

# An Integrated Land Use Model for Switzerland

## Detailed Description of the FaLC Template 2015

### FaLC Working Paper 03

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# **An Integrated Land Use Model for Switzerland**

## **Detailed Description of the FaLC Template 2015**

January 2015 (revised 12/09/2015)

### **Abstract**

The main goal 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 January 2015. 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 2014 and is part of the FaLC documentation. Those implementations will also serve as a template for further Case Studies.

This Working Paper is an extended version of FaLC Working Paper 02.

### **Preferred citation style**

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# 1 Introduction

## 1.1 Goals

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 years. It is a revision of a former description of the Case Study (see Bodenmann et al. 2014b), and therefore, contains large passages of its predecessor. Indeed, there are some major changes to be noted:

- **Migration Models:** a new migration model has been included.
- **Check of residents:** in the new FaLC version, it is possible to compare simulated FaLC-population with given number of residents (e.g. real data or official scenarios for cantons) and correct FaLC-simulations to these numbers.
- **Relocations within large cities:** the results showed that relocation rates (between locations), especially for firms, depend significantly on the size of the municipality. Large municipalities and cities give opportunities to relocate within location. Relocation rates therefore decrease with increasing size of the settlement.

It is meant as the final report of the work done in 2014 and additionally documents the status of the current FaLC implementations. 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

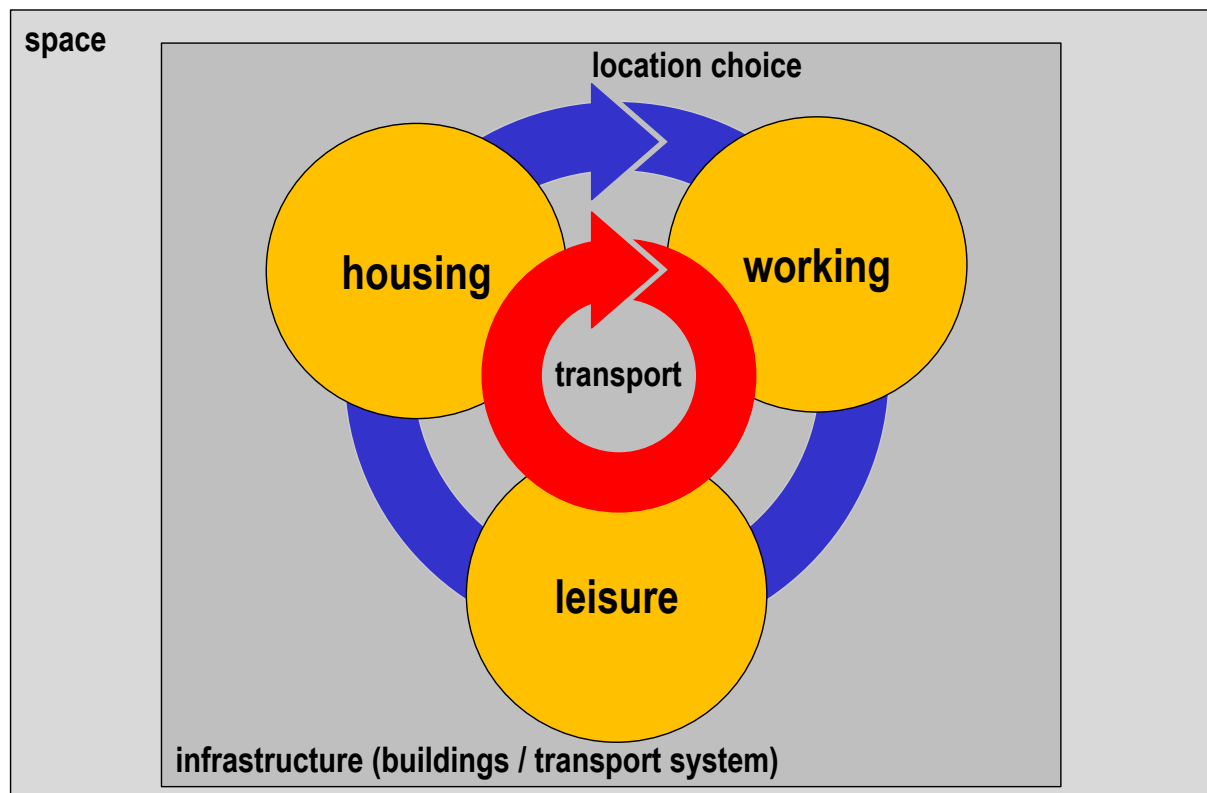
Compared to other (integrated) land-use and transport simulation tools, FaLC will focus on the following main objectives:

- **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

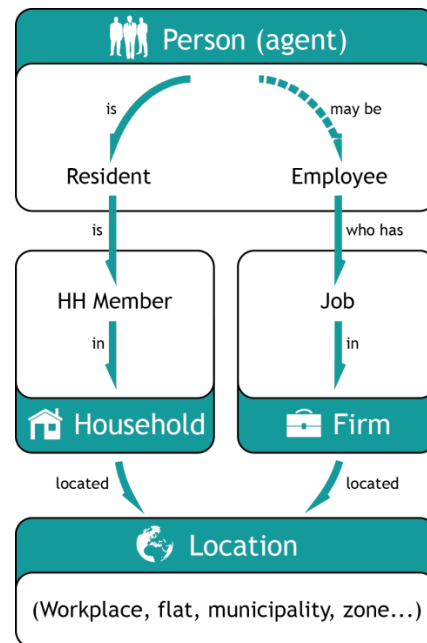


These two cycles are strongly connected and in integrated land-use models consequently modelled in the same framework to consider interdependencies. Indeed, the FaLC project focuses mainly on long-term location and relocation strategies with time steps of generally one year.

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 focuses 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.

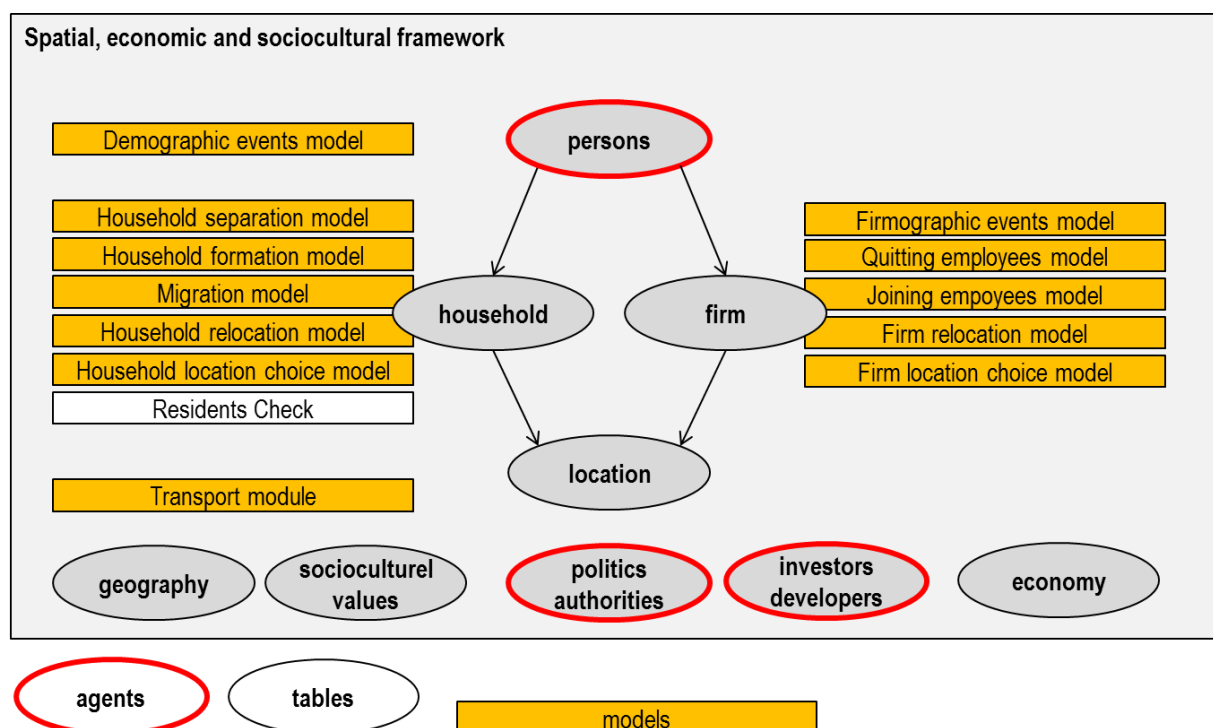
**Discrete choice models** are used to model a choice process such as new locations for households or firms. In general, these models consist of different sub-models: a) calculation of the utility of possible alternatives (by a so called “utility function”); b) comparison of the utilities



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<sup>1</sup>), 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.

<sup>1</sup> 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.

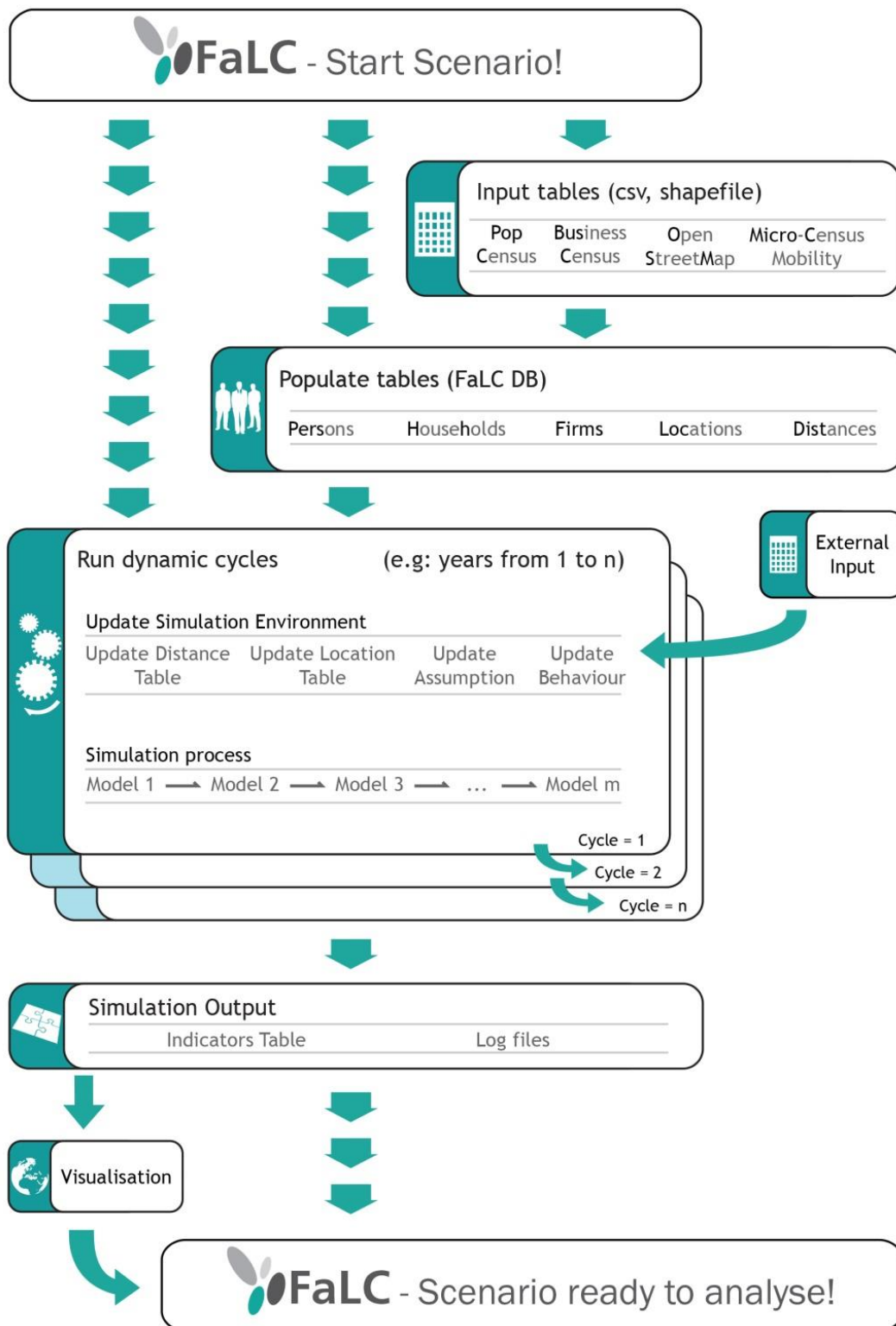
The source database for the generation of a synthetic population is composed primarily by official census data (e.g.: Federal Census of Population or Business Census from FSO) and micro-census on mobility. Thanks to this information, it is possible to generate a synthetic population adapted to the different 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

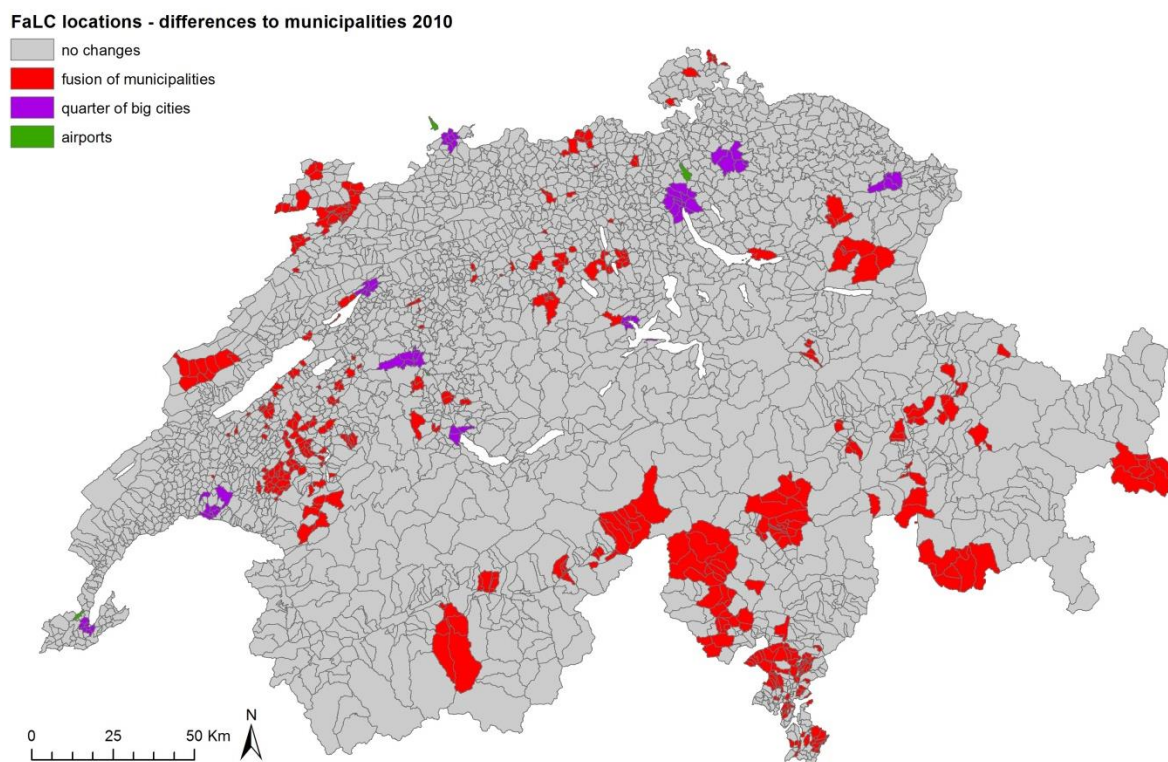


## 2 Swiss Case Study

### 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 5).

Figure 5 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<sup>2</sup> 2006 data, and the official perimeter<sup>3</sup> in the specific case of Zurich airport.

<sup>2</sup> The European Environment Agency (EEA)

<sup>3</sup> 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 municipalities	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	<b>probabilistic model</b>
sources	<b>Indikatoren der Fruchtbarkeit in der Schweiz, 1950-2050 Sterberaten nach Alter und Geschlecht 2000-2050 FSO (BEVNAT, ESPOP), Bodenmann et al. (2009)</b>
FaLC implementation	<b>.agentmodel.service.methods.LDMethodsNew_Impl_1</b>
FaLC property files	<b>app-config.xml org.falcsim.agentmodel.app.domain.RunParameters demographyOn = true</b>
FaLC tables in DB	<b>deathtable birthtable</b>
Parameters	<b>probability of death for old people = 0.33 age limit for death.probability parameter = 93</b> 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.

**Household separation model**

model type	<b>probabilistic model</b>
sources	<b>Population Census 2000 (FSO)</b> <b>Beige (2008)</b> <b>Bodenmann et al. (2009)</b>
FaLC implementation	<b>.agentmodel.service.methods.HHSeparationMethodsImpl_1</b>
FaLC property files	<b>app-config.xml</b> <b>org.falcsim.agentmodel.app.domain.RunParameters</b> <b>hhSeparationOn= true</b>
FaLC DB tables	<b>umzugsraten_n_alter</b> (rate of children that leave home) <b>scheidung_n_jahr</b> (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	<b>Discrete choice model</b>
sources	<b>Beige 2008</b> (see also Killer and Axhausen, 2012)
FaLC implementation	<b>.agentmodel.service.methods.HHFormationMethodsImpl_1</b>
FaLC property files	<b>app-config.xml</b> <b>org.falcsim.agentmodel.app.domain.RunParameters</b> <b>hhFormationOn= true</b>
Parameters	<b>mate probability = 0.1</b> (probability that a single-person gets in relation to another person) <b>minimal distance = 2 [km]</b> (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	
single persons changing household t+1	households in 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.



### Migration model

model type	<b>probabilistic model</b>
sources	-
FaLC implementation	<b>org.falcsim.agentmodel.service.methods.MigrationImpl1</b>
FaLC property files	<b>migration_v01.csv (balance if migrants)</b> <b>migration_households_types.csv</b> <b>org.falcsim.agentmodel.app.domain.RunParameters</b> <b>immigrationOn = true</b>

For each year, the number of migrants can be included in the FaLC framework based on migration balance on the level of municipalities, cantons, or the case study area. If the migration balance is negative, the according number emigrants will be randomly deleted out of the single households in the area. If the balance is positive, FaLC will a) generate new persons and families, b) distribute the households in the regions based on attracting points, and c) (re)locate the households to the residents place.

### Generate new persons and families

Based on the assumptions regarding household type, its share, and ages of parents and children (assumptions in file migration\_households\_types.csv), the migrating persons and households are modelled. The number of migrants base on BFS-statistics (PETRA, STATPOP) on the level of Switzerland (possible other levels of aggregations are municipalities and cantons).

Table 2 Immigrating household types

Type	Name	pax	Share	Age m	Age w	Age child	Age chld2	+/- age
0	Single	1	65%	30	30			10
1	Pair with no children	2	25%	32	30			10
2	Family with one child	3	5%	32	30	2		4
3	Family with two children	4	5%	37	35	7	5	4

File: migration\_households\_types.csv

### Distribution the immigrating households in the regions based on attracting points

In the implemented case study, we assume that migration and job (place or search) are strongly connected. Therefore, the immigrating households are distributed within the region according to the distribution of workplaces. Indeed, this is only the starting point to look for a flat.

### (Re)locate the households to the residents place

Finally, the households are located in the region based on the utility function defined in the location choice model (see below).

**Household relocation model**

model type	<b>probabilistic model</b>
sources	<b>Population Census 2000 (FSO) (Bodenmann et al., 2009)</b>
FaLC implementation	<b>.agentmodel.utility.UtilityMoveSwiss_2_weighted1</b>
FaLC property files	<b>app-config.xml org.falcsim.agentmodel.app.domain.RunParameters utilitiesOn = true</b>
FaLC property files	<b>umzugsraten_n_alter</b> (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	<b>discrete choice model</b>
sources	<b>Schirmer et al. (2011)</b>
FaLC implementation	<b>.agentmodel.utility.UtilityMoveSwiss_2_weighted1</b>
FaLC property files	<b>app-config.xml org.falcsim.agentmodel.app.domain.RunParameters utilitiesOn = true</b>

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 $\beta$
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.<sup>4</sup>

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:<sup>5</sup> 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.

<sup>4</sup> 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.

<sup>5</sup>  $A_i = \sum_m \sum_j O_j \times e^{\beta \times t}$ , 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 modulus m between i and j [min.],  $\beta = 0.20$ .

**Residents check**

model type	<b>probabilistic model</b>
sources	-
FaLC implementation	<b>org.falcsim.agentmodel.service.methods.MigrationImpl1</b>
FaLC property files	<b>controll_residents_v01_2000-2050m_decades.csv</b> <b>org.falcsim.agentmodel.app.domain.RunParameters</b> <b>resCheckOn = true</b>

After the distribution of residents in the case study area based on the models in FaLC, the simulated FaLC-population of residents can be compared with data from other sources: e.g. real values in the past or official forecasts of statistical offices.

By setting the parameter on true, the number of residents can be corrected based on these values. In fact, the procedure is the same as for migrants. If the balance between FaLC-results and the check data is negative, the according number emigrants will be randomly deleted out of the single households in the area. If the balance is positive, FaLC will a) generate new persons and families, b) distribute the households in the regions based on attracting points, and c) (re)locate the households to the residents place.

## 3.2 Firmographic events

### Economic development model

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

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

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	

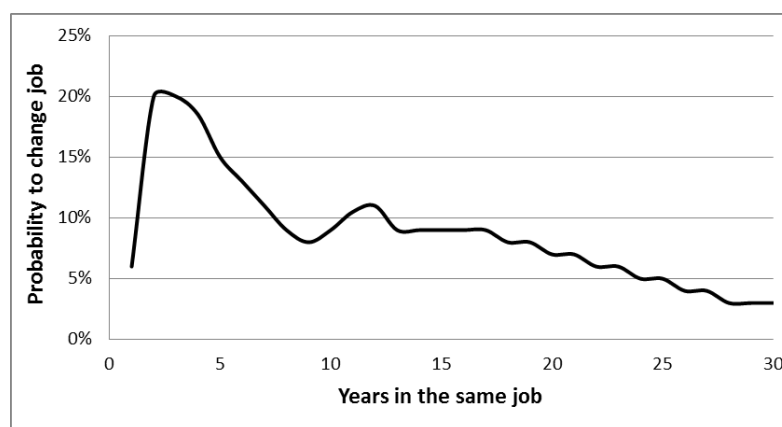
### Quitting employees model

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

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

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<sub>wa</sub>* in the working age:

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

if  $LE \leq MLE$  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

<i>J</i>	Sum of jobs in the Case Study Area
<i>E</i>	Sum of employees in the Case Study Area
<i>R<sub>wa</sub></i>	Sum of residents <i>R<sub>wa</sub></i> in the working age (18 years - 64 years)



<i>LE</i>	Level of Employment
<i>MLE</i>	Maximum Level of Employment (defined by parameter MAX_LEVEL_EMPL)
<i>P<sub>E</sub></i>	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. The maximum level of employment has been fixed to the 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	<b>probabilistic model</b>
sources	<b>Bodenmann 2011</b>
FaLC implementation	<b>.agentmodel.utility.UtilityMoveSwiss_2_weighted1</b>
FaLC property files	<b>app-config.xml</b> <b>org.falcsim.agentmodel.app.domain.RunParameters</b> <b>utilitiesOn = true</b>

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 <sub>S</sub>
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.

During the calibration phase, the results showed that rates, especially for firms, depend significantly on the size of the municipality. Large municipalities and cities give opportunities to relocate within the conurbation. Relocation rates therefore decrease with increasing size of the settlement. This problem has been solved by multiplying the relocation rates (RR<sub>S</sub>) for sector S with a factor indicating size of the settlement  $\alpha_{loc}$ . This size correction is additionally weighted by a correction factor  $\beta_S$ , depending on the economic sector:

$$RR_{Corr} = RR_S * \alpha_{loc} * \beta_S$$

With

RR <sub>Corr</sub>	corrected relocation rate
RR <sub>S</sub>	average relocation rate of sector S
$\alpha_{loc}$	average number of employees in all locations / employees in location loc
$\beta_S$	correction factor depending on economic sector S

The results of these calculations are probability rates that depend on the size of the location and sector of the company. In general, the noted probability rates hold for medium-sized locations while larger municipalities will have smaller rates and smaller municipalities will have larger relocation rates.  $\beta_S$  has been estimated during the calibration process.

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

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 $\beta$ 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 7.

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 7 Implement conditions for relevant locations

HOUSEHOLDS	FIRMS
Inner circle ( $r < 25\text{km}$ by car) <b>100%</b>	
Outer circle ( $r < 50\text{km}$ by car) <b>50%</b>	
Motorway connections ( $r < 30\text{km}$ ) <b>50%</b>	Motorway connections ( $r < 50\text{km}$ ) <b>100%</b>
Agglomerations + cities <b>10%</b>	Agglomerations + cities <b>10%</b>
Large cities <b>50%</b>	Large cities <b>100%</b>

To avoid white noise effects due to different sets of alternatives in the multiple runs (chapter 0), the current implementation of FaLC can save sets of precalculated sublocations by year. These sets are stored in the database and FaLC and are used congruently in all following runs.

Figure 8 Set of alternative locations to relocate firms from Luzern (example)

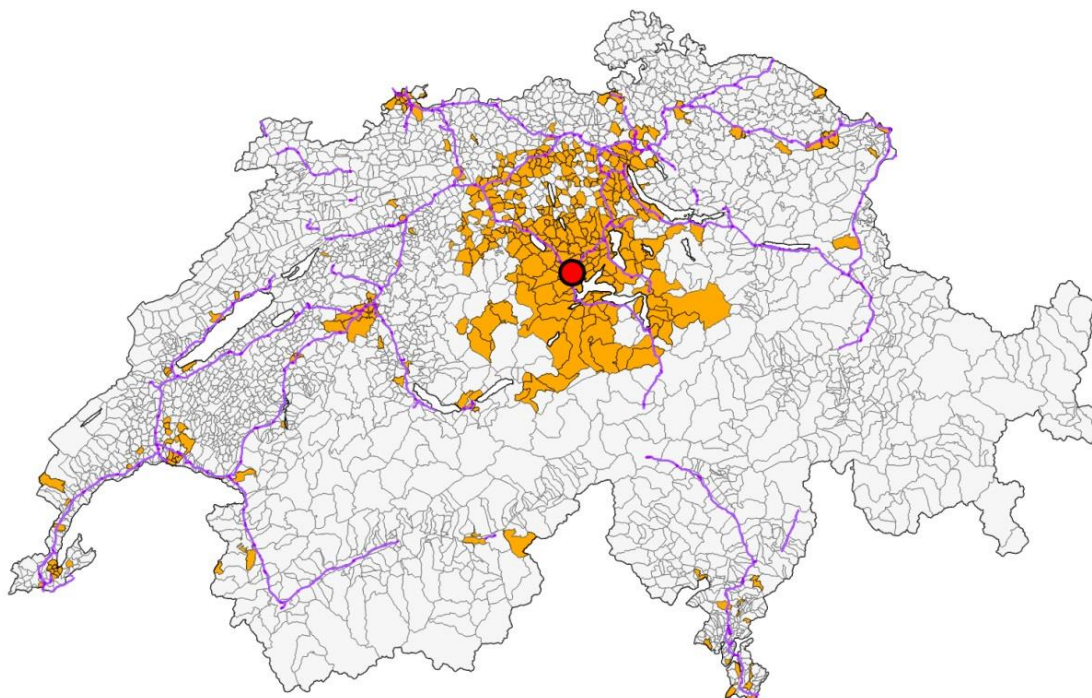


Figure 8 presents an example of the set of alternatives (orange locations) which will potentially allocate firms moving from Luzern Innenstadt (red circle). As we can see, the big cities in Switzerland as well as all the motorway connections (purple lines) in less than 50 kilometres from Luzern Innenstadt 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:

$$occFA(\ell, u) \leq \sum_z maxFA(\ell, u, z)$$

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

with:

$occFA()$	occupied Floor Area (by location $\ell$ and use type $u$ )
$maxFA()$	maximum Floor Area (by location $\ell$ , use type $u$ , zone type $z$ )
$\ell$	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

$$\begin{aligned} occFA(u=r) &= R * FApp(u=r) \\ occFA(u=j) &= J * FApp(u=j) \end{aligned}$$

with:

$R$	sum of residents in the location (municipality)
$J$	sum of jobs in the location (municipality)

$FApp(u)$  Floor Area per person [m<sup>2</sup> 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<sup>6</sup> (Altwegg et al., 2003), Gilgen (2001), Huber (1992). Although some additional assumptions have been made: e.g., in Gastronomy, we assume 30 m<sup>2</sup> per room and 0.46 jobs per room<sup>7</sup>. This results in about 65 m<sup>2</sup> 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 [m <sup>2</sup> /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<sup>2</sup> per decade. In 1980, each resident occupied 34m<sup>2</sup>; two decades later, in 2000, residents occupied 44 m<sup>2</sup> per person. In FaLC, the same growth is considered till 2020. After 2020, a smaller growth is assumed (2.5 m<sup>2</sup> per decade).

<sup>6</sup> Monet indicator, see [www.bfs.admin.ch/bfs/portal/fr/index/themen/21/02/ind32.indicator.70401.3212.html](http://www.bfs.admin.ch/bfs/portal/fr/index/themen/21/02/ind32.indicator.70401.3212.html)

<sup>7</sup> Referring to data from Steigenberger Hotel Group for 2007 ([www.steigenbergerhotelgroup.com](http://www.steigenbergerhotelgroup.com)) and Hotel-fachschule Thun ([www.hfthun.ch](http://www.hfthun.ch)).



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:

$$maxFA(u=r,z) = A(z) * UF(z) * ms(u,z)$$

$$maxFA(u=j,z) = A(z) * UF(z) * ms(u,z)$$

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

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)<sup>8</sup> 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 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):

$$occFA(\ell, u) \leq \sum z maxFA(\ell, u, z) + obzFA(\ell, u)$$

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

with:

$occFA()$	occupied Floor Area (by location $\ell$ and use type $u$ )
$maxFA()$	maximum Floor Area (by location $\ell$ , use type $u$ , zone type $z$ )
$obzFA()$	Floor Area outside the considered zoning plan (by location $\ell$ , use type $u$ )
$\ell$	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.<sup>9</sup>

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

<sup>8</sup> In German: Ausnützungsziffer AZ

<sup>9</sup>  $x = (occFA(\ell, u) \times 1.10) - \sum z maxFA(\ell, u, z)$ ; if  $x > 0$ :  $obzFA(\ell, u) = x$ ; if  $x \leq 0$ :  $obzFA(\ell, u) = 0$ ;

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.

#### **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 aim of the results validation in FaLC is to verify the scale of precision of the simulation and, consequently, detect the points to enhance the level of quality of FaLC which has been considerably increased during the latest implementations (e.g: migration module).

It should be noted that since the assumptions of firms and households models in the current version of FaLC, are based in a very simplified level, only the number of residents and employees in the level of municipalities has been taken into consideration during the validation process.

The validation of FaLC simulation has been then made by comparing:

- FaLC indicators for residents in 2010 with the Population Census of 2010 (FSO/BFS)
- FaLC indicators for employees in 2008 with Business Census 2008 (FSO/BFS)

### 5.1 General fit

The coefficient of determination ( $R^2$ ) indicates between 0 and 1, how well data points fit a statistical model by following the adapted equation below:

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

with:

n      number of municipalities i

$R^2$     coefficient of determination

$Y_i$     result of FaLC for municipality i

$\bar{Y}_i$     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  $Y_i$

With a high level of achievement,  $R^2$  analysis shows that FaLC fits quite well for residents and especially well for employees. In that sense, the level of achievement for employees is 1.00 (maximum level!) and for residents 0.99 which is more than a good indicator. Neverthe-

less, within the aim to reach a maximum level of achievement for residents also, some differences which are nowadays existent concerning the distribution of residents by large or small municipalities (Chapter 5.3) can be completely solved thanks to future implementations in process. -

Figure 9 Validation for residents (2000-2010) and for employees (2000-2008)<sup>10</sup>

Coefficient of Correlation		
R2_Residents 2010	R2_Employees 2008	R2_AVERAGE
0.99	1.00	0.99

## 5.2 Fit of absolute values by agent groups

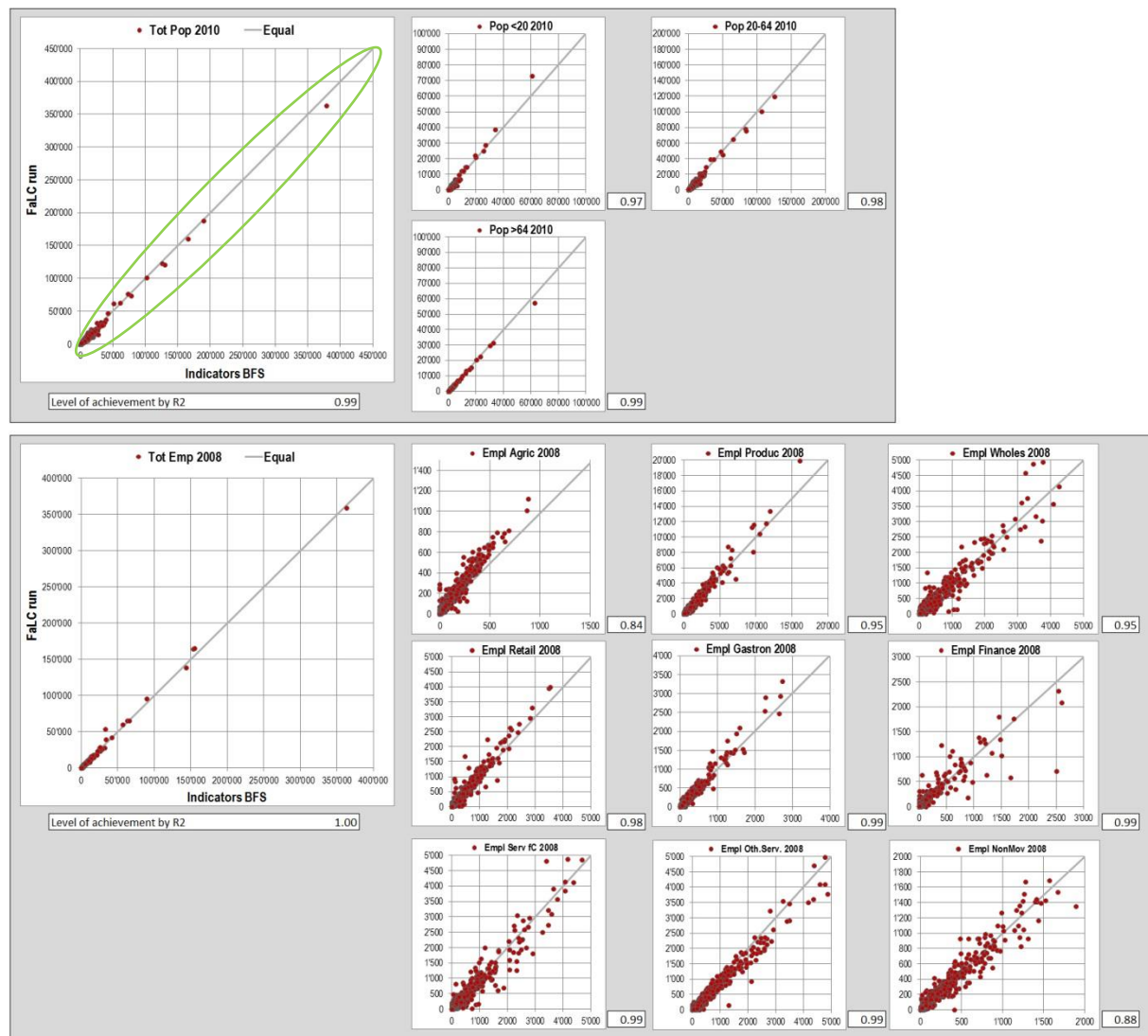
The following set of diagrams compares the total number of residents and employees simulated by FaLC with FSO official data for the year 2010 and 2008 (explained in the previous chapter), as well as some subcategories like residents by group of ages or employees by sector of activity. For each group, a given degree of achievement (in  $R^2$ ) 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). For example, in the case FaLC exports exactly the same value for 2008/2010 as the official number of FSO, the dot will be located over the “equal” line.

Consequently, the more the dots are close to the “equal” line, the better FaLC results fit to reality (see green circle over the Figure 10).

Total residents as well as total employees graphically show a good fit.

<sup>10</sup> Reference run: “2014-11-27-11-40” (OSM Network)

Figure 10 FaLC indicators vs FSO official data for residents (2010) and employees (2008)<sup>11</sup><sup>11</sup> Reference run: “2014-11-27-11-40” (OSM Network)

### 5.3 Spatial distribution of FaLC results

The next four maps (Figure 11 and Figure 12) have been created in order to visualise the distribution of residents and employees for the time steps 2008 and 2010 estimated by FaLC and contrasted with the official FSO values.

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, residents and employees, 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.

In order to graphically understand the differences between FaLC and FSO regarding the evolution of residents (2000-2010) and employees (2000-2008), it is important to have a look at the following set of maps showing the evolution of residents and employees (Figure 13f).

As described previously, the evolution of employees in FaLC and FSO are favourable and apart from some special cases, the differences between reality and FaLC is small.

However, concerning residents and despite the good level of achievement described in the previous chapter, in the current status of FaLC we detect a general relocation of households, and consequently, residents, from the rural areas to the suburban and urban core zones. The reason why suburban areas are growing faster than cities is that they (generally) reach their maximal capacity while, in contrast, municipalities near the centre often have good ratings in the relocation processes and offer free space to live and work.

Those differences which are nowadays existent concerning the distribution of residents by large or small municipalities can be solved with further applications.



Figure 11 Distribution of residents by municipality in 2010. FaLC (top) and FSO (bottom)

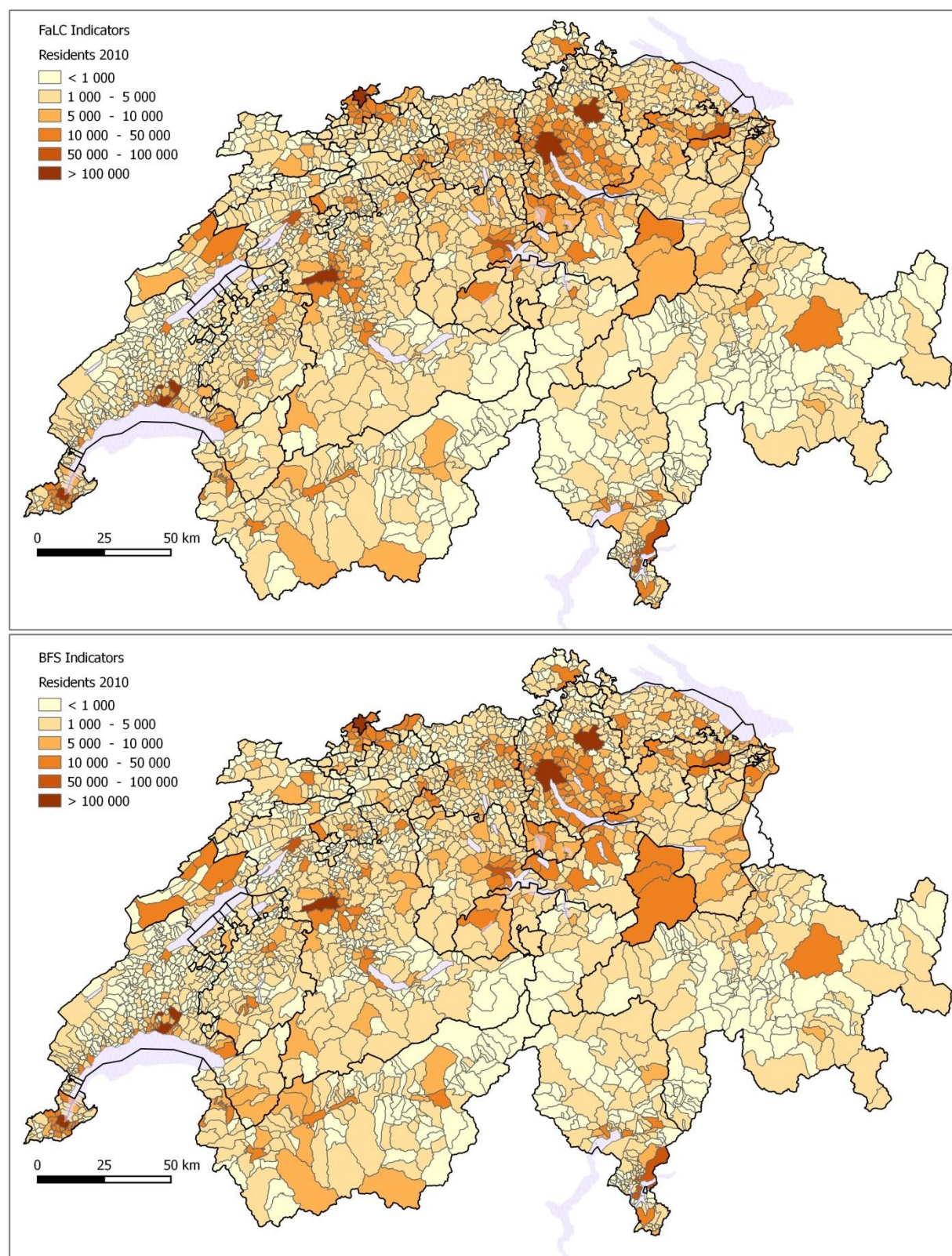




Figure 12 Distribution of employees by municipality in 2008. FaLC (top) and FSO (bottom)

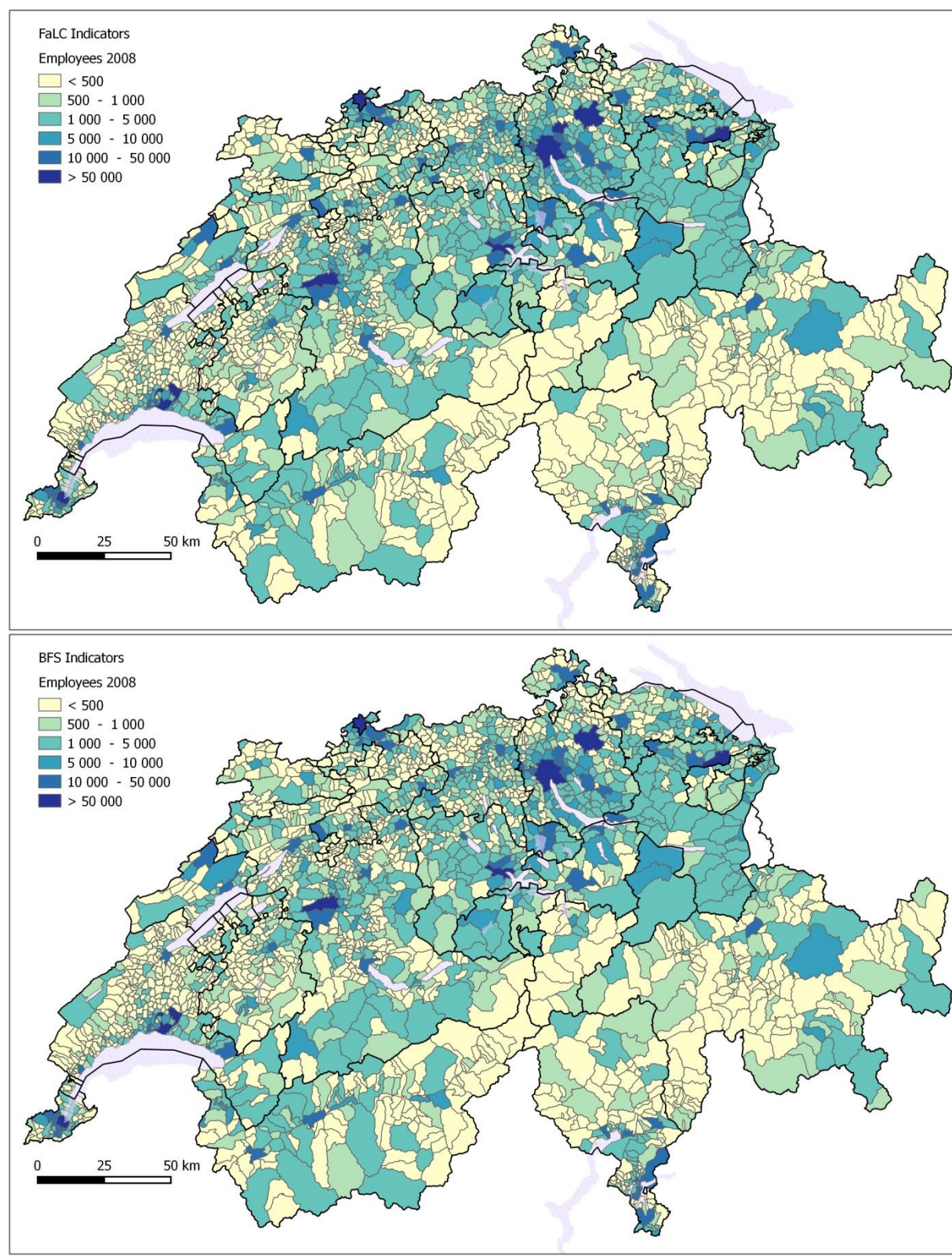




Figure 13 Evolution of residents from 2000 to 2010.  
Compared indicators between FaLC (top) and FSO (bottom)

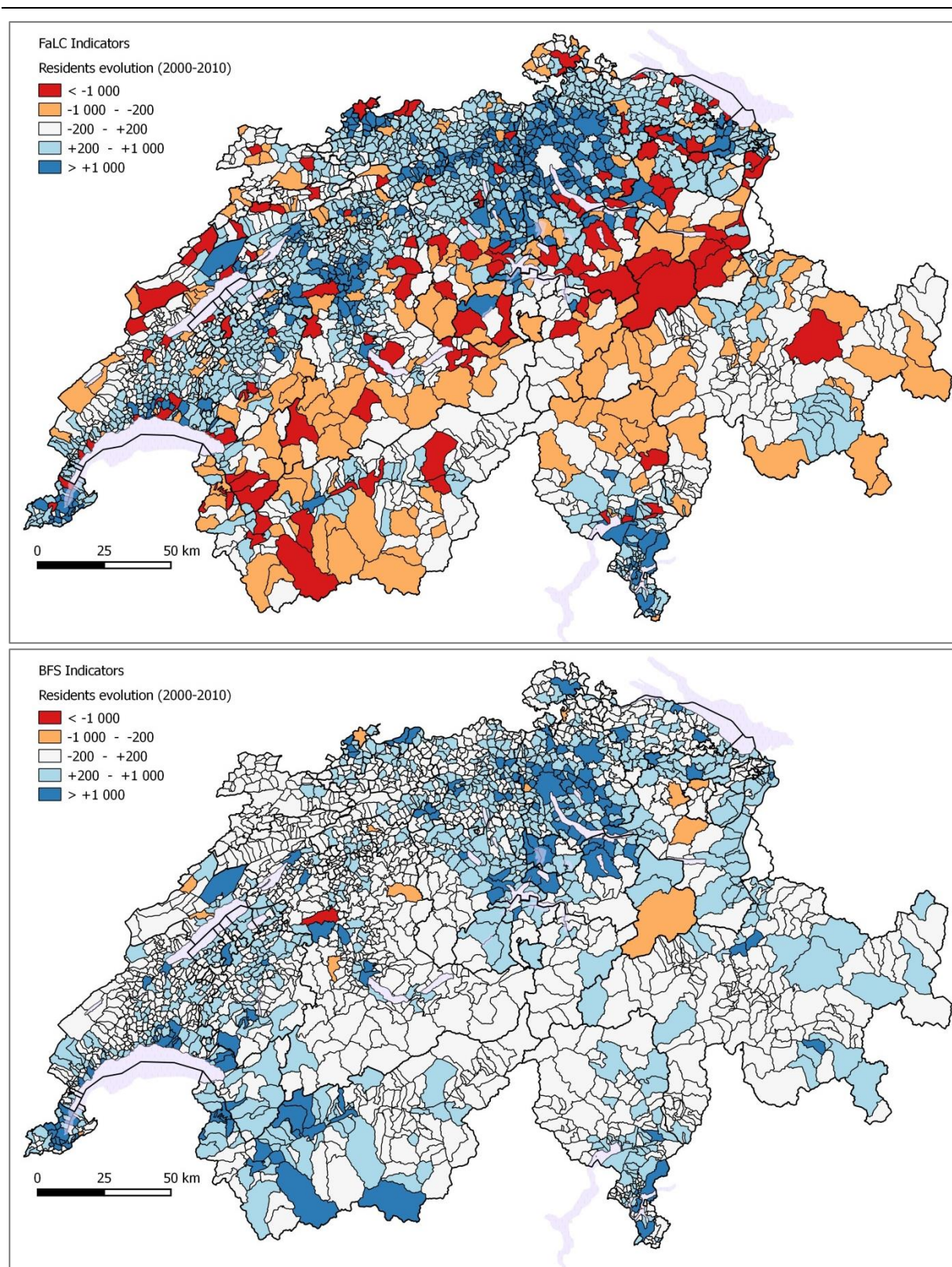
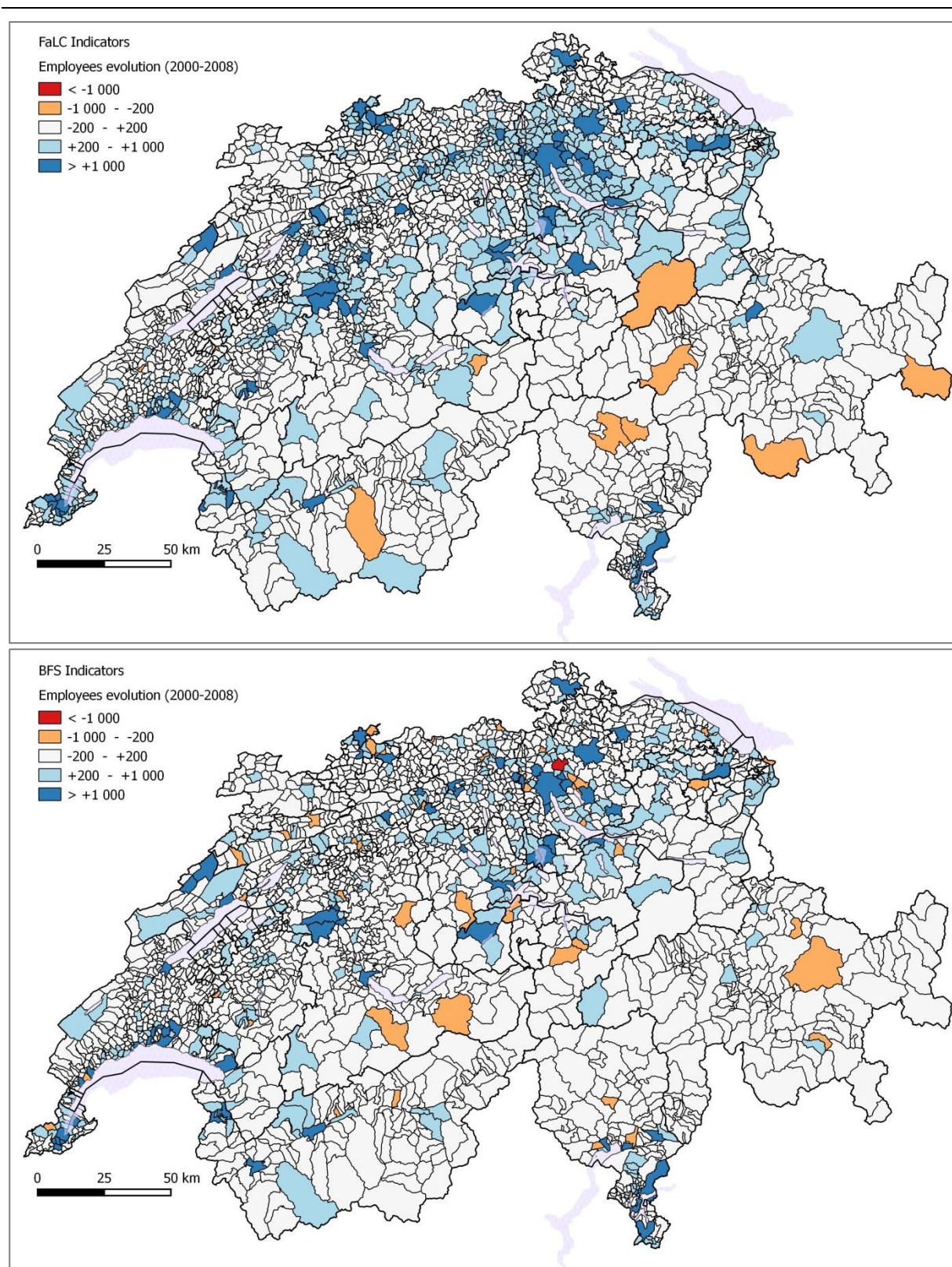




Figure 14 Evolution of employees from 2000 to 2008.  
Compared indicators between FaLC (top) and FSO (bottom)



## 5.4 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).

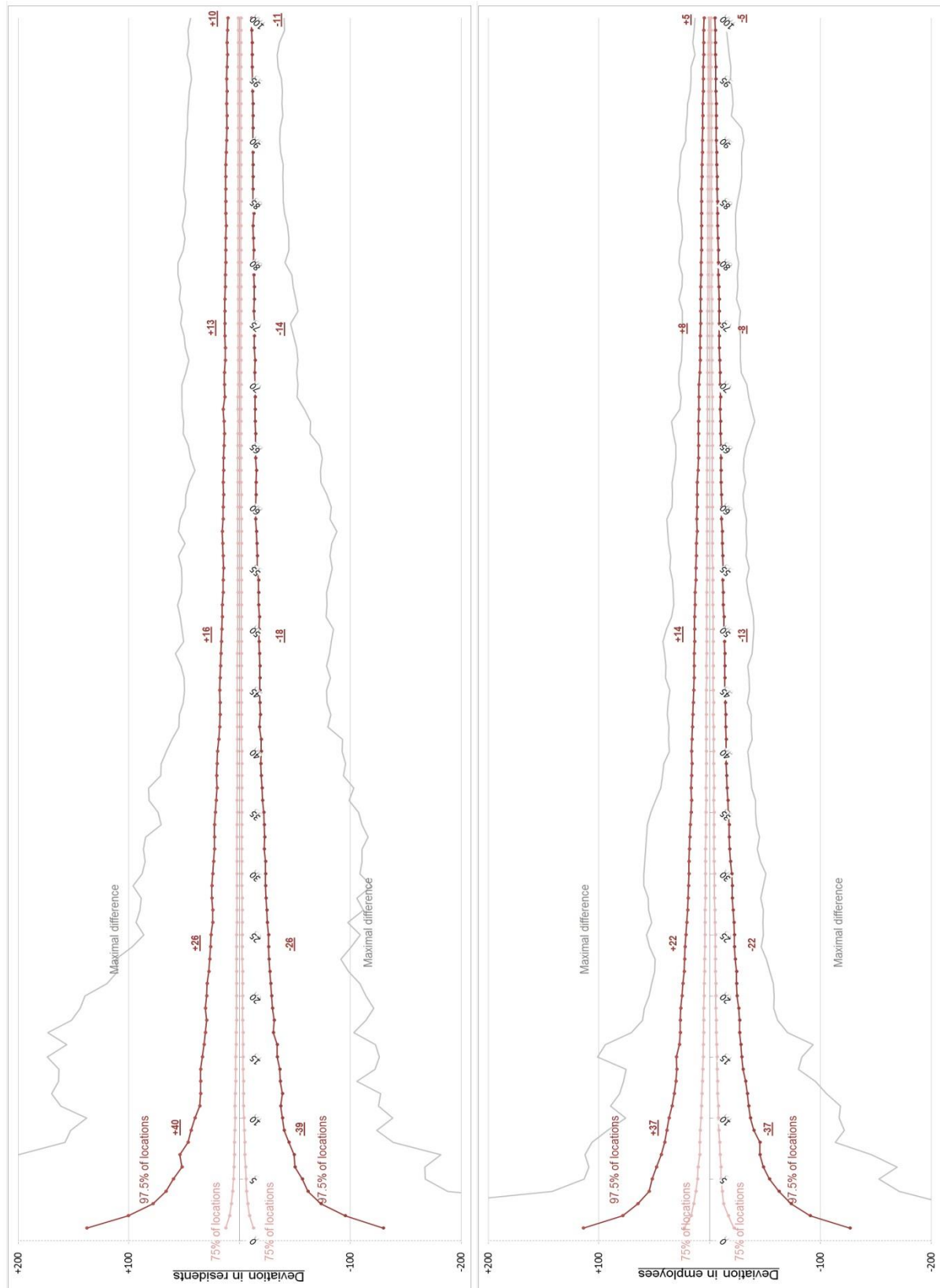
A very important reason for this observation is the so-called “white noise”. White noise is a side-effect due to the various Monte Carlo Simulations in different models. To better understand this relation, the following figures show the variation, or white noise, by comparing different identical FaLC runs with a standard value (obtained by calculating the average of 250 runs).

Figure 15 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 increasing number of runs defined in the “x” axis. The according number of runs have been compared to the mean values of the 250 runs.

Concerning the 95% confidence interval, the variation of residents (left chart) decreases considerably from +40-49 after 10 runs to  $\pm 26$  after 20 runs. Further on, the accuracy is still slightly better with each additional run, but to reach results with accuracy of about  $\pm 15$  at least 50 runs are needed. For the case of the firms (right chart), the deviation of employees is much less important, achieving less differences and consequently less white noise with the same number of runs..

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 15 White noise reduced by using the average of several runs



***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 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 provide the mean values.

## **5.5 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.

## 6 Conclusion

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:

The yearly cycles include about one dozen of different models (partly including several sub-models). Based on the validation results, different weaknesses and errors of FaLC have been detected and corrected. Additionally, since the last version of this Case Study, a migration model has been included.

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 shows a coefficient of determination  $R^2$  generally higher than 0.95 (depending on the individual runs).

As a general conclusion, we state that FaLC achieved very good fit to reality (at least for the past). Over all, the simulation results regarding residents and employees are coherent with real data. Indeed, the behaviour of residents is – at this stage – biased by a strong attractiveness of agglomerations. A reason for this certainly is the weak utility function used for relocation process of household. Focus of future work lies on integrating a more comprehensive behavioural model for the residents’ location choice processes.

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	[integer]
	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	
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: 1 agriculture 2 production 3 wholesale 4 retail 5 gastronomy 6 finance 7 services fC 8 other services 9 others 10 non movers	NOGA08 1-7 10-35, 41-43 45-46, 49-53 47 55-56 64-66 58, 60-63, 69-82 59, 68, 86-90, 92-96 97-98 8-9, 84-85, 91, 99
Type_2	Legal form (Rechtsnatur): 1 holding (hg) 2 partnerships (pg) 3 companies (kg)	[integer]
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	[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	[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]
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\* 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-polygons 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	Entities
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 divorce\_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 of parents' home per year by age	[numeric]
Pc_rel_parent	cumulated rate moving out of parents' home per year by age	[numeric]
P_rel_in_rethome	moving rate into a retirement home by age	[numeric]

## B Output tables FaLC

### B 1 Standard output tables

Standard indicators, with possibility to switch them on/off by properties and in GUI. It is also possible to setup filters for years, runs, locations and output level (location, municipality, canton). According to output level, tables names are with postfix: loc, mun or can. They can be written as independent tables per year or all years in one file. If independent file for each year is specified, table name contains also year to which belongs.

Each table contains header with information about table name, extended description (defined by user) and full path where table was stored by application. Extended description is defined by property *run.indicators.extra.description*

#### B 1.1 Locations\_zones (locations)

Table contains location's parameters for current year and cycle of universe calculation. It is not possible to setup up output level, only locations are exported.

Attribute	Description	Entities	Value/column
locid	Location code	[integer]	1-max.loc.id
denot	Location name	[character]	
code_mun	Municipality code	[integer]	1-max.mun.id
name_mun	Municipality name	[character]	
subarea_nr	Canton code	[integer]	1-26
name_can	Canton name	[character]	
run	ID of run	[integer]	Not used
res_tot	Total number of residents	[integer]	
emp_tot	Total number of employees	[integer]	
settlement_area	Location_attributes table	[integer]	Area_settl
flat_rent	Location_attributes table	[integer]	Rent_4flat
urban_centre	Initial value is taken from Location_attributes table Then $res\_tot + emp\_tot > 50.000$ , location cannot lost status of urban centre.	[integer]	0,1 urban_centre
diversity_sector	2* number of different businesses sectors in location	[integer]	0-20
motorway_access	Location is connected to motorway from locations_development	[integer]	0,1/ aansch_YEAR
railway_access	Location is connected to railway from locations_development	[integer]	0,1/ bhf_YEAR



Attribute	Description	Entities	Value/column
resident_landprice_n	Normalized value of land price from location_attributes	[double]	LP_res
landuse_density_n	Normalized value of res_tot + emp_tot	[double]	
university_degree_n	Normalized value of education from location_attributes	[double]	ED_18_xx_
diversity_sector_n	Normalized value of diversity_sector	[double]	
tax_holdingcomp_n	Normalized value of taxes for holdings from locations_development	[double]	st_hold_YEAR
tax_partnership_n	Normalized value of taxes for public companies from locations_development	[double]	st_hold_YEAR
tax_companies_n	Normalized value of taxes for standard companies from locations_development	[double]	st_gh_YEAR
accessibility_t_n	Normalized value of all accessibility variables	[double]	
bus_dev_cant_n	Location_attributes table	[double]	Bus_dev_index
accessibility_res_n		[double]	Not used
bus_dev_mun_n		[double]	0, Not used
av_1	Accessibility variable: residents/cars	[double]	
av_2	Accessibility variable: workers/cars	[double]	
av_3	Accessibility variable: residents/public	[double]	
av_4	Accessibility variable: workers/public	[double]	
av_5	Accessibility variable: residents/bicycle	[double]	
av_6	Accessibility variable: workers/bicycle	[double]	
landtype	Location_attributes table	[integer]	91, 92, 94 loc_type
maxfloorareares	Max. floor area for residents	[double]	
usedfloorareares	Used floor area for residents	[double]	
maxfloorareawrk	Max. floor area for workers	[double]	
usedfloorareawrk	Used floor area for workers	[double]	
maxfloorareaall	Max. floor area ftotal	[double]	
usedfloorareaall	Used floor area for total	[double]	

**B 1.2 Overview table**

<b>Attribute</b>	<b>Description</b>	<b>Entities</b>
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
R_T	Residents total	[integer]
R_00_19	Residents under 19 years	[integer]
R_20_64	Resident between 20 and 64 years	[integer]
R_65_XX	Residents older than 65 years old	[integer]
E_T	Employees total	[integer]
E_S01... E_S10	Employees by sector	[integer]
FA_MAX_	T Maximum floor area for total residents and firms	[numeric]
	R Maximum floor area for total residents	
	F Maximum floor area for total firms	
OCCFA_	T Occupied floor area for total residents and firms	[numeric]
	R Occupied floor area for total residents	
	F Occupied floor area for total firms	

**B 1.3 GIS table**

For compatibility with GIS systems, file with columns types with the same name as table and CSV extension is exported as well.

Attribute	Description	Entities
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
R_T	Residents total	[integer]
E_T	Employees total	[integer]
H_T	Households total	[integer]
F_T	Firms total	[integer]
E_S01... E_S10	Employees by sector	[integer]

#### B 1.4 Firms table

Attribute	Description	Entities
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
E_T	Employees total	[integer]
F_T	Firms total	[integer]
F_S01... F_S10	Firms by sector	[integer]
F_Z	Number of firms by size (no of employees + CEO) Size category:	[integer]
	00 Inactive companies	
	01 Freelancers	
	02_04 Firms with 2 - 4 employees	
	05_09 Firms with 5 - 9 employees	
	10_49 Firms with 10 - 49 employees	
	50250 Firms with 50 - 259 employees	
	250 Firms with 250 and more employees	

**B 1.5 Firm types table**

Attribute	Description	Entities
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
E_T	Employees total	[integer]
F_T	Firms total	[integer]
E_S01_XX...S10_XX	Employees by sector and business type 01 Holdings 02 Public companies 03 Standard companies	[integer]
F_S01_XX...S10_XX	Firms by sector and business type 01 Holdings 02 Public companies 03 Standard companies	[integer]

**B 1.6 Households table**

Attribute	Description	Entities
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
H_T	Households total	[integer]
H_Pa-Cb	Households by number of parents and children a= 1 or 2 b = X, means more that 5 children	[integer]
H_Pair	Households with adult pair	[integer]
H_Sing	Households with adult single	[integer]
H_P0-C0	Households as adult children live without parent	[integer]
H_P0-CX	Households with children live without parent	[integer]

H_Error	Households which do not belong to any group	[integer]
R_T	Residents total	[integer]
R_Pa-Cb	Residents by number of parents and children a= 1 or 2 b = X, means more that 5 children	[integer]
R_Pair	Residents as adult pair	[integer]
R_Sing	Residents as adult single	[integer]
H_P0-C0	Residents as adult children live without parent	[integer]
R_P0-CX	Residents as children live without parent	[integer]
H_Error	Residents, their households do not belongs to any group	[integer]

### B 1.7 Persons table

Attribute	Description	Entities
ID_GEN	ID General (10 digits) containing year (4 digits) + id municipality (6 digits)	[integer]
CODE_LOC	Location code	[integer]
NAME_LOC	Location name	[character]
CODE_MUN	Municipality code	[integer]
NAME_MUN	Municipality name	[character]
CODE_CAN	Canton code	[integer]
NAME_CAN	Canton name	[character]
CYCLE	Year, month...	[integer]
R_	T Residents total 00_19 Residents under 19 years 20_64 Resident between 20 and 64 years 65_XX Residents older than 65 years old	[integer]
R_xx_yyM	Male persons in age group between XX and YY	[integer]
R_xx_yyW	Female persons in age group between XX and YY	[integer]
E_T	Employees total	[integer]
E_S01... E_S10	Employees by sector	[integer]
E_UE_T	Unemployed persons	[integer]
E_Dxx_yy	Persons commuting by distance in kilometres Distance commuting: 00-04 Less than 5 kilometres 05-09 Between 5 and 9 kilometres ... 100-XX More than 100 kilometres	[integer]

### B 1.8 Relocation table

It is strongly recommended to define filter for locations or municipalities for this output table, because it contains row for each combination of locations pair.

Attribute	Description	Entities
CYCLE	Year, month...	[integer]
FROM	Source location code	[integer]
TO	Destination location code	[integer]
R_T	Moved residents	[integer]
H_T	Moved households	[integer]
E_T	Moved workers	[integer]
F_T	Moved firms	[integer]
J_T	Moved work places (jobs)	[integer]
E_S01...S10	Moved workers by sector	[integer]
F_S01...S10	Moved firms by sectors	[integer]

### B 1.9 Runinfo table

This table contains data about running time for each active model. Sum of these values is not application running time, because application needs additional time to load, save universe and output tables. Time is stored in milliseconds.

Attribute	Description	Entities
CYCLE	Year, month...	[integer]
Service Initialization	Initialize time for all active models	[integer]
Demographic Change	Life and Death	[integer]
Migration	Immigrants and control total residents	[integer]
Households separation	Children leave parents, divorces	[integer]
Households formation	Marriages	[integer]
Economic development	Calculate evolution for first	[integer]
Firmographics Change	Close and create companies	[integer]
Quitting employees	Employees leave their jobs	[integer]
Joining employees	Unemployed work aged persons try to find new jobs	[integer]
Relocation	Moving households and firms, location choice	[integer]

### B 1.10 Tables with average run indicators

If several cycles(reference runs) of universe calculation is setup, FaLC will generate subdirectory for each cycle. If defined, FaLC will calculate tables with average values for run indicators. They are stored in "run\_average" subdirectory. Tables are the same, but entities can be stored as values with two decimal places (Double).

## B 2 all\_calibration table

Former output table with almost all possible run indicators. It can be switch on by setup property *run.indicators.export.level=2*

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 With 1 parent and more than 5 children	
	Paar Couple without children	
	Single One single person living	
	Error For empty household or more than 2 parents, probably here will be all-ways 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 T Total employees Sectors: see FIRM_sec	[numeric]
COM	Persons commuting by distance in kilometres Distance commuting: 00-04 Less than 5 kilometres 05-09 Between 5 and 9 kilometres ... 100-XX More than 100 kilometres	[numeric]
EDUC_lev_	Number of students by education level Level: 01 Without education 02 Elementary/obligatory school 03 Apprenticeship 04 Secondary Education 05 High education/University	[numeric]
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) Size category: 0 Inactive companies 1 Freelancers 02-04 Firms with 2 - 4 employees 05-09 Firms with 5 - 9 employees 10-49 Firms with 10 - 49 employees 50-250 Firms with 50 - 259 employees 250-XX Firms with 250 and more employees	[numeric]
MAXFA	Maximum floor area 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	[numeric]
OCCFA	RES_T Occupied floor area for total residents FIRM_T Occupied floor area for total firms 01 agriculture 02 production ... 10 non movers	[numeric]



## B 3 Debug table

Usually big tables with detailed information calculated during relocation model and location choice. It is important to define filter on locations to keep size of tables under control. They can be switch on by setup property *run.indicators.export.level=4*

Additional properties for setup debug tables:

Property name	Value
<i>run.indicators.export.relocation.ripis.intervals.bussineses</i>	True/false
<i>run.indicators.export.relocation.ripis.intervals.households</i>	True/false
<i>run.indicators.export.relocation.ripis.intervals.locations</i>	IDs of locations
<i>run.indicators.export.relocation.ripis.intervals.cantons</i>	IDs of cantons

### B 3.1 Business relocation debug table (bb\_moving)

Table contains information about dynamic change for firms and workers in year. Numbers of created and closed companies are result of firmographic model. Moved firms and workers are result of relocation businesses model. If relocation of new companies is switched on, output contains also values for them. New companies are relocated without passing move probability.

Attribute	Description	Entities
LOCID	Location code	[integer]
NAME	Location name	[character]
BB_PASS_PROB	Firms pass probability for leave location	[integer]
BB_GO_AWAY	Firms passed and moved out of location	[integer]
WRK_GO_AWAY	Workers passed and moved out of location	[integer]
BB_STAY	Firms passed and decided to stay in location	[integer]
BB_COME_IN	Firms moved into location	[integer]
WRK_COME_IN	Workers moved into location	[integer]
NEW_BB	New firms created in location	[integer]
NEW_BB_GO_AWAY	New firms moved out of location	[integer]
NEW_WRK_GO_AWAY	Workers in new firms moved out of location	[integer]
NEW_BB_STAY	New firms decided to stay in location	[integer]
NEW_BB_COME_IN	New firms moved into location	[integer]
NEW_WRK_COME_IN	Workers in new firms moved into location	[integer]
BB_CLOSED	Firms closed in location	[integer]
IS_OVER_LIMIT	Location reach land limit for firms	[boolean]
FINAL_BB_COUNT	Total firms after relocation model	[integer]
FINAL_WRK_COUNT	Total workers after relocation model	[integer]

### B 3.2 Household relocation debug table (hh\_moving)

Simplified version of businesses table.

Attribute	Description	Entities
LOCID	Location code	[integer]
NAME	Location name	[character]
HH_PASS_PROB	Households pass probability for leave location	[integer]
HH_GO_AWAY	Households passed and moved out of location	[integer]
RES_GO_AWAY	Residents passed and moved out of location	[integer]
HH_STAY	Households passed and decided to stay in location	[integer]
HH_COME_IN	Households moved into location	[integer]
RES_COME_IN	Residents moved into location	[integer]
IS_OVER_LIMIT	Location reach land limit for residents	[boolean]
FINAL_HH_COUNT	Total households after relocation model	[integer]
FINAL_RES_COUNT	Total residents after relocation model	[integer]

### B 3.3 Migration output

Table contains output of migration model.

Attribute	Description	Entities
LOCID	Location code	[integer]
NAME	Location name	[character]
IMM_H_NEW	Migration, new households created	[integer]
IMM_R_NEW	Migration, new residents created	[integer]
MIGR_H_DEL	Control total res., households deleted	[integer]
MIGR_R_DEL	Control total res., residents deleted	[integer]
MIGR_H_NEW	Control total res., new households created	[integer]
MIGR_R_NEW	Control total res., new residents created	[integer]
RELOC	Control total res., new households relocated	[integer]

**B 3.4 RIPIS intervals - location choice(relocation\_ripis\_hh/bb)**

Table is the same for businesses and households.

<b>Attribute</b>	<b>Description</b>	<b>Entities</b>
sourcelocid	Location code	[integer]
businessid	Business/Household id	[character]
sector	Business sector/zero for households	[integer]
type	Company type/zero for households	[integer]
is_new_b	0,1 for businesses/zero for households	[boolean]
destlocid	Destination location code (choice)	[integer]
ripis list	List of RIPIS intervals for each location from subset Values: List< Location code, size of RIPIS interval> List< integer, double>	