several dozens to hundreds of residents and employees over 10 years, it is very important to reach reliabilities of +/-50 residents or employees. Unfortunately, this holds not only for small villages, but also for large cities, as impacts are (or should not be) dependent from the size of a location. To analyse simulation results, we have to focus therefore first and foremost on absolute values.[18]

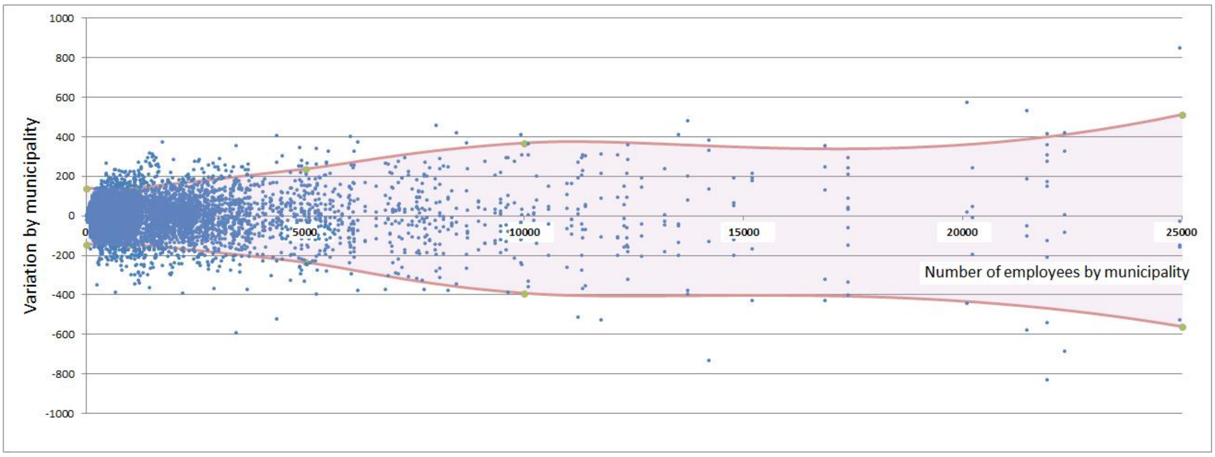
This leads us to the question of how large confidence intervals for residents and employees are. In **Fehler! Verweisquelle konnte nicht gefunden werden.** and Figure 20 the 95% confidence intervals for residents and employees are shown. The general assumption of a size-independent white noise can’t be hold. Instead, the white noise is increasing with the size of a zone with an increasing number of residents and employees until about 10’000 persons. For larger zones, the confidence interval keeps more or less stable. Empoyees start with a confidence interval of +/- 150 for small municipalities and the interval increases to +/-350 for large

18 This does not mean that results have to be presented only in absolute values. But with adequate absolute values, it is also possible to show reliable relative values. In contrast, the reverse will not lead to reliable results in small locations.

cities. In contrast, the confidence interval for residents is between +/-100 and +/-200 residents.

The reason for this is, that in the current implementation, the locations all are more or less equally represented in the choice set. Only rural municipalities are considerably less often part in the choice set – with the effect, that these locations show less white noise.

Figure 20 Confidence interval of 95% for employees (after 10 years)



We have to note that these intervals are valid for 10-year-runs. Therefore, +/- 200 residents correspond to at average +/- 20 residents per year. This is less than 10 households per year and shows that even small yearly simulation errors result in important white noise effects.

Reducing white-noise

The results above show that there are different possibilities to reduce white noise in micro simulation:

- (more) accurate utility functions in relocation processes
- (more) similar processes between scenario runs
- multiple simulation runs to stabilise results

Getting more accurate utility functions needs additional research work and has to be postponed to a further step of the FaLC project. Indeed, as discussed earlier in this chapter, the white noise can be considerably be reduced with accurate functions.

In contrast, getting as similar scenario runs as possible is a consecutive task. The current implementation of FaLC provides e.g. the possibility that sets of alternatives for relocation processes can be used identically for all scenarios.

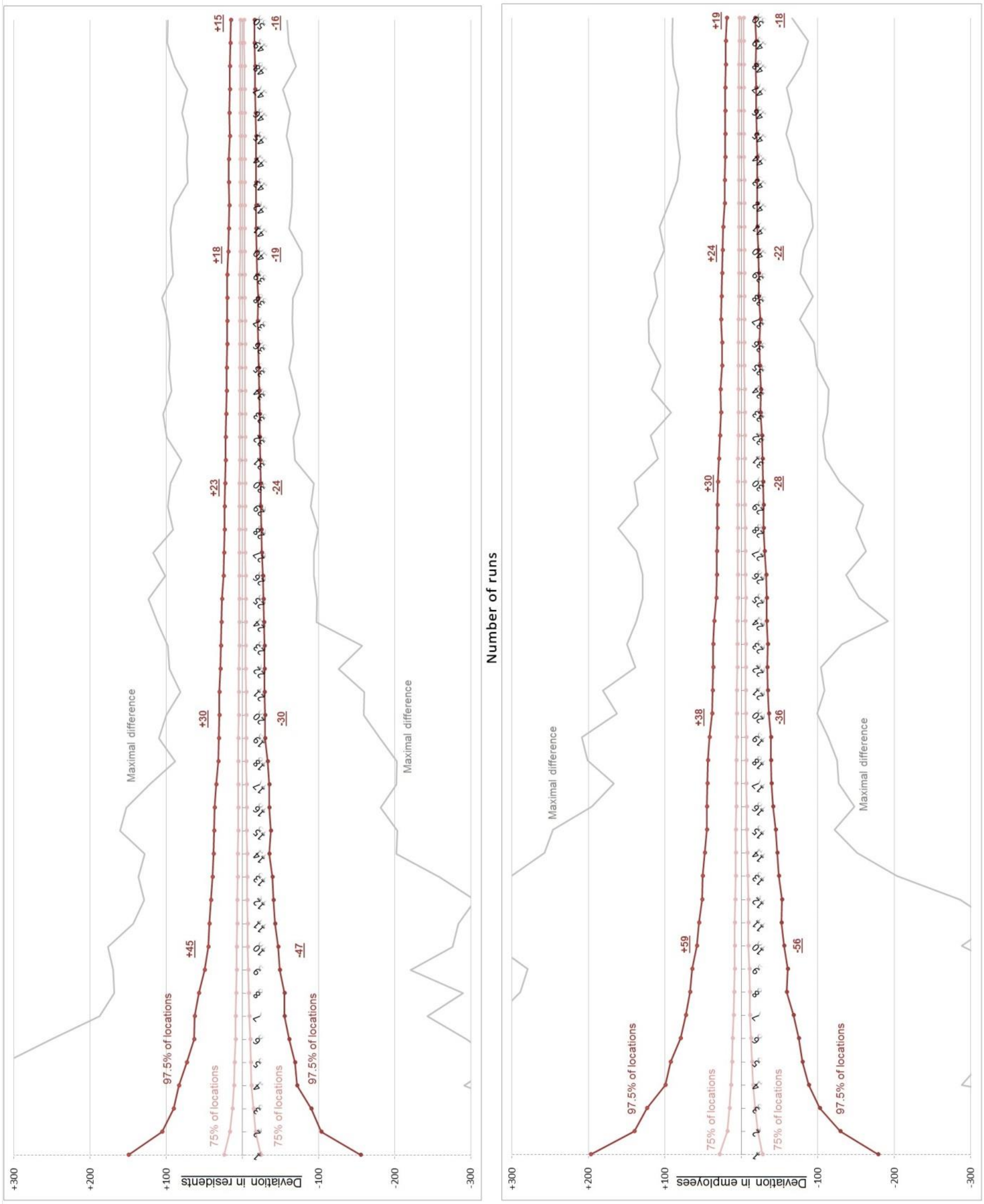
Wolf (2001) gives an overview of different approaches to reduce white noise. A very effective way to reduce white noise is the use of multiple runs. In FaLC, the user/modeller can select how many times will FaLC run a given scenario and FaLC will not only calculate the results for each run, but also the mean values.

Figure 21 shows the effect of multiple runs on the reliability of the results. The graphs show 95% and 50% confidence intervals as well as minimum and maximum errors by an increasing number of runs. The according means have been compared to the mean values of 100 runs. For residents, the 95% decreases considerably from +45 to -47 after 10 runs to +/-30 after 20 runs. After 20 runs the accuracy of still slightly better with each additional run, but to reach results with accuracy of about +/- 15 at least 50 runs are needed. For firms, the according graph is quite similar, but slightly less good.

This is the reason why for the scenarios presented in chapter 6, for the base scenario 75 runs (95% confidence intervals of about +/- 10 residents and +/- 15 employees) and for the scenarios 50 runs (+/- 15 residents and +/- 20 employees) have been used. The results are therefore +/- 25 residents and +/- 35 employees. Indeed, this is “only” the 95% confidence intervals – in other words, about 5% of the locations still show errors larger than this interval.

In further development of FaLC, it should be considered to use more sophisticated methods to estimate confidence intervals and potential bias. This is quite an important task as e.g. 50 runs of 10 years for 7 Millions of residents in 3000 municipalities (in other words: the Swiss Case Study) need 16 hours to be calculated on a 32 GB RAM Computer with SSD-Disc. This is quite “expensive” if we consider that also calibration runs and further reference runs have to be done. A possible solution could be Efron’s bootstrap method or other resampling methods to reduce the number of parallel runs (see also Wolf, 2001). Indeed, also these approaches will need several parallel runs.

Figure 21 White noise reduced by using the average of several runs



5.7 Calibration

Due to the good results in the validation process, the FaLC Swiss Case Study hasn't been calibrated in the narrow sense of the word. This means, parameter of the utility functions in general were kept as they had been derived from empirical work. However, after analysing some simulation results and cause-effects relations, different amendments have been made:

- Amendment of the workflow of the different models to get more randomness in the results – and avoid bias due to the modelling workflow.[19]
- Additionally, growth limitation based on legal land use limitations has been introduced (see chapter 4.3) where no more people are allowed to move into a zone once no more floor space is available.
- In the location choice model of households, we introduced also the distance to the former place of domicile to avoid too many relocations over long distances. Additionally, the negative parameter for accessibility of Private Vehicule Transport has been corrected (see chapter 3.1).
- In rare cases, very attractive locations show up very high growing rates. As setting up new settlements in a larger scale are long lasting processes, growing rates have been restricted to plausible values (see chapter 4.4).
- Finally, different smaller errors and bugs have been detected and fixed. This concerns the FaLC code as well as base data (e.g. the simplified OSM-Network).

Further amendments are postponed to a later phase of the FaLC project for two reasons: the general validation results are already very good; and we suggest to revise first the model parameters (especially regarding household relocation processes) before risking a over-calibration due to wrong assumptions.

[19] Indeed, micro simulation is always a tightrope walk between the less possible randomness (causing white noise) and the prevention of potential biases (causing just wrong results).

6 Scenario Simulation Results

The FaLC simulation tool focusses on land-use and transport. For ARE a specific interest is on investigating the relationship between land-use and transport, to analyse how land-use is affected by different impacts such as changing land regulations and transport infrastructure, political and governmental decisions. In the following, we focus exemplarily on three possible scenarios:

- Effects of a specific road network modification
- Effects of the future street network (ARE)
- Effects of a land regulation modification (capacity)

The following chapters show the effects of these impacts. Indeed, there are other spatially relevant political and governmental decisions that could be tested in FaLC. Beside the political and governmental decisions tested for this report, diverse other possible options for actions are changes in taxes, incentives for the establishment of firms, providing good leisure and school infrastructure etc.

6.1 Scenario 1: Effects of road network modification

Different researchers prove a direct impact of changing transport infrastructure on different land use indicators such as number of residents, businesses and land price in concerned regions (Tschopp, 2007; Cheshire and Sheppard, 2005; Boarnet and Chalermpong, 2001). Indeed, also indirect effects can occur unexpectedly, for example loss of firms in adjacent hinterlands (e.g. Bodenmann, 2011). What are the demographic and business effects of improvements in transport infrastructure? In order to know how firm and household choices are influenced by accessibility, one scenario was created in FaLC by modifying the existing road network.

As this scenario needs specific adaptation of the transport network, this scenario does not base on travel times of NPVM, but on travel times calculated directly in FaLC based on the network of OpenStreetMap. Specifically, we included a new motorway access connecting Herisau and Waldstatt with the motorway A1 between the cities of St.Gallen and Zurich. The adapted network was designed and applied in FaLC.

The following map shows the effect of the new motorway connection in direction of Herisau and Waldstatt after 10 simulation years. Due to multiple simulation runs of the base scenario (75 parallel runs) and the scenario itself (50 runs), white noise is reduced to about +/-30 residents and employees (95% confidence interval). Even by showing only values with a difference of more than 40 residents and employees, we still observe some municipalities affected by white noise.

The only municipality that is likewise affected in both simulations is Herisau. This is in line with the results of Bodenmann (2011), simulating the same new motorway connection. Also this simulations showed the largest positive effect in Herisau. The positive impacts for Waldstatt as well as the negative impacts for St.Gallen and Gossau revealed in Bodenmann (2011) can also be found in the FaLC simulations – but often on a very low level and therefore within the white noise boundaries.

Figure 22 Relocation effects due to new motorway connection

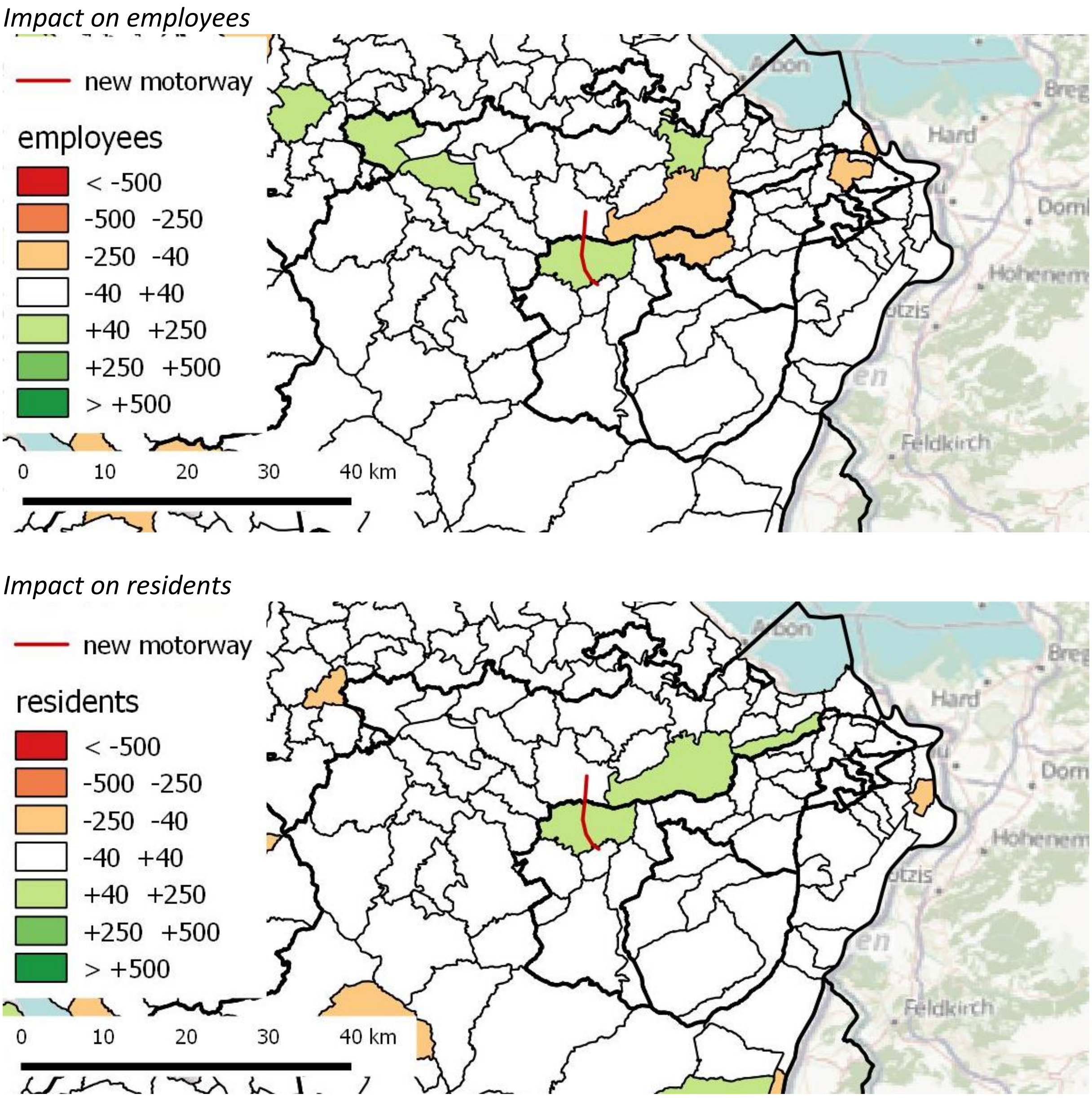
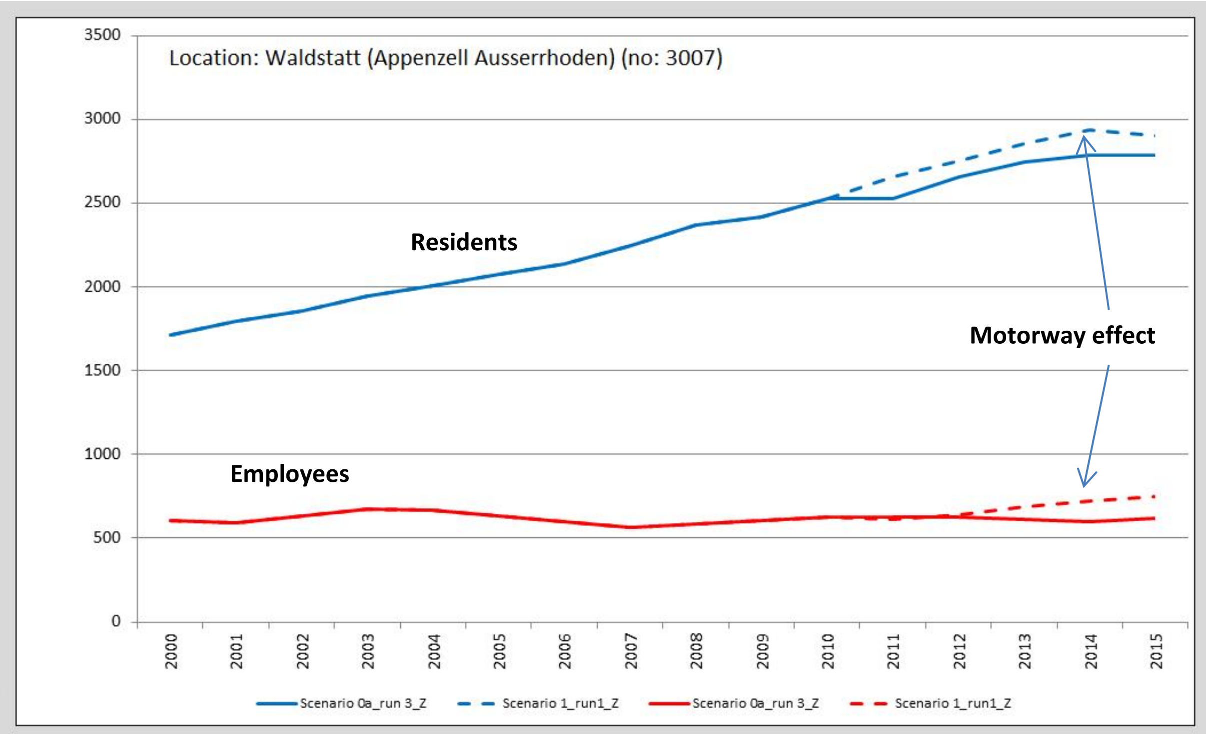


Figure 23 shows the case of Waldstatt in a randomly selected simulation run. The example reveals the evolutionary impact on residents and employees starting in 2010. Astonishingly, the effect of a new motorway access and its higher accessibility of other locations mainly has an impact on residents for the first year. The reason for this is that the new motorway connection re-rates the attractiveness of the locations considerably – this results in a new spatial distribution of residents. As in the following years the model does not receive a further large impact, attractiveness of locations do not change measurably. The resulting changes in land use distribution therefore keeps accordingly minor.

Figure 23 Firm relocation effects due to new motorway connection in Waldstatt



In contrast, for companies, the impact seems to be less strong and to last longer. This reveals that the economic development model, estimating the future number of firms and employees in all locations tends to reduce the impact of the different scenarios on firms and employees. As long as impacts are very high (e.g. the following two scenarios), this leads “only” to a calibration problem (impacts are too small). But, when impacts are smaller, the result tends to be hidden by white noise.

In consequence, the results show that a confidence interval of 95% is still very week to test local scenarios. 100 multiple runs of both scenarios (base scenario as well as the scenario itself) would result in a more appropriate 95% confidence interval of about +/-20. Additionally, in a further improvement of the model, the mechanism in FaLC to control the (general) number of firms and employees should be revised.

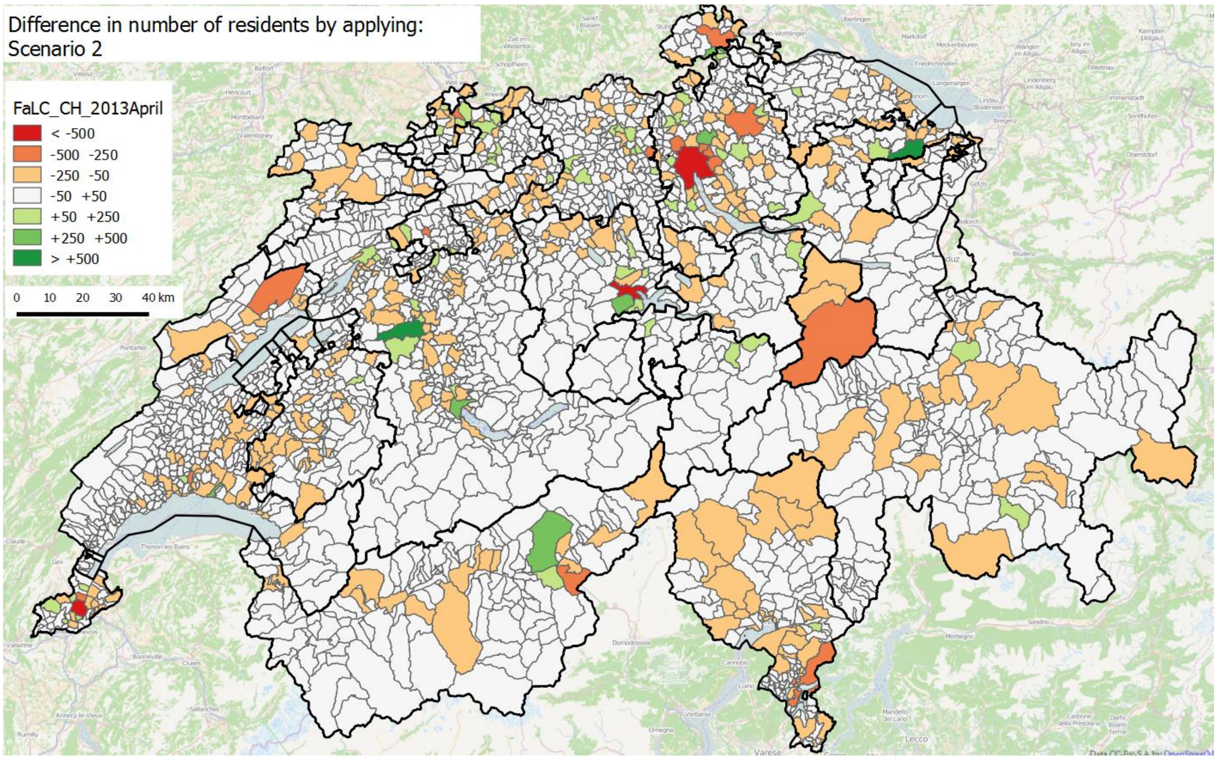
6.2 Scenario 2: Effects of the future road network (NPVM 2030)

In this scenario, FaLC simulates the effects on the spatial distribution of the population considering the presumably road network of 2030 (ARE network for NPVM-scenarios). Based on the ARE networks, the travel time between locations can be calculated. The travel time is considered in the location choice processes for firms and households as it represents a variable assessed within the utility functions.

ARE provided two versions of the road network, first a version of 2005, second a version of 2030 including all network changes resulting from the 1. Programmbotschaft Engpassbeseitigung. So, this scenario shows the effects of the future network on the relocation of firms and households. According results of FaLC could be the base for the assumed demographic and socio-economic data needed in transport models estimating future travel behaviour (such as NPVM 2030).

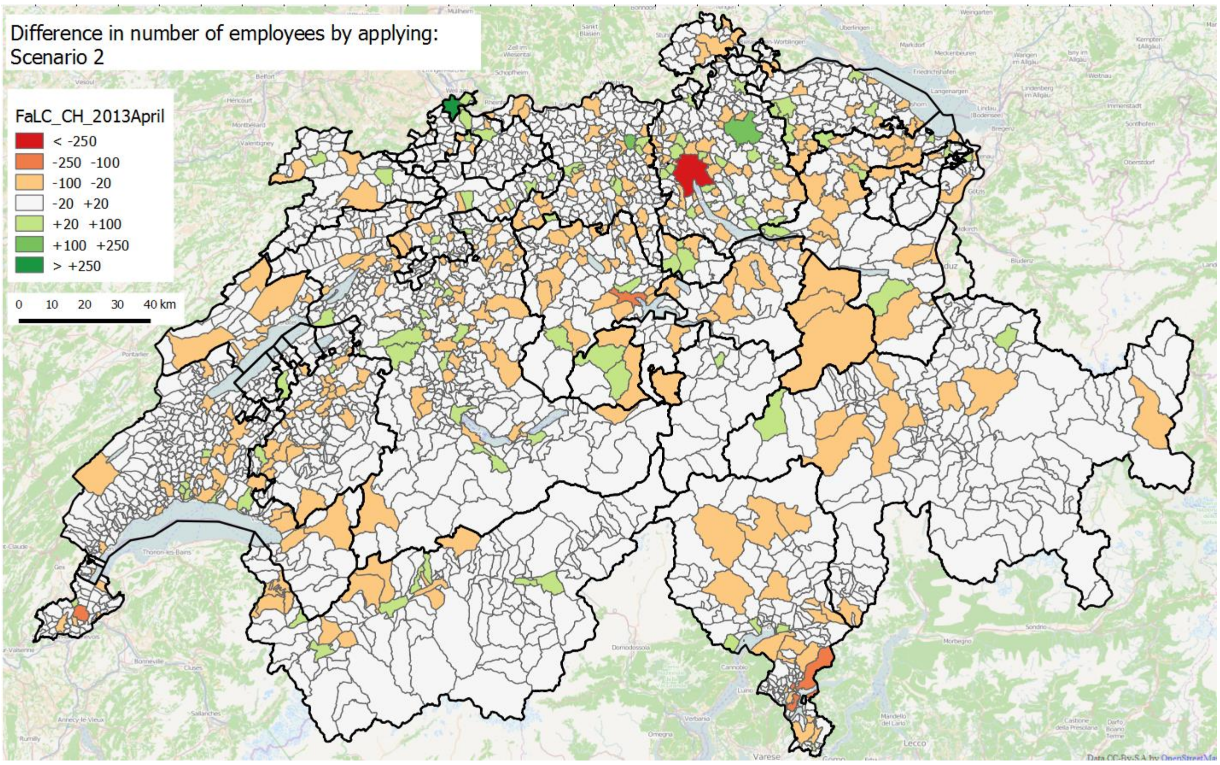
In the following map we see the effects on the spatial distribution of residents in Switzerland. In general, a decrease of residents in rural areas is noted. But in some in peri-urban areas, population tends to increase (e.g. near Zürich and in Aargau). These areas become better accessible and, consequently the number of residents increases in this area. Interestingly, the cities show a very diverse benefit of the planned network advancements. Cities like St.Gallen and Bern profit of changing accessibilities, whereas first and foremost Zurich and Geneva seem to loose attractiveness and therefore residents.

Figure 24 Relocation effects on residents due to improvements in transport infrastructure



Regarding employees, the results are similar. Especially Zurich will also loose employees. Other cities show different effects as for residents. This could be a consequence of suppression effects between the different use types.

Figure 25 Relocation effects on employees due to improvements in transport infrastructure

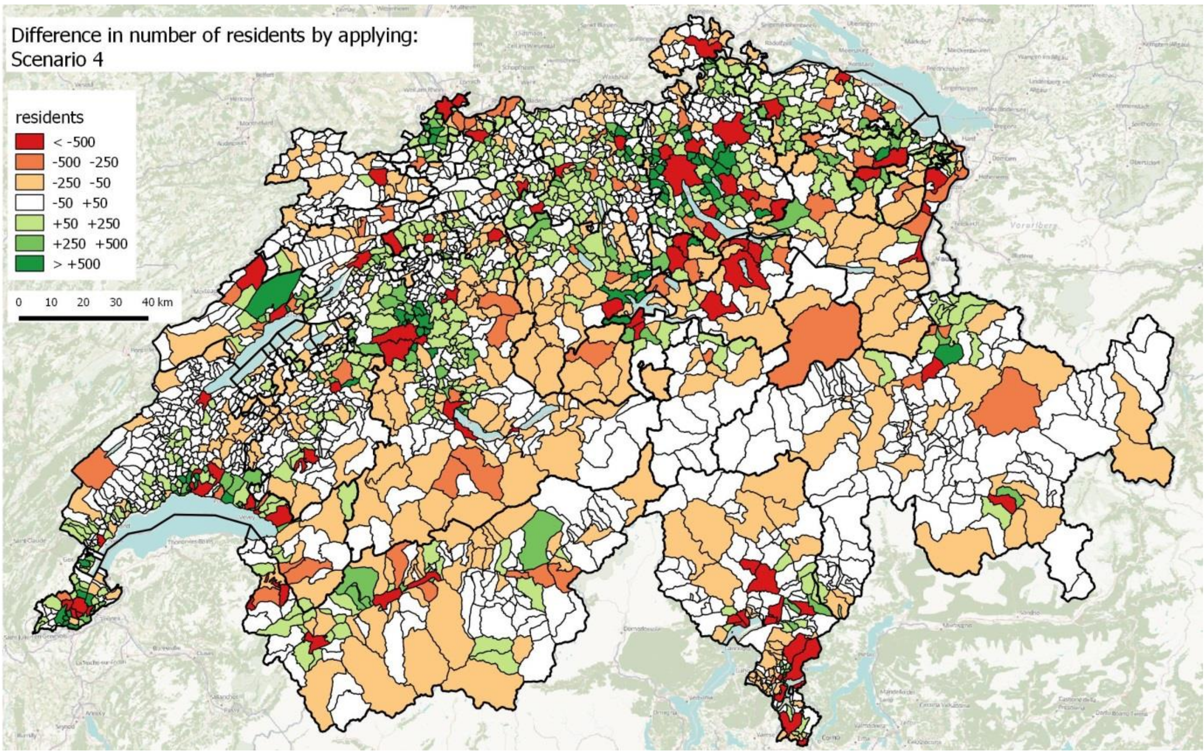


6.3 Scenario 3: Effects of land-use regulation modification

What are the demographic and firmographic short- and long-term effects of changing land use regulations such as densification of existing building zones or designation of new building zones? One common option for action in spatial planning is to change land-use regulations. For example freezing the limits of building zones is an option observed as realized in the new cantonal directive plan of Zurich. Usually, this strategy is applied by spatial planners to densify the building park within the building zones. To evaluate and compare effects of these strategies, a scenario assuming much higher utility factors for building zones was implemented.

To get significant effects, we assume that all over Switzerland the maximum floor area is raised by 20%. Applying this change we assume that cities can handle an important number of additional residents and employees.

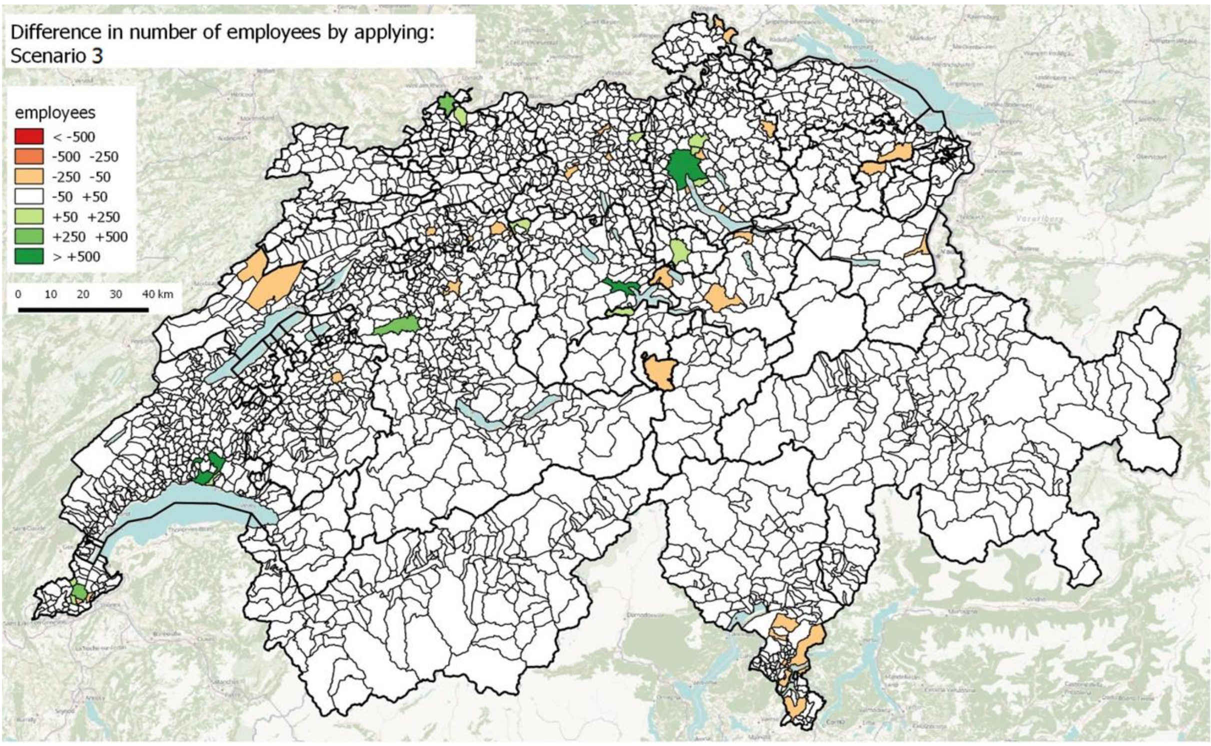
Figure 26 Resident relocation effects due to land regulation modification



As we can see in Figure 27, the impact in large cities and adjacent suburban areas is much stronger than in rural areas. In general, agglomerations tend to become considerably denser. But – at first sight astonishingly – the results show a restructuration in the core of the agglomerations: households leave the core area and in return, firms move in the core of the agglomeration. This is due to the composition of the utility function, where firms react stronger on additional capacities in building zones. But, this results are in line with the approach of von Thünen. Transfering the rings of von Thünen to cities, we would also assume that especially firms (of the third economic sector) tend to move to the city.

Comparing the results for employees to those for residents, we state – similar to the results discussed in scenario 1 – a considerably smaller impact on firms. Disregarding the cities, most locations show smaller effects than the +/- 50 employees, we considered as limit to avoid most impact of white noise.

Figure 27 Employees relocation effects due to land regulation modification



7 Conclusion

About two years after the start implementing FaLC, the consortium is happy to present the first prototype of FaLC. The software has already achieved a status that allows the comparison of different scenarios. FaLC runs very stable and performs fast (bearing in mind that FaLC is a micro simulation tool simulating decisions and events for individual agents). One cycle of one year, modelling 7 million residents and 4 million employees in about 3000 zones, takes about 3-4 minutes to calculate. This allows multiple runs to reduce white noise in simulation results. Indeed, it is important to mention that FaLC still has to deal with much data, this results in long times to read and write in the data base. Depending on the content to be saved, saving data lasts between 10-20 minutes with fast SSD drives. Additionally, FaLC is compatiblewith different platforms and has been tested on Windows 7, 8, 8.1 and Ubuntu (Linux), and also in the cloud (Amazon's Elastic Compute Cloud EC2).

7.1 Validation of the Swiss Case Study

The results of the Swiss Case Study show that – despite of the sometimes very simplified models – the estimations in FaLC are quite accurate in comparison to data from the Swiss Census. As the current FaLC implementation shall "only" allow a proof of concept, the presented validation so far focuses on totals of number of residents and firms. The different parts of FaLC have been tested separately:

Synthetic Population Module
Base of each simulation is a population for the starting year that should be as realistic as possible. Usually, this population including detailed information about socio-economic characteristics on micro-level is not available and has to be pre-processed synthetically – at least partially. If needed, FaLC provides methods to set up a synthetic population based on totals from official statistics (e.g. the total number of residents by age and sex in the municipalities).

A comparison with real data from population census and business census show that also after connecting persons to households and firms, the totals can be hold. But, at the current stage, the commuting distances are only visually controlled. In a next step of the Synthetic Population Module, the commuting distances should be modelled and validated more accurately.

Simplified Transport Module
The Swiss Case Study implemented for ARE bases on distance and travel time tables drawn from the Swiss National Passenger Transport Model (NPVM). According NPVM data are in FaLC neither validated nor calibrated. Distances and travel times provided by the FaLC internal transport module are only used for the simulation 1 where the transport network was adapted with only one additional project. Currently, the implemented transport module bases on the street network of Open Street Map and estimated velocities of this network. In the current implementation, these velocities depend on the maximum allowed speed for different

street types. Therefore, a comparison of the resulting travel times between municipalities with those of the National Passenger Transport Model (NPVM) generally show lower travel times. But, the errors are in general only in the range of some percentages. This is the reason, why the travel times were not additionally calibrated (a detailed comparison of the different approaches gives Zeiler et al. 2014). .

Yearly cycles

The yearly cycles include about one dozen of different models (partly including several submodels). Based on the validation results, different weaknesses and errors of FaLC have been detected and corrected. But, due to the finally very good results, no further calibration was made. This will be done – if needed – after a further amelioration of parameters in the models. Focus lies on integrating a more comprehensive behavioural model for the residents' location choice processes.

Due to data availability, the validation process covers the time period from year 2000 (base year) to 2010. Although, no calibration was performed, the fit of the modelling results are unexpectedly high. The comparison with real data of the population census and business census show a coefficient of determination R^2 generally higher than 0.90 (depending on the individual runs). Indeed, we note that considering the size of the municipalities, we get lower values: the proposed indicator of Relative Weight Correlation gets values between 0.70 and 0.90. Which are still very good results, as this indicator is not directly comparable to R^2 and tends to result in lower values.

7.2 Results of the scenarios

To test sensitivity of FaLC, different scenarios were calculated. The results show that especially powerful effects (e.g. increasing the Utilization Factors in all municipalities of Switzerland) deliver correspondingly strong and plausible results. Scenarios with weaker and more local effects (e.g. the motorway connection) tend to remain invisible in the white noise – and therefore need means to reduce white noise in the results.

In contrast to macro simulation, micro simulation processes usually base on decisions of individual so called agents (discrete choice models). In FaLC, these decision makers are persons (as residents or employees), households or firms. To simulate these processes, usually the Monte-Carlo-Approach is implemented. This approach considers also less probable decisions – as we often see in real live – and leads naturally in each run to slightly different results. This white noise causes no obvious problem during the validation process. In contrast, the white noise leads to some problems as soon as different scenarios with small differences are compared. In this case, the results tend to be hidden by the white noise. In the future, scenario runs have to run several times to eliminate these problems.

To get plausible results, the scenarios were calculated multiple times (base scenario with no amendments 75 runs and scenarios 50 times) and the mean values were then analysed and compared. This allows reducing white noise of about +/- 300 residents and employees (95% confidential interval for comparison of two individual runs, 10 years,)[20] to about +/-30.

With these multiple runs, it is possible to show also the effect of a single motorway connection like the link from Waldstatt and Herisau to motorway A1 (scenario 1). Stronger impacts like the future road network 2030 (scenario 2) and changing land-use regulation in whole Switzerland (scenario 3) result in appropriately distinct effects on land-use.

7.3 Next steps

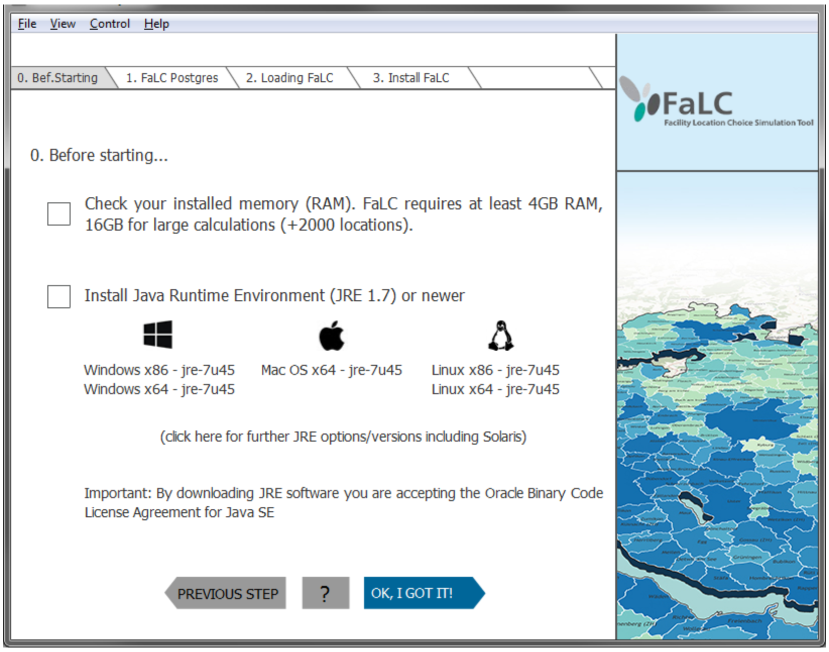
The next steps in the development of FaLC take place in two areas. First, an advancement of the software is desired, and, secondly, a revision of the models and model parameters will be made.

Software
Regarding the technical advancements, it is very important to do further work on a functionality to implement, control and analyse multiple runs in FaLC. Additionally, FaLC will improve the implementation of different scenarios.

In general, the aim of FaLC is to provide a user-friendly software for modellers. Therefore, a simple GUI to edit property files and to control outputs, as well as an extended GUI with additional support e.g. for data import and analyses is planned. A central concern are also usability of FaLC for the first steps. In this regard, a prototype of an Installation Assistant has already been implemented (see Figure 28). This wizard simplifies the installation of FaLC considerably.

[20] The 95% confidence interval of one individual run over 10 years is in the current implementation of the FaLC Swiss Case Study +/- 150 residents and +/-200 employees. As we compare two individual runs, the 95% confidence interval of the result is about the double.

Figure 28 FaLC Installation Assistant (test version)



Revision of the models and model parameter

As part of the further advancements of the models, different steps are planned. One of the highest priorities is the correction of the simulation population to be coherent with spatially superior assumptions and priorities (e.g. demographic forecast of BFS for cantons by sex and age of residents). Additionally, the household relocation model shall include further information, such as nationality of household members. A further, very important step includes the implementation of a market module considering realistically prices for land, buildings, flats and offices. To reduce white noise, it is also planned to review all model parameters of the location choice models (first of all, the parameters of the household relocation model).

Regarding transport modelling and calculation of travel time, the estimated velocities used at the current stage will be exchanged with more reliable values of a new speed regression model (Zeiler et al., 2014).

The second priority includes additional attributes for persons regarding education, wages, nationality, languages. Furthermore, these attributes need a set of additional transition models and will be integrated in existing models, such as job choice and relocation models.

A work step of lower priority includes the extension of FaLC with a Developer Module to model new constructions and refurbishments. Nevertheless, in a long-term perspective, this module is also quite interesting as it is crucial to estimate future energy consumption.

As a general conclusion, we state that FaLC achieved the announced goals. Over all, the simulation results regarding residents and employees are coherent with real data. On the technical side, FaLC runs stable and fast and is already very user friendly. All these consecutive achievements will turn FaLC into an incredibly reliable spatial planning tool that is just “around the corner”.

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A Tables in FaLC database

A 1 FaLC core tables

FaLC Table persons

Attribute	Description	Entities
person_id	ID person	[bigint]
Run	Number of cycles (years) passed	[int]
business_id	ID business	[bigint]
household_id	ID household	[bigint]
position_in_hh	Position in household 1 Female Partner 2 Male Partner 3 Kid	[integer]
position_in_bus	Position in business 1 CEO 2 Employee	[integer]
partnership_since*	Partnership since (creation year of hh)	[integer]
employed_since*	Employed since (year)	[integer]
Workingstatus*	Status of working (unemployed or not)	[integer]
Sex	Sex 1 Male 0 Female	[integer]
Income*	Income (in CHF)	[integer]
Dbirth*	Date of birth (year)	[date]
Status*	Status 7 Immigrant	[integer]
Ddeath*	Date of Death (year)	[date]
Map*	Not used	[bytea]
Education*	Level of education	[integer]

* variable not used in Swiss Case Study 2013

FaLC Table households

Attribute	Description	Entities
Oid	ID postgres internal	[integer]
Household_id	ID household	[integer]
Run	Number of cycles (years) passed	[integer]
Location_id	ID location	[integer]
Dfoundation	Date of foundation	[date]
Dclosing	Date of closing	[date]
Type_1*	(empty)	[integer]
Type_2*	(empty)	[integer]
Type_3	Attribute for Household model Synthesis: 1 Single male or female working OR mother + children 2 Father + mother + children 0 2 persons household (male + female adults) 4 Single old person 5 Single working person working outside location 6 Single underage living alone Separation model: 10.11 (old attribute correspond to divorced HH) 12 Divorced female household 13 Divorced male household	[integer]
Partner_id_a	ID Partner A	[integer]
Partner_id_b	ID Partner B	[integer]
Map*	Not used	[bytea]

* variable not used in Swiss Case Study 2013

FaLC Table business

Attribute	**Description**			**entities**
Business_id	ID business			[integer]
Location_id	ID location			[integer]
Type_1	Sectors:		NOGA08	[integer]
	1	agriculture	1-7	
	2	production	10-35, 41-43	
	3	wholesale	45-46, 49-53	
	4	retail	47	
	5	gastronomy	55-56	
	6	finance	64-66	
	7	services fC	58, 60-63, 69-82	
	8	other services	59, 68, 86-90, 92-96	
	9	others	97-98	
	10	non movers	8-9, 84-85, 91, 99	
Type_2	Legal form (Rechtsnatur):			[integer]
	1	holding (hg)		
	2	partnerships (pg)		
	3	companies (kg)		
Type_3*	(empty)			[integer]
Vacancies	(empty)			[integer]
Run	cycle number of last access			[integer]
Dfoundation	Date of foundation			[date]
Dclosing	Date of closing			[date]
Map*	Not used			[bytea]
Nr_of_jobs	Number of jobs (0..x)			[integer]

* variable not used in Swiss Case Study 2013

FaLC Table distances

Attribute	Description	entities
location_a_id	ID location A	[double]
location_b_id	ID location B	[double]
distance_1	Car distance in kilometers	[numeric]
distance_2	Car distance in minutes	[numeric]
distance_3	Public transport distance in kilometers	[numeric]
distance_4	Public transport distance in minutes	[numeric]
distance_5*	Bicycle distance in kilometers	[numeric]
distance_6*	Bicycle distance in minutes	[numeric]
distance_7*	Not used	[numeric]
distance_8*	Not used	[numeric]
gld_id	ID (primary key)	[integer]

* variable not used in Swiss Case Study 2013

FaLC Table locations_zones

Attribute	Description	Entities
locid	ID location	[integer]
Denot	Location name	[character]
Canton_nr	Number of canton	[integer]
run	Number of cycles (years) passed	[integer]
Pop_tot	Census: total number of population	[integer]
Emp_tot	Census: total number of employess	[integer]
fl_sdl	Area of building zone	[integer]
mia_4	Yearly rent for 4-room-flats	[integer]
gt_gmz	Municipality is a large or medium centre (calculation to be revised)	[integer]
bst_dbr	Diversity of sectors	[double]
se_aansl	Access to highway (0/1)	[integer]
se_bahn	Access to railway (0/1)	[integer]
lp_wohn_norm	Land prices for residential use (normalized)	[double]
bz_totnd_norm	Density in Building Zones (normalized)	[double]
wb_hsabs_q_norm	Quote of persons with university degree (calculation to be revised)	[integer]
bst_dbr_norm	Diversity of sectors (normalized)	[double]
st_hg_k_norm	Tax rate for holding companies (normalized)	[double]
st_pg_e_norm	Tax rate for partnerships (normalized)	[double]
st_kg_g_norm	Tax rate for private coorporations (normalized)	[double]
se_ac_at_norm	Accessibility (total, normalized)	[double]
se_wfk_norm	Cantonal business development (normalized)	[double]
se_ac_wt*	Accessibility of residents (normalized)	[integer]

se_wfr_vf_norm	Promotion as business location (normalized)	[double]
pop_1	Not used (replaced by pop_tot)	[integer]
pop_2	Not used (replaced by emp_tot)	[integer]
av_1	Accessibility value: car, residents	[numeric]
av_2	Accessibility value: car, employees	[numeric]
av_3	Accessibility value: public transport, residents	[numeric]
av_4	Accessibility value: public transport, employees	[numeric]
av_5*	Accessibility value: bicycle, residents	[numeric]
av_6*	Accessibility value: bicycle, employees	[numeric]
motorway_access	Access to motorway, yes or no	[boolean]
landtype	Economic sector in FaLC and large, small cities and agglomerations	[numeric]
maxfloorareares	Maximum floor area where residents can live	[numeric]
usedfloorareares	Occupied floor area by residents	[numeric]
maxfloorareawrk	Maximum floor area where firms are installed	[numeric]
usedfloorareawrk	Occupied floor area by firms	[numeric]
maxfloorareaall	Maximum floor area for residents and firms	[numeric]
usedfloorareaall	Occupied floor area by residents and firms	[numeric]

* variable not used in Swiss Case Study 2013
Sources: see according read_me files of input data.

FaLC Table geolocations

Attribute	**Description**	**entities**
The_geom	Multipolygon	[geometry]
Gid	ID of Order (primary key)	[integer]
Ch1903x	Swissgrid x-coordinate	[numeric]
Ch1903y	Swissgrid y-coordinate	[numeric]
Latitude	Latitude	[numeric]
Longitude	Longitude	[numeric]
Locid	ID Location	[integer]

Table geolocations contains GIS-polygones for visualisations and potential GIS analyses.

A 2 Probability tables

FaLC Table death_rate

Attribute	Description	Entities
Age	Age	[integer]
s_m2000..s_m2050	Death rate men	[integer]
s_f2000..s_f2050	Death rate women	[integer]

FaLC Table Fertility

Attribute	Description	Entities
From (7 rows)	Age group lower boundary each groups = 5yrs from 15 to 49	[integer]
To	Age group upper boundary	[integer]
f2000..2050	Mean number of children per 1000 women by age group	[double]

FaLC Table marriages_p_age

Attribute	Description	Entities
Age	Age (18..60)	[smallint]
P_marriage_m	Probability to marry (women)	[double]
P_marriage_w	Probability to marry (men)	[double]

FaLC Table employment_durations

Attribute	Description	Entities
Duration	P (= the primary key)	[character]
1..30	Probability to be in the same company for 1 to 30 years	[numeric]

FaLC Table closures migration

Attribute	Description	Entitites
sector_id	ID sector	[smallinteger]
sector	Sector	[character]
d2000..2050	D = closures; probability of a company to close in the specified year	[character]
m2000..2050	M = migration; probability of a company to migrate in the specified year	[character]

FaLC Table divorce_age

Attribute	Description	Entities
Age	Age (18..80)	[smallint]
p_div_age	Probability to divorce by age	[double]

This table has been replaced by divorse_year.

FaLC Table divorce_year

Attribute	Description	Entities
Year	Year (0..50)	[integer]
P_div_year	Probability to divorce after x (0..50) years of marriage	[double]
P_div_year_c	Cumulated probability to divorce after x (0..50) years of marriage	[double]

FaLC Table moving_rate

Attribute	Description	Entities
Age	Age (0..100)	[smallint]
P_relocation	moving rate per year by age	[numeric]
P_rel_parent	rate moving out ouf parents’ home per year by age	[numeric]
Pc_rel_parent	cumulated rate moving out ouf parents’ home per year by age	[numeric]
P_rel_in_rethome	moving rate into a retirement home by age	[numeric]

A 3 Other tables

FaLC Run Indicators table

Attribute	Description		Entities
ID_Gen	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)		[numeric]
CODE_LOC	Location code		[numeric]
CYCLE	Year, month…		[numeric]
NAME_LOC	Location name		[numeric]
RES	Residents		[numeric]
	T	Total residents	
	00-04	Under 4 years	
	05-09	Between 5 and 9 years	
	…		
	100-XX	Older than 100 years old	
HH	Households		[numeric]
	T	Total households	
	P2-C0	With 2 parents and 0 child	
	P2-C1	With 2 parents and 1 child	
	…		
	P1-CX children	With 1 parent and more than 5	
	Paar	Couple without children	
	Single	One single person living	
	Error ways	For empty household or more than 2 parents, probably here will be all-zero	
FIRM_sec	Firms		[numeric]
	T	Total firms	
	Sectors:		
	01	agriculture	
	02	production	
	03	wholesale	
	04	retail	
	05	gastronomy	
	06	finance	
	07	services fC	
	08	other services	
	09	others	
	10	non movers	

EMPL_sec	Employees		[numeric]
	T	Total employees	
	Sectors:		
	01	agriculture	
	02	production	
	03	wholesale	
	04	retail	
	05	gastronomy	
	06	finance	
	07	services fC	
	08	other services	
	09	others	
	10	non movers	
COM	Persons commuting by distance in kilometres		[numeric]
	Distance commuting:		
	00-04	Less than 5 kilometres	
	05-09	Between 5 and 9 kilometres	
	…		
	100-XX	More than 100 kilometres	
EDUC_lev_	Number of students by education level		[numeric]
	Level:		
	01	Without education	
	02	Elemen-tary/obligatory school	
	03	Apprenticeship	
	04	Secondary Education	
	05	High education/University	
JOB_OCC_sec	Working places occupied per economic sector		[numeric]
JOB_VAC_sec	Empty working places by sector		[numeric]
FIRM_size	Number of firms by size (no of employees + CEO)		[numeric]
	Size category:		
	0	Inactive companies	
	1	Freelancers	
	02-04	Companies having between 2 and 4 workers	
	05-09	Companies having between 5 and 9 workers	
	10-49	Companies having between 10 and 49 workers	
	50-250	Companies having between 50 and 250 workers	
	250-XX	Companies having more than 250 workers	
MAXFA	Maximum floor area		[numeric]

	T	Maximum floor area for total residents and firms	
	RES_T	Maximum floor area for total residents	
	FIRM_T	Maximum floor area for total firms	
OCCFA	RES_T	Occupied floor area for total residents	[numeric]
	FIRM_T	Occupied floor area for total firms	
	01	agriculture	
	02	production	
	…		
	10	non movers	

FaLC Floor Area (in hectares) outside the considered zoning plan (obzFA) table:

Location	obzFA res	obzFA emp	obzFA tot	Location	obzFA res	obzFA emp	obzFA tot
Aarau (AG)	-	2.75	-	San Vittore (GR)	3.35	1.69	5.06
Baden (AG)	-	11.53	18.48	Müstair (GR)	4.02	3.58	7.60
Schwellbrunn (AR)	7.91	1.66	9.57	St.Antönien Ascharina	0.45	-	0.55
Wald (AR)	4.75	1.58	6.33	Churwalden (GR)	6.53	2.64	9.30
Oeschenbach (BE)	0.65	-	0.35	Le Peuchapatte (JU)	0.20	0.02	0.22
Rohrbachgraben (BE)	1.60	0.45	2.13	Montmelon (JU)	0.07	0.10	0.21
Oberbalm (BE)	0.76	-	0.68	Roche-d'Or (JU)	0.18	0.03	0.21
Meienried (BE)	0.32	0.04	0.36	Romoos (LU)	0.22	-	-
Mötschwil (BE)	0.57	0.11	0.71	Littau (LU)	1.76	-	-
Rumendingen (BE)	0.73	0.46	1.19	Luzern Ost (LU)	-	24.90	3.23
Mont-Tramelan (BE)	0.63	0.12	0.74	Luzern Nord (LU)	-	36.82	48.87
Ballmoos (BE)	0.33	0.02	0.35	Luzern Innenstadt (LU)	-	-	20.57
Scheunen (BE)	0.31	0.08	0.39	Luzern Süd (LU)	-	68.80	98.30
Kandergrund (BE)	1.24	-	-	Neuchâtel (NE)	-	3.43	74.77
Lütschental (BE)	0.04	-	-	Rorschach (SG)	-	-	9.51
Landiswil (BE)	3.22	0.79	4.04	Rapperswil (SG)	-	-	7.79
Oberthal (BE)		-		St. Gallen Centrum	-		

	0.05		0.44	(SG)		27.17	54.09
Schlosswil (BE)	0.25	-	0.65	St. Gallen Ost (SG)	-	-	14.26
Clavaleyres (BE)	0.29	0.02	0.31	Gänsbrunnen (SO)	0.23	0.09	0.34
Châtelat (BE)	0.66	0.30	0.96	Kammersrohr (SO)	0.21	0.01	0.22
Monible (BE)	0.19	0.03	0.22	Solothurn (SO)	-	24.80	5.28
Schelten (BE)	0.28	0.08	0.36	Beinwil (SO)	0.13	0.09	0.38
Seehof (BE)	0.43	0.05	0.48	Innerthal (SZ)	0.90	0.31	1.21
Rebévelier (BE)	0.16	0.02	0.19	Riemenstalden (SZ)	0.32	0.08	0.40
Epsach (BE)	0.67	-	0.58	Bellinzona (TI)	-	15.63	-
Englisberg (BE)	1.10	-	0.51	Calonico (TI)	-	0.01	-
Jaberg (BE)	-	-	0.04	Faido (TI)	-	1.93	-
Kienersrüti (BE)	0.28	0.03	0.31	Ascona (TI)	-	0.80	-
Noflen (BE)	1.34	0.20	1.54	Muralto (TI)	-	6.17	5.91
Rüeggisberg (BE)	3.08	-	1.48	Onsernone (TI)	-	0.01	-
Eggiwil (BE)	2.20	-	0.38	Croglio (TI)	-	2.69	-
Röthenbach im Emmental (BE)	2.52	-	1.46	Lugano (TI)	-	132.93	151.68
Schangnau (BE)	0.21	-	-	Massagno (TI)	4.87	3.41	11.76
Fahrni (BE)	2.29	0.14	2.75	Neggio (TI)	-	0.10	-
Schwendibach (BE)	0.55	-	0.35	Paradiso (TI)	2.31	10.37	14.24
Uebeschi (BE)	0.00	-	-	Savosa (TI)	-	0.09	-
Wachseldorn (BE)	1.29	0.09	1.61	Sorengo (TI)	6.94	4.92	12.06
Berken (BE)	0.27	0.21	0.48	Tesserete (TI)	4.44	2.87	7.70
Ochlenberg (BE)	3.06	0.18	3.39	Viganello (TI)	0.47	3.60	7.78
Bern Belpmoos (BE)	-	0.12	0.12	Besazio (TI)	-	0.12	-
Birsfelden (BL)	7.04	-	-	Bruzella (TI)	0.09	-	0.11
Basel Euroairport (BS)	-	2.23	2.23	Chiasso (TI)	-	21.48	31.23
Basel Innenstadt	-	-		Bosco/Gurin (TI)	-		

(BS)			48.73
Basel St. Alban (BS)	-	2.93	50.07
Basel Bruderholz (BS)	11.13	85.44	155.35
Basel Bachletten (BS)	18.91	70.40	127.71
Basel St. Johann (BS)	69.82	86.32	202.94
Basel Clara (BS)	43.91	71.06	191.04
Basel Hirzenbrunnen (BS)	7.04	31.13	51.73
Basel Kleinhüningen (BS)	12.85	-	-
Praratoud (FR)	0.34	0.04	0.38
Bionnens (FR)	0.38	0.15	0.53
Les Ecasseys (FR)	0.27	0.09	0.36
Lieffrens (FR)	0.31	0.09	0.40
La Magne (FR)	0.26	0.09	0.35
Mossel (FR)	0.66	0.23	0.89
La Neirigue (FR)	0.27	0.09	0.36
Autafond (FR)	0.44	0.03	0.47
Fribourg (FR)	-	-	36.58
Pierrafortscha (FR)	0.67	0.14	0.82
Villarsel-sur-Marly (FR)	0.36	0.01	0.37
Greng (FR)	-	0.10	-
Carouge (GE)	-	-	22.66
Genève Aéroport (GE)	-	4.64	4.64
Genf Cité Centre Nord (GE)	137.45	124.30	355.22
Genf Champel Cluse (GE)	-	-	65.33
Genf Eaux-Vives (GE)	-	-	27.54
Genf Châtelaine (GE)	-	-	33.15
Wiesen (GR)		0.73	

		0.40	-
Prato-Sornico (TI)	-	0.14	-
Lugano Agno (TI)	-	0.17	0.17
Corbeyrier (VD)	-	0.09	-
Prilly (VD)	-	-	3.40
Pully (VD)	-	5.78	-
Renens (VD) (VD)	14.92	-	18.14
Chavannes-près-Renens (VD)	8.07	-	2.41
Morges (VD)	3.80	-	11.25
Les Tavernes (VD)	0.46	-	-
Vevey (VD)	2.26	15.63	50.30
Lausanne Centre-Ville (VD)	4.78	7.86	41.16
Lausanne Nord-Ouest (VD)	71.48	83.40	172.67
Lausanne Sud-Lac (VD)	45.00	60.58	126.66
Lausanne Sud-Est (VD)	3.65	62.80	80.58
Lausanne Nord-Est (VD)	45.46	81.29	142.02
Lausanne Foraines (VD)	10.48	9.56	20.07
Zug (ZG)	-	10.50	28.67
Kloten (ZH)	-	39.31	63.25
Zürich Flughafen (ZH)	-	13.56	13.56
Winterthur Seen (ZH)	-	0.65	-
Zürich Kreis 2 (ZH)	-	3.49	33.89
Zürich Kreis 3 (ZH)	-	81.07	201.54
Zürich Kreis 4 (ZH)	-	-	68.20
Zürich Kreis 6 (ZH)	-	80.72	128.57
Zürich Kreis 7 (ZH)	-	88.47	77.31
Zürich Kreis 8 (ZH)	-	-	

	1.62		2.35				19.21
Salouf (GR)	1.10	0.70	1.80	Zürich Kreis 9 (ZH)	-	6.95	75.62
Sils im Domleschg (GR)	4.73	1.18	5.93	Zürich Kreis 10 (ZH)	-	136.81	177.79
Medels im Rhein-wald (GR)	0.25	0.12	0.36	Zürich Kreis 11 (ZH)	-	-	41.61
Clugin (GR)	0.18	0.09	0.27	Zürich Kreis 12 (ZH)	-	87.12	129.45
Lohn (GR)	0.27	0.04	0.31				