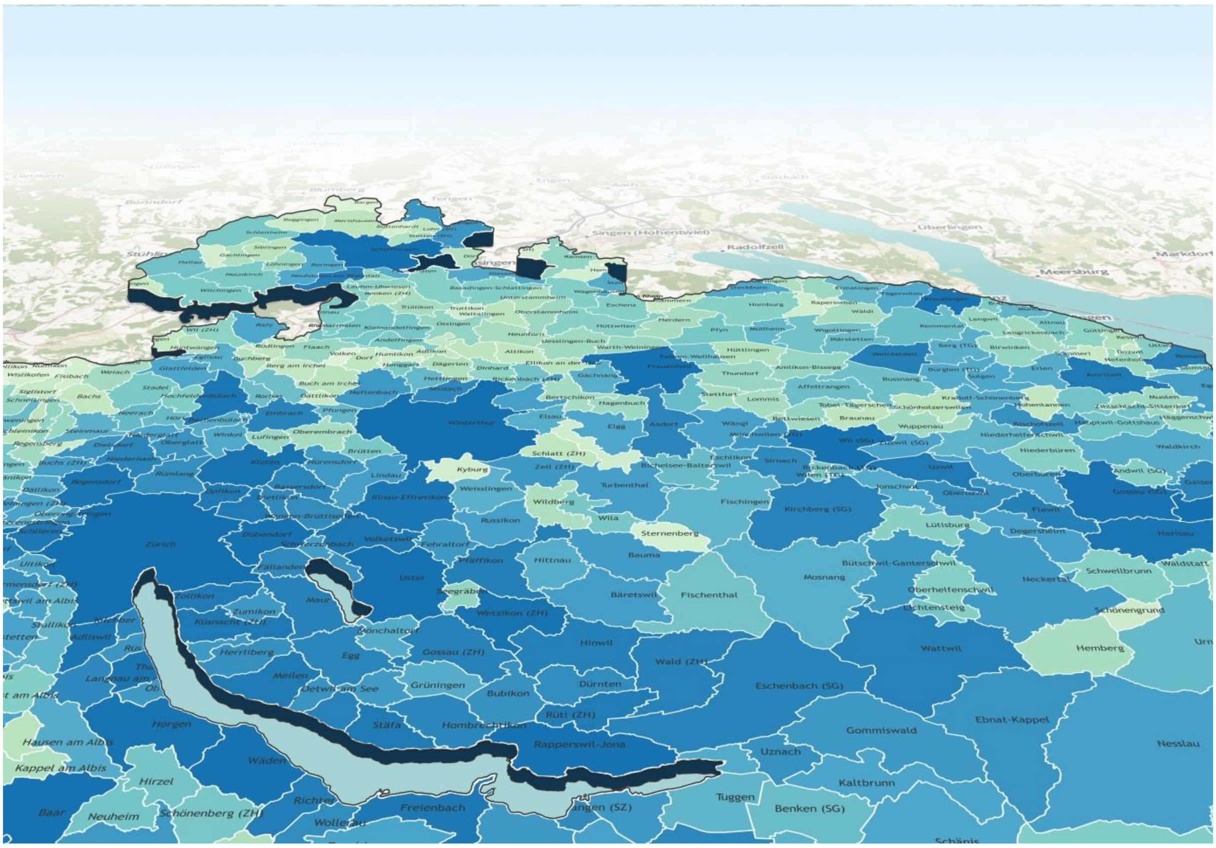

Implementation of a Synthetic Population for Switzerland

Swiss Case Study 2013

FaLC Working Paper 01

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Abstract

The main goal of the first version of the Swiss Case Study is to test convenience and achievement of the stated objectives of the whole FaLC project.

This report focusses on the Synthetic Population that has been implemented during the year 2013. This Implementation will also serve as a template for further Case Studies. Therefore, the report takes part of the FaLC documentation (comparable to an implementation guide).

This paper is integral part of the FaLC documentation. The reader is encouraged to report any technical or editing issues/problems with this specification to info@falc-sim.org

Keywords

Land Use, Transport, Simulation, FaLC, Synthetic Population

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1 Synthetique Population

"Synthese CH01" has been used to create the synthetic population for the Swiss Case Study models implemented in 2013 for the Smart Urban Adapt Project (SUA)[1] as well as for the Federal Office for Spatial Development (ARE). Both Case Studies base on the same Synthese, described in this paper.

Since nearly no data at the micro level are available and especially since, when available, they are very sensitive in terms of privacy, as a first step a synthetic population of persons, households and businesses has to be built. Goal of this implementation is to receive a synthetic population for the base year of the FaLC runs. Year 2000 has been defined as base year. This allows a comparison of the evolution between 2000 and 2010. The description of the dynamic yearly models is subject of a further paper "Swiss Case Study 2013" by the same authors.

Please note that this synthesis implementation is the first attempt to reach a coherent synthetic population. At this status, it is not the aim to get the perfect fit to real population. Goal of this implementation is a stable output with a realistic population for Switzerland. Therefore, we focused only on the marginal totals for the zones defined by the Swiss National Transport Model (NPVM)[2], for example:

- Number of residents by age
- Number of households
- Number of jobs by sector
- Number of firms by sector

As the marginal totals are controlled, these totals generally reach a fit of 100%. Minor deviations can occur – e.g. due to the different datasets used. Indeed, there are some larger fields: especially, the implemented connections between job (location) and resident (location). This has been done by IPF and has been tested visually. But, there has to be done further work.

This guide will first focus on the data used for this implementation and its preparation. In a second step, the systemisation mechanism will be explained. In the final chapter, a short overview of the result is presented.

[1] See also www.sua.ethz.ch

[2] Nationales Personenverkehrsmodell (NPVM), the zones for 2010 have been considered; see also http://www.are.admin.ch/themen/verkehr/00256/00513/index.html?lang=de

2 Base Year 2000

2.1 Data used

The case study covers the whole area of Switzerland on a spatial scale of municipalities as of the year of 2000. As base input various publicly available datasets of the Swiss Federal Statistical Office (FSO) (base for synthetic population) as well as a database including information of different sources describing municipalities (Bodenmann, 2011) are used. The main datasets are listed in Table 1. In the following the creation of synthetic population, the modeling of demographic events, households, firms, locations, economies and politics are described.

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 synthetic populations
Variables of municipalities	different sources (Bodenmann, 2011)	free (aggregated Data)	Utility functions
OpenStreetMap (OSM)	Openstreetmap.org	--	Distances
Distance Tables	NPVM (ARE)	-- (Contract needed)	Distances

The generated distances from OpenStreetMap are used for the general template and are needed to test the impact of potential infrastructure projects such as new motor ways. In contrast, the distance tables of ARE are used to prepare and test a potential interaction with external transport models (such as the NPVM of ARE).

2.2 Synthetisation processes

Creating synthetic population of businesses

To get the number, size (measured by the number of employees) and distribution of businesses within a certain sector and area the Swiss Federal Business Census[3] (BusC) data from the FSO can be used. The main attributes of this dataset are the number of businesses within a sector (by NOGA-Code) and the size (classified) per hectare. Because the spatial scale was chosen to be at municipality-level, the data will be aggregated.

Knowing these control totals, simplified businesses without employees can be created and – if necessary – randomly distributed within the municipality.

Indeed, publicly available data of BusC do not include profit and structure of the businesses. Therefore probabilistic parameters depending on the already known data, have to be estimated. They can then be used within a Monte-Carlo simulation to set the unknown variables for each business.

Parameters are established through a mixture of extrapolation from publicly available data, plausibility assumptions and a posteriori data-fitting.

Creating synthetic population of persons

The Swiss Federal Population Census[4] (PopC) dataset (available from FSO) contains the number of residents subdivided by sex and age (5-year-classes) per hectare. According to the chosen spatial scale the data has to be aggregated.

Knowing the control totals, it is possible to create a synthetic population of persons. However since such agents cannot tell us much about their behavior, further steps are required to "complete" them with attributes such as education, job, position, income, household and business (amongst others).

To do so, other control totals, included in the PopC- and the BusC-dataset as well as probabilistic-values have to be taken into account.

To determine the education of a person, the control totals of earners by sex and education-level which are given in the PopC-data and the probabilities depending on the already known variable age have to be estimated. The combination of these two sources allows estimating the education of a person by sex and age. The person's job is seen to be strongly influenced by the education. The control totals of earners by sex and socio-professional category are given by the PopC-data, the distribution of employees by sector (NOGA-Code) is given in the BusC-data and the probability to have a certain job with a certain education must be estimated. By combining these three sources, for each earner a job can be assigned. Going one step

[3] Betriebszählung

[4] Volkszählung

further, the probability of incorporating a specific position in a business is seen dependent on the age, education and job. Once again, the control totals are given by the PopC-data and the probabilities of having a certain position depending on the already known variables have to be estimated based on publicly available data. Accordingly the position of a person can be set.

So far, we know some relevant characteristics of a person but nothing about its spatial behavior. One of the most crucial questions is: “where does a person work?” To answer this question the probabilities of commute-distances and costs by sector are estimated based on the publicly available data. Knowing the job of a person, the commute-distance can then be assigned probabilistically according to an empirical gravitation model. Accordingly to the distance/cost to workplace all candidate businesses can then be determined and a randomly chosen business with an open position is assigned to the person. Now all attributes except the household-membership are defined.

Creating a synthetic household dataset

The PopC-dataset contains the number of households by size and the number of households with children. The probabilities of household structures (e.g. age and education of the household members and the household-type) have to be estimated. Combining the PopC-data and the estimated parameters, an empty household dataset can be created in a first step. Now the households must be populated with appropriate persons from the persons-dataset in a way that at the end all persons are located in a household and no persons (especially children!) are left out.

3 Technical Guide: Data

3.1 Data preparation

The current implementation relies on data from different sources prepared for the synthesis process:

- NPVMplus_2000.csv (containing relevant data from PopC 2000 and BusC 2001)
- AlterMutter.csv (containing the assumed age of mothers according tot eh number of children)
- Umzugsraten_nAlter.csv (with the migration rates of residents per age)
- distances tables (either generated from OSM or from ARE)

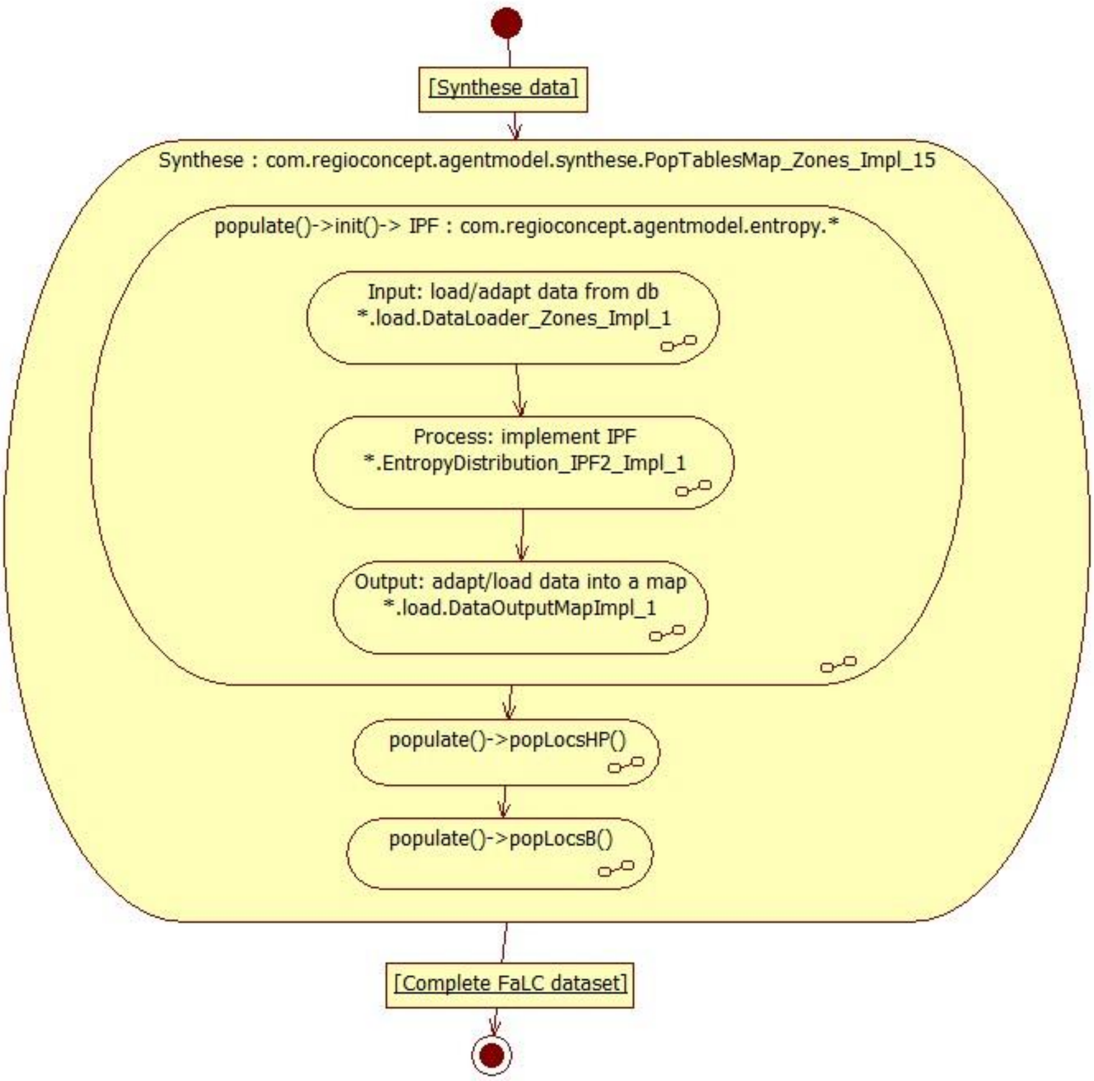
First copy the relevant csv files in a folder where the postgres user has read rights, such as C./tmp, then after selecting the FaLC db within PostresSql execute the script sql/import/import_aufbereit.sql. The script empties the tables corresponding to the csv files and then fills them with the csv data.

The synthesis module requires the standard configuration of app.properties and run.properties as explained in the "Getting started" section. The results depend also on the configuration of entropy properties: the relevant parameters are entropy.parameter1 which corresponds to the beta exponent in the weight function of the IPF distribution and entropy.numStep, which encodes the number of iterations for IPF optimization. The IPF configuration described here has been successfully tested with entropy.parameter1=0.15. However, for large and diverse populations such as the whole of Switzerland even in this case several tries may be needed to successfully synthetize a complete population. Higher values lead to higher distance costs and increasing concentration of the IPF distribution, with possible smaller choice ranges and increased difficulties in the allocation of workers residences in the step 2 of phase 2. The other relevant parameter is entropy.numStep, corresponding to the number of iteration steps in IPF. Higher number lead to longer processing times and to somewhat improved accuracy.

3.2 Initializing – IPF

At initialization the data necessary for the synthesis are loaded from the db tables: distances for the chosen set of locations, population distribution data from npvmplus_2000, age distribution data from alter_mutter and umzugsraten_n_alter. Then the IPF distribution assigning residence locations for workers is loaded. IPF implementations typically consist of a data loader for input, a process implementation which will create an optimized IPF distribution and an output method which will deliver the optimized IPF distribution in a given format. In this case the input, process and output modules are respectively DataLoader_Zones_Impl_1, EntropyDistribution_IPF2_Impl_1 and DataOutputMapImpl_1.

Figure 1 Overview IPF workflow



First an IPF distribution map is created by the EntropyDistribution_IPF2_Impl using the total sum of b_br01 - b_br10 (number of employees by branche by location), the sum of et_m_00 and et_f_00 (male and female working persons in the location) and the sum of wegp_m_00 and wegp_f_00 (out-of-location commuters). The resulting IPF distribution ripisIPF is then fed to the synthese implementation class where the methods popLocsHP() and popLocsB() create persons households and businesses, as explained in detail later.

3.3 Data import

The data used in the synthesis are read from the corresponding files into the db tables of the same name:

Table npvmplus_2000 - location data

Data relative to the year 2000, except se_wfk, which is not used in synthesis.

zone-> location identifier

name-> location name

ew_00_04m, ... , ew90_xxm-> number of male residents by age range, from 0-4 to 90 and above.

ew_00_04w, ..., ew90_xxw-> number of female residents by age range, from 0-4 to 90 and above.

The ew_00 _... age ranges encompass 5 years, except ew_15_17... (3 years), ew_18_19... (two years) and ew90_xx... (undetermined).

hh_e2_k0 , ... , hh_e2_k5-> number of households with a parents pair by number of children (0 to 5).

hh_e1_k0 , ... , hh_e1_k5-> number of households with a single parent by number of children (0 to 5).

b_br01, ... , b_br10-> number of employees by sector(from sector 1 to sector 10).

as_br01, ... , as_br10-> number of companies/workplaces by sector (from sector 1 to sector 10).

asg_br01, ... , asg_br10-> average number of employees per company/workplace by branche (from sector 1 to sector 10).

et_m_00-> number of male employees.

et_f_00-> number of female employees.

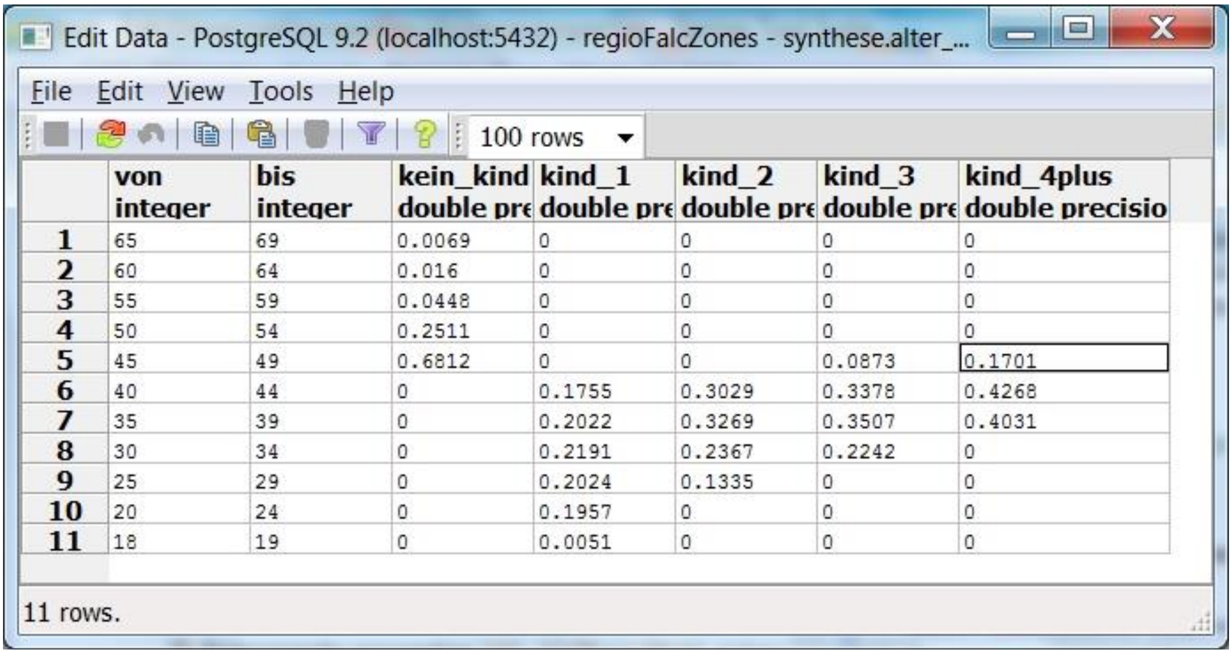
wegp_m_00-> number of male commuters, working outside the location.

wegp_f_00-> number of female commuters, working outside the location.

hh_paar-> number of pairs living together without children and older offspring.

Table alter_mutter - mothers age distribution – probability that a mother belongs to a certain age rangr (from-von, to-bis) by number of children in the household (from kein_kind->no children to kind4_plus->4 or more children). Children are offspring under 18 years. When offspring lives in the same house the mother belongs to the "kein_kind" (no children) category.

Figure 2 mothers age



	von integer	bis integer	kein_kind double pre	kind_1 double pre	kind_2 double pre	kind_3 double pre	kind_4plus double precisio
1	65	69	0.0069	0	0	0	0
2	60	64	0.016	0	0	0	0
3	55	59	0.0448	0	0	0	0
4	50	54	0.2511	0	0	0	0
5	45	49	0.6812	0	0	0.0873	0.1701
6	40	44	0	0.1755	0.3029	0.3378	0.4268
7	35	39	0	0.2022	0.3269	0.3507	0.4031
8	30	34	0	0.2191	0.2367	0.2242	0
9	25	29	0	0.2024	0.1335	0	0
10	20	24	0	0.1957	0	0	0
11	18	19	0	0.0051	0	0	0

von->lower end of the mother's age range

bis->upper end of the mother's age range

kein_kind->probability that the mother belongs to the corresponding age group when there are no children living within the household

kind_1-> probability that the mother belongs to the corresponding age group when there is one children living within the household

kind_2-> probability that the mother belongs to the corresponding age group when there are two children living within the household

kind_3-> probability that the mother belongs to the corresponding age group when there are three children living within the household

kind_4plus-> probability that the mother belongs to the corresponding age group when there are three children living within the household

Table umzugsraten_n_alter - offspring moving out ratess by age under the assumptioer that all offsprings have left the parents household by the age of 45.

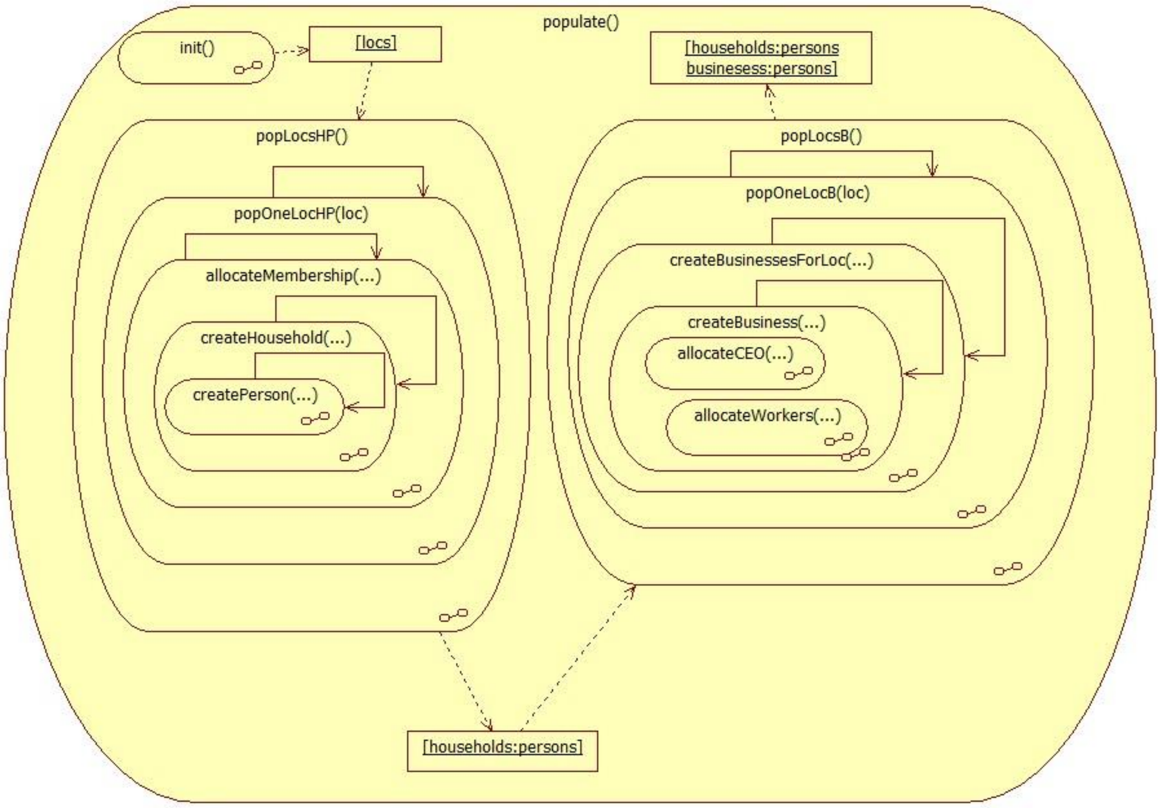
pc_rel_parent->cumulative moving out rate from the parents household by age,

4 Technical Guide: Synthese processing

4.1 Processing – overview

The synthesis implementation within the method populate() is divided into two phases corresponding respectively to method popLocsHP() and method popLocsB(). In the first phase a complete Household and Person population is created for every location. In the second phase businesses are created and filled with employees, chosen among the available population, on the basis of the available IPF distribution.

Figure 3 method populate

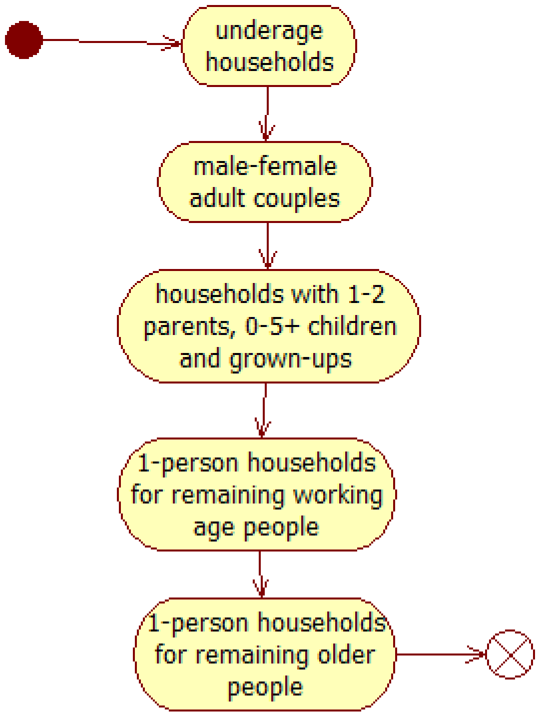


The method popOneLocHP(loc) iteratively creates and populates households, as described in the next section.

4.2 Processing phase 1 – Populating households

Within the method popLocsHP() each location loc is processed iteratively by the method popOneLocHP(loc). Within the latter there are five stages.

Figure 4 Populating households



First the underage households (15-17) are created, then the male-female adult couples (adult couples without offspring, corresponding to the parameter hh_paar) are created. The the working age households with offspring are created, corresponding to the parameters hh_e2_k0, ... , hh_e2_k5 and hh_e1_k0 , ... , hh_e1_k5.

Then the age distribution data are matched by adding 1-person households for working age people and 1-person households for older people.

4.2.1 Processing phase 1 – step 1 – underage household

Creating underage households within popOneLocHP(loc)

For each location a lower bound lbk for the number of children (age<=17) is obtained by summing the number of households multiplied by the number of kids (lbk=(hh_e2_k1+ hh_e1_k1)+ (hh_e2_k2+ hh_e1_k2)*2+…+ (hh_e2_k5+ hh_e1_k5)*5). Then lbk is subtracted from the total number of underage people (sum(ew_00_04…, ew_15_17…)). The resulting number is partly assigned to underage households, estimated by multiplying the cumulative probability of having left the parents' household between 15 and 17 by the number of people in the 15-17 age range. The rest is later assigned to households with at least 5 children (hh_e…_k5), if any. If no hh_e…_k5 household is available or if the resulting households would have more than 8 kids, underage (15-17) households are created instead for the above-threshold children.

4.2.2 Processing phase 1 – steps 2 and 3 – adult and working age households

When the ages of couples living together are assigned, the age of the male partner is assigned on the basis of the age of the female partner, which is assigned first. In the current implementation the male age is randomly assigned within a 8 years interval centred around the female partner age + 2 years.

Creating hh_paar and hh_e..._k... households within popOneLocHP(loc),

- Step 2 - hh_paar male-females adult (age>17) couples living together are created.
- Step 3a - hh_e2_k0-hh_e2_k5 male-female +kids+grown-ups are created. If kids are present, the age distribution of the mother is determined by the distribution in alter_mutter.cvs, the age of the male partner is distributed probabilistically around the age of the mother plus 2 years, the ages of the kids around the age of the mother minus 29 years, according to the probability distributions extracted from alter_mutter. Grown-ups are assigned to the household based on the probability that a kid of the mother is still living at home.
- Step 3b - hh_e1_k0-hh_e1_k5 female, in case no kids are present, either a male or a female of working age are allocated. If kids are present, then a female is allocated and kids ages and grown-ups living at home are allocated as described in Step3a.

4.2.3 Processing phase 1 – steps 4 and 5 – remaining people

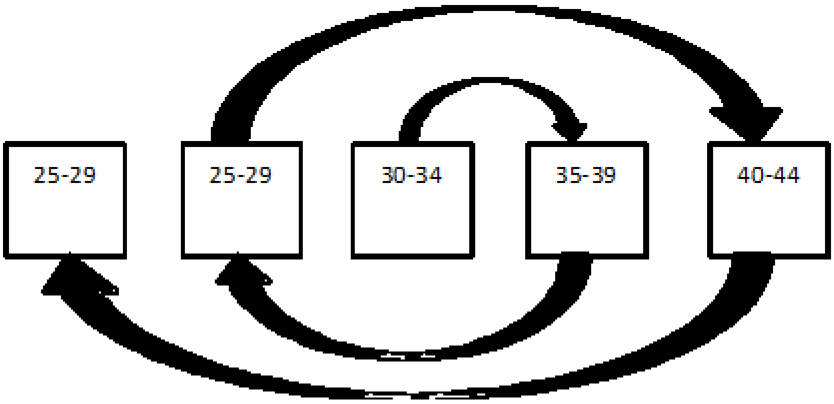
The remaing people are allocated within popOneLocHP(loc).

- Step 4 – the remaining working age people are allocated to 1-person households
- Step 5 – The remaining older age people are allocated to 1-house households

4.2.4 Technical remark: age allocation

Age allocation is performed recursively within an age range, in steps of increasing length and alternating direction, the initial one-step direction being chosen randomly. If there are no more available entries in a certain age slots, i.e. if the number of people within a given age slot (e.g. 30-34) has been already exhausted, the search process for an alternative age proceeds until a slot with an available entry is found and age is correspondingly assigned.

Figure 5 age allocation

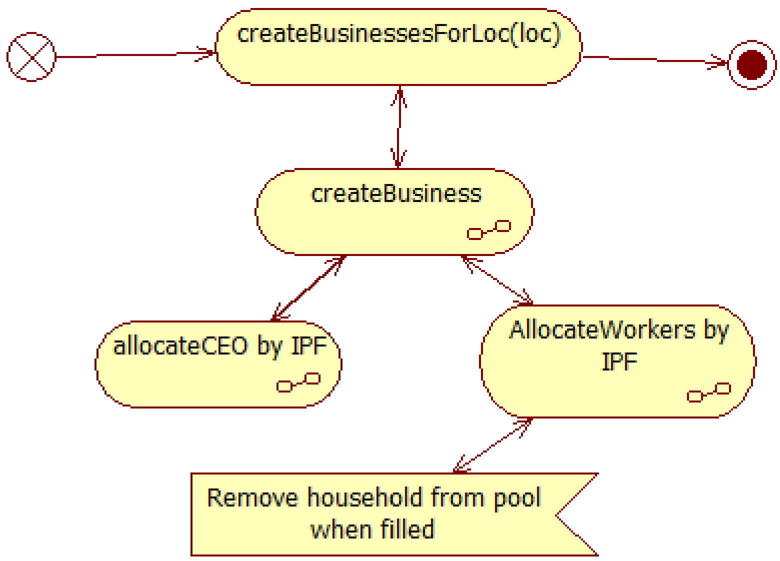


Age ranges are: Underage (0-17), WorkAge(18-64), Older(64-94), Adult(WorkAge+Older).

4.3 Processing phase 2 – creating businesses

Within the method popLocsB() each location loc is processed iteratively by the method popOneLocHP(loc).

Figure 6 creating businesses



The businesses are created and assigned to a location, matching the sector distribution data. A ceo and a certain number of workers is assigned to every businesses, according to the average number of workers per business for sector (according to asg_br01, ... , asg_br10) . The number of employees by sector (b_br01, ... , b_br10) are matched in the last business for every sector.

4.3.1 Processing phase 2 – step2 – creating a workers exclusion map

Create an exclusion workersExMap, containing households whose members will be assigned to the businesses as CEO and workers. Later, during the allocation process, whenever a household is full, i.e. all ist members of fitting age have been assigned a position, it is removed from the list. The purpose is speeding up the search for still available workers within the population.

4.3.2 Processing phase 2 – step 2 – creating and populating businesses

Creating and populating businesses P – popLocsB() createBusinessesForLoc(…)

The probability distribution ripisIPF created at initialization is used here for assigning residence locations of workers in the businesses at the current location. The businesses are assigned workers according to ripisIPF until all working places have been assigned. The ripisIPF assignment worker's assignment is called for every ceo and worker's assignment, so as to avoid clumps.

4.4 Logging

The logger output allows checking for output deviations from the input quantities provided by the npvmplus_2000 table.

An excerpt illustrates some key points:

5447 persons in 2238 households allocated in location Appenzell with 0 ageBreakers

ageArrayMales = [0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0]

ageArrayFemales = [0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0 , 0]

check total age arrays 0 =0 checkCounter = 5447

check total work age arrays 0 =0 checkWorkAgeCounter = 3235

122 grown-ups living at home

testCounter found 3235 people of working age and 5447 people in location Appenzell

The first line summarizes the result of the population syntheses in the location Appenzell. There are no ageBreakers, meaning that the age distribution of the input data has been preserved in the synthetic population. The entries in the arrays ageArrayMales and ageArrayMales correspond to age-slots. So for example the first entry in ageArrayMales correspond to the 0-4 age range. If age distribution of the synthetic population corresponds exactly to the ew_00_04m, ... , ew90_xxm and ew_00_04f, ... , ew90_xxf data in npvm2000_plus, then the ageArrayMales and ageArrayMales are supposed to be rows of 0s. This is generally the case, but it may happen that some locations exhibit discrepancies, due to inadequacies of the synthetic implementation. So for example a 1 value in the first entry of the ageArrayFemales means that in the synthetic population there is one less female in age range 0-4 than prescribed by the data in the npvmplus_2000. A value of -2 would be that there are 2 females more than prescribed by the data in the npvmplus_2000.

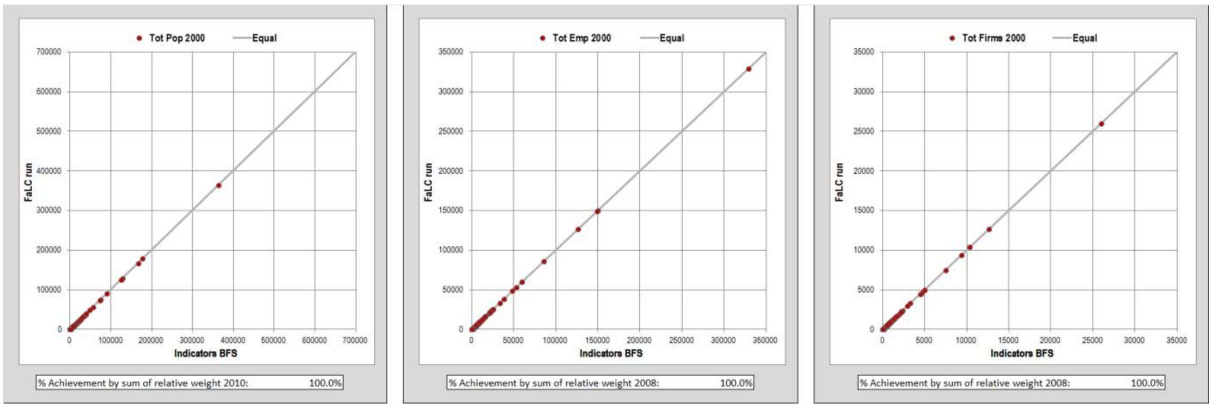
5 Results and further steps

Supported by a special MS-Excel application for the analysis of the resulting indicators, regioConcept analyses the results and calibrates FaLC simulation tool.

Comparison of absolute values

The following set of diagrams compares the number of inhabitants, employees and firms respectively from FaLC indicators and from FSO official data for the year 2000.

Figure 7 FaLC indicators vs FSO official data (Population, Employees and Firms) for 2000



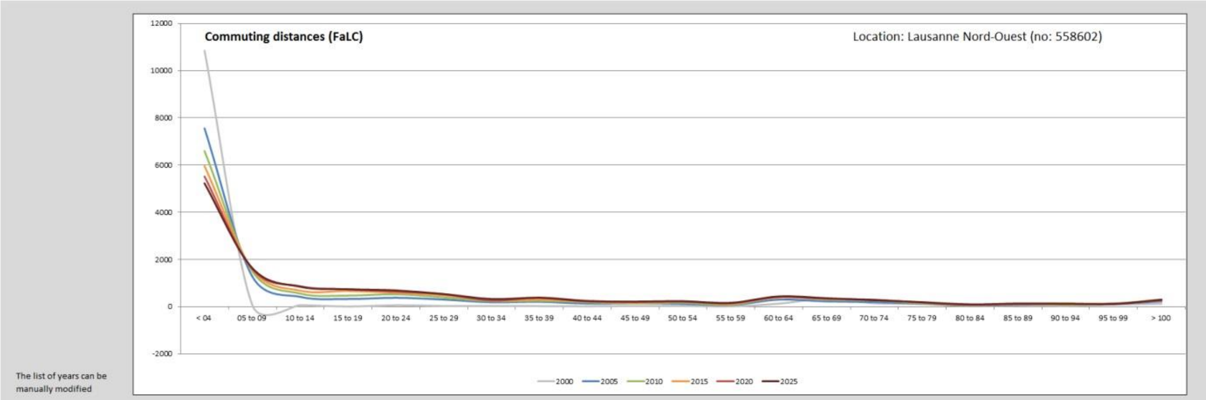
The double entry diagrams contain a series of dots that represent the number of inhabitants, workers or firms for each municipality (FaLC indicators in the “y” axis and FSO official data in the “x” axis). As we can observe, both entries have the same values, consequently, the dots are located over the “equal” line.

This results proves that marginal sums of the resulting population are coherent with the input data from FSO. This holds also for other distributions such as household size. In contrast, the size of companies is at this stage of the company generally equal to the average size of companies in the according sector. As the dynamic models (e.g. relocation of firms) do not consider largeness of companies, this is (at the moment) a minor issue.

Commuting distances evolution

Using the same special MS-Excel application, each location is represented in a multi-linear diagram showing, in a time interval, the number of workers commuting X kilometres from the chosen location (e.g: Lausanne Nord-Ouest from 2000 to 2025) to the workplace.

Figure 8 Commuting distances diagram



Year / Km		< 04	05 to 09	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54	55 to 59	60 to 64	65 to 69	70 to 74	75 to 79	80 to 84	85 to 89	90 to 94	95 to 99	> 100
2000		10845	58	61	4	57	24	20	20	12	26	27	8	124	330	143	113	25	50	39	80	122
2005		7551	1269	413	322	372	298	182	203	127	140	115	63	295	219	189	120	33	75	104	114	220
2010		6588	1496	552	467	522	390	231	249	190	137	166	75	402	294	265	136	57	103	79	122	306
2015		5953	1579	674	661	590	479	261	296	207	163	212	118	388	324	277	169	61	105	119	122	264
2020		5516	1591	861	731	634	524	255	380	243	197	208	135	411	331	290	169	75	121	120	121	270
2025		5222	1628	842	735	685	531	320	372	229	211	228	160	429	355	271	186	94	127	121	112	288

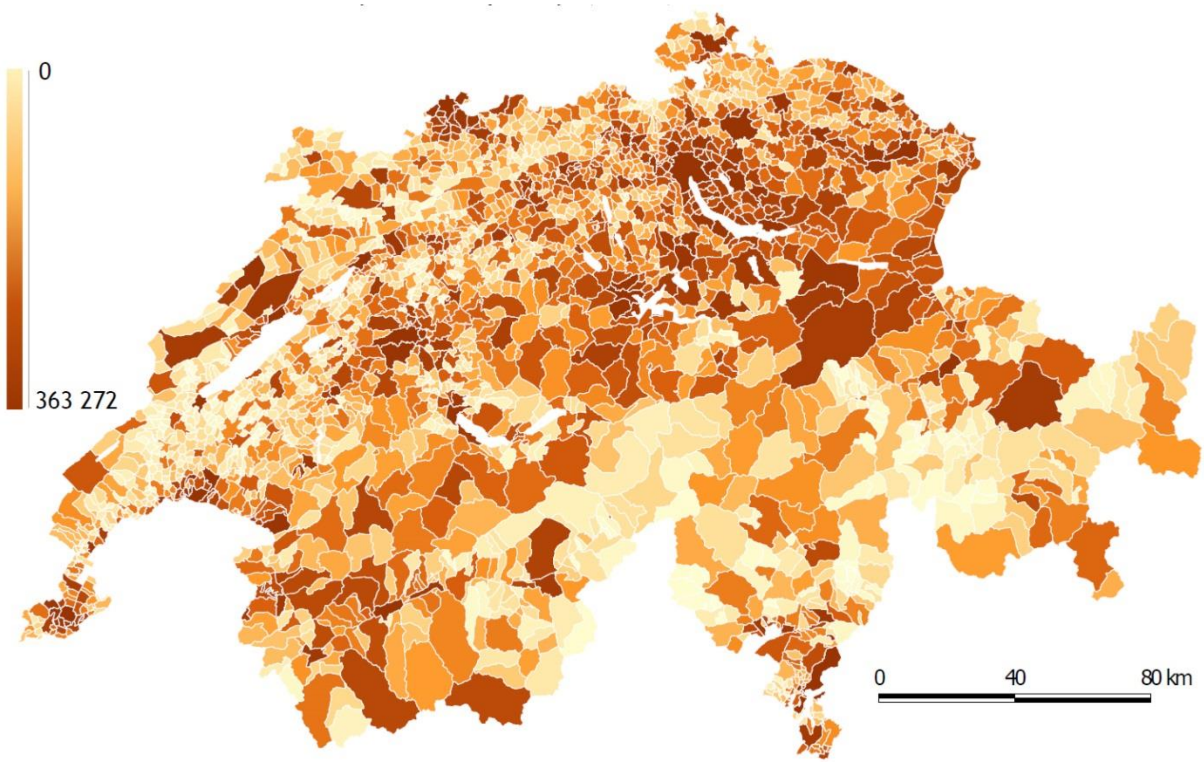
As we see in fig. 8, the initial commuting distances in the year 2000 apparently behave not as we would expect. Main problem is a too low number of commuters over short distances. However, in the following years, the distribution of commuters by distance seems to be more coherent to the reality. Unfortunately, this problem still has to be fixed.

GIS visualisation

Once the results are integrated in the MS-Excel application, two files ".csv" and ".csvt" are automatically generated and incorporated on a special visualisation folder for each run. These files allow any GIS software (in this case QuantumGIS) to graphically represent any variable resulting from FaLC indicators.

As an example, the following figure (fig.9) shows the number of inhabitants for each Swiss municipality.

Figure 9 Number of inhabitants in Switzerland by municipalities. 2000



Next steps to a coherent population

Apart from the commuting distances, the synthetic population has different issues to be implemented in the near future:

- For different models, we need additional attributes for the agents: e.g. education, wages, nationality, language skills
- The IPF may has to be revised to consider education for job allocation. A first step in this direction has been by implementing a CEO
- The attributes for jobs have to be extended by additional information about the work that employees are doing and the skills they need. This will have a direct effect on wages.

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