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Conference Paper

Planning for the Future: A Land-Use and Transport Interaction Model for Switzerland

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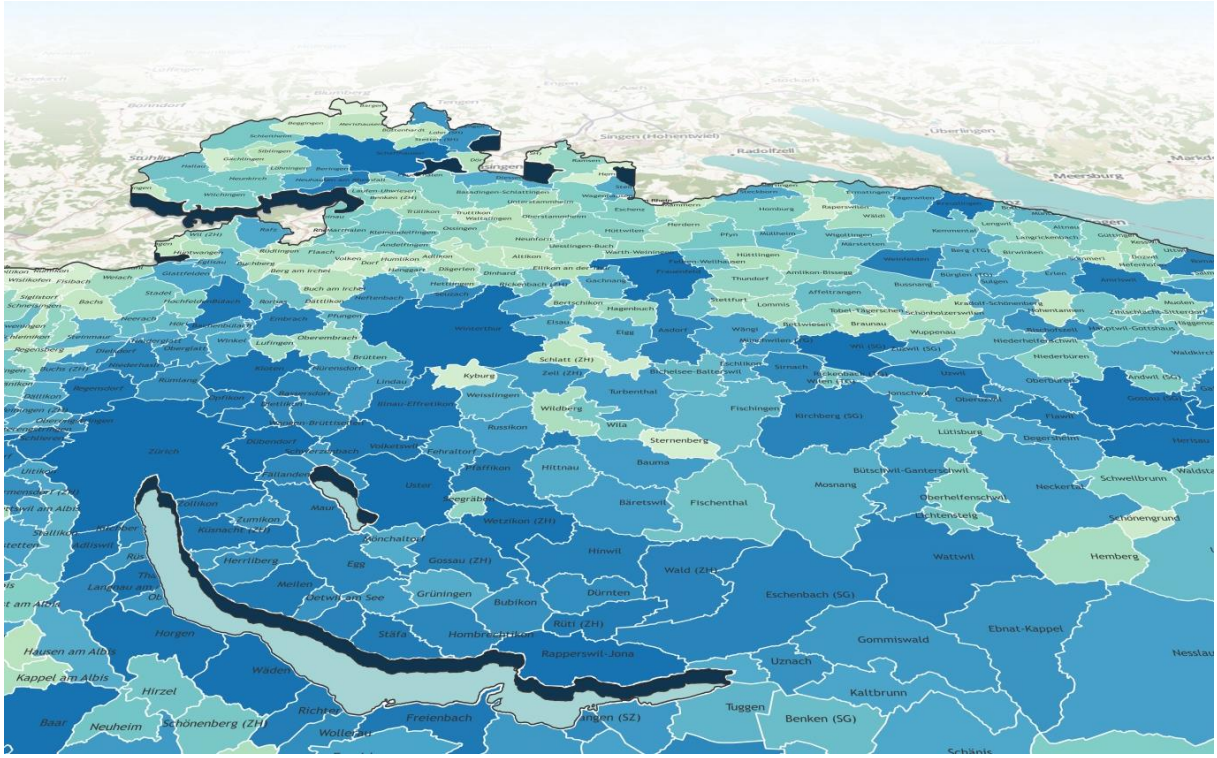

Planning for the Future: A Land-use and Transport Interaction Model for Switzerland

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Abstract

FaLC (Facility Location Choice Simulation Tool) is an integrated transport and land use simulation tool developed in a joint project of the Institute for Transport Planning and Systems (IVT) at ETH Zurich and regioConcept. The idea of FaLC is to develop a tool to answer different questions for scientific as well as planning purposes. The modelling focus are effects of changing infrastructure supply, political decisions, and economic conditions on the spatial behaviour (location and relocation choices, transport flows) of persons (places of residence, work, leisure and shopping), firms (domicile, branches) and goods (freights, wholesale, retail, cash flow).

This paper presents the first results of an implemented Case Study for Switzerland. Especially, it shows the effects and side-effects of different assumed spatial interventions. Additionally, it discusses some problems of the chosen micro-simulation approach (e.g. data availability, white noise, choice of subsets).

Keywords

Land-Use, Transport, Simulation, Location Choice, Case Study, Switzerland, FaLC

1. Introduction

Spatial and transport planners, authorities, real estate developers, investors, re-locating residents and businesses have different questions related to space and transport. These questions may concern specific land parcels, or cover a much larger area such as a city, a region, or even a whole nation. Amongst others, these questions include:

- How will our society respond to influences of global economy and political decisions (e.g. regarding demographics and firmographics)?
- Which strategies will help authorities and politicians to reach their goals?
- What are the spatial effects (and side-effects) of these decisions and demographic changes (e.g. spatial/social segregation, use of resources and infrastructure, climate impact)?

To answer these questions, different scenarios have been simulated including all 3000 municipalities in Switzerland using the integrated transport and land use simulation tool FaLC (Facility Location Choice Simulation Tool). FaLC incorporates interactions between land use, transportation, economy and public policy and has been developed in a joint project between the Institute for Transport Planning and Systems (IVT) at ETH Zurich, regioConcept (Switzerland) and ESMO (Slovakia).

The models in FaLC focus on the effects of changing infrastructure supply, political decisions, and economic conditions on the spatial behaviour (location and relocation choices, transport flows) of persons (places of residence, work, leisure and shopping), firms (domicile, branches) and goods (freights, wholesale, retail, cash flow). In FaLC, persons move (or stay) in a certain space divided into a number of subareas (locations), comparable to a chess board. The agents' movement includes the daily commuters between home, work and leisure, as well as long-term decisions such as; where they live, work and generally spend their spare time.

The first prototype of FaLC is already in operation and ready to create future scenarios. The implemented case study for Switzerland focusses basically on three scenarios:

- Effects of road network modification
- Effects of company taxes reduction
- Effects of land regulation modification

This paper shows the effects and side-effects of these assumed spatial interventions. Additionally, it discusses some problems of the chosen micro-simulation approach (e.g. data availability, white noise, choice of subsets).

The presented paper bases on a preliminary version discussed at the STRC Conference in May 2014 (Bodenmann et al., 2014c).

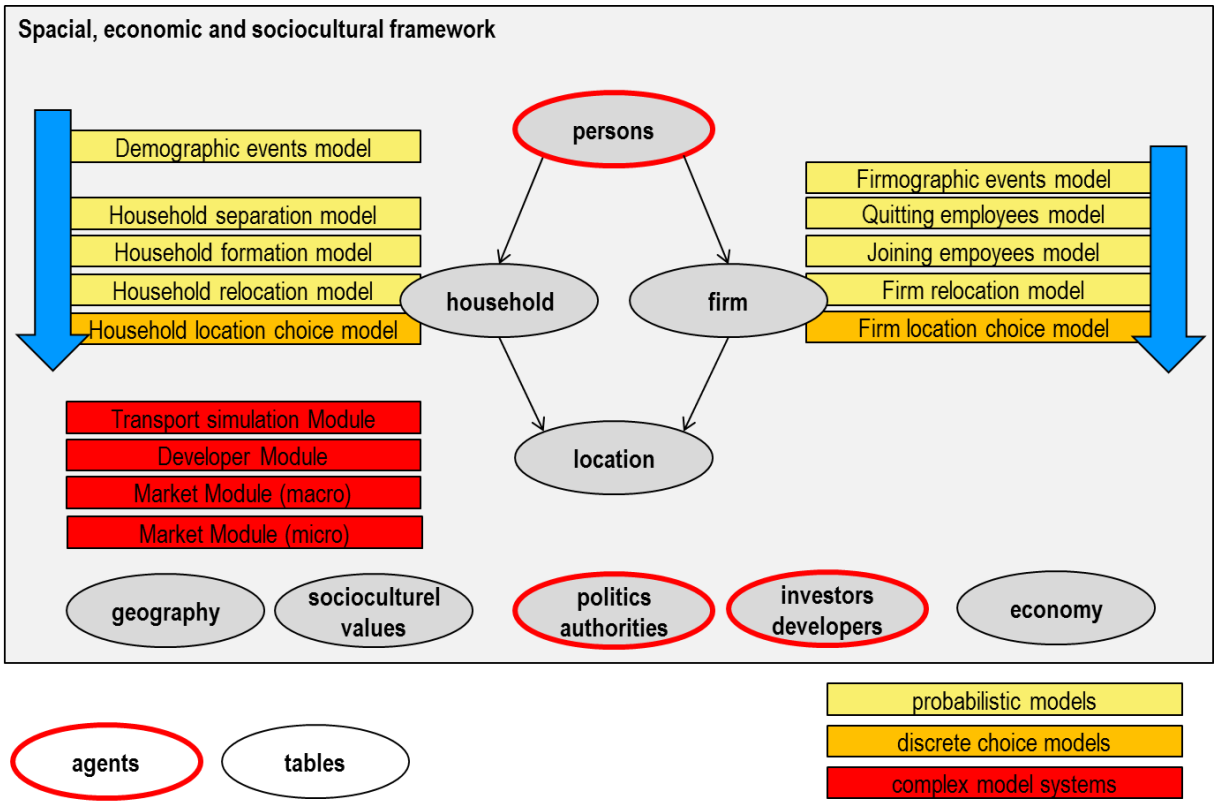
2. Swiss Case Study

2.1 Modelling framework

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 paper.

Figure 1 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.

Figure 1 Base models (2013)



Each time step or cycle (usually one year[1]), 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.

2.2 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 2, 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.

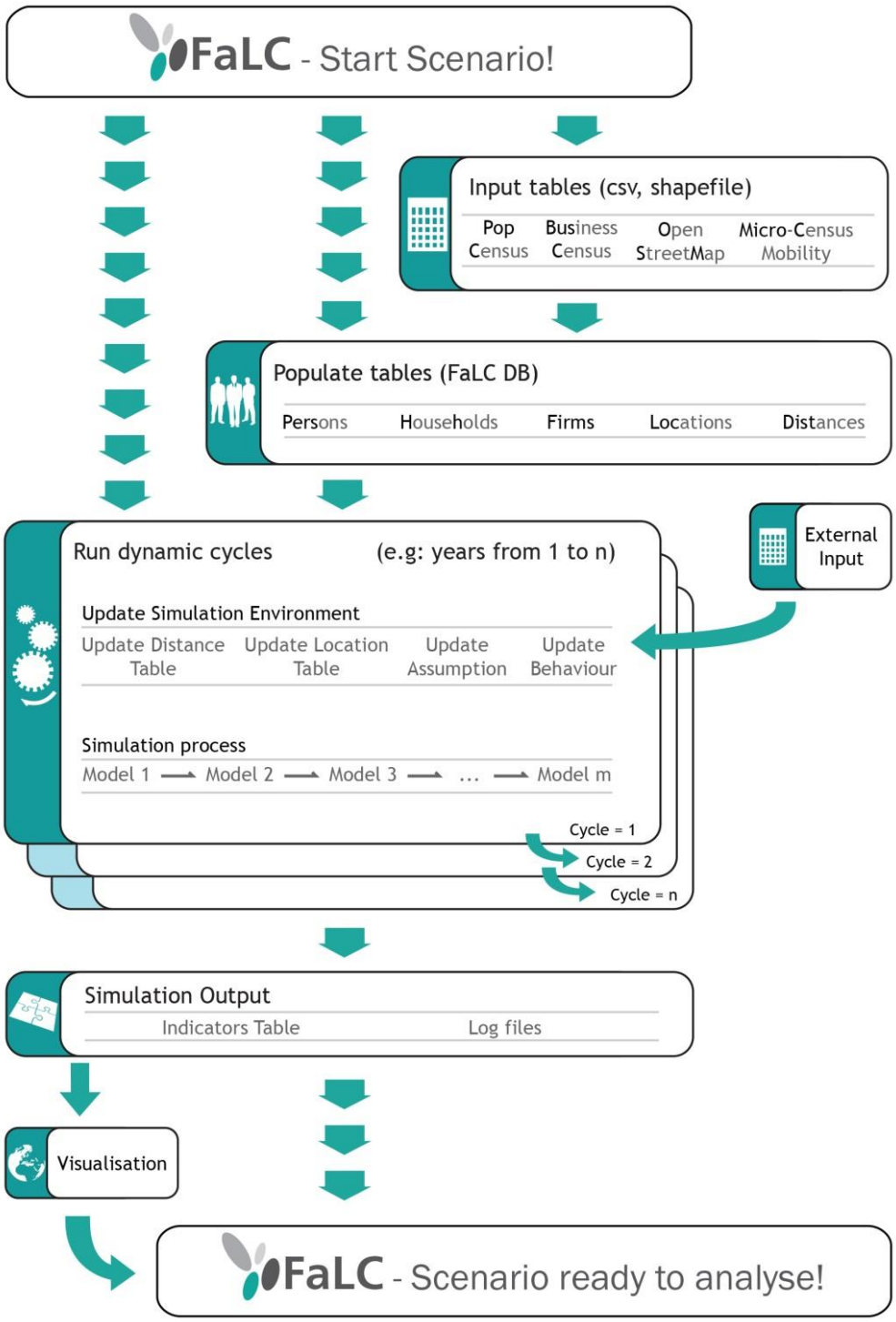
The source database for the generation of a synthetic population is composed primarily by official census data (e.g.: Federal Census of Population or Business Census from FSO) and micro-census on mobility. Thanks to this information, it is possible to generate a synthetic population adapted to the different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

[1] 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.

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.

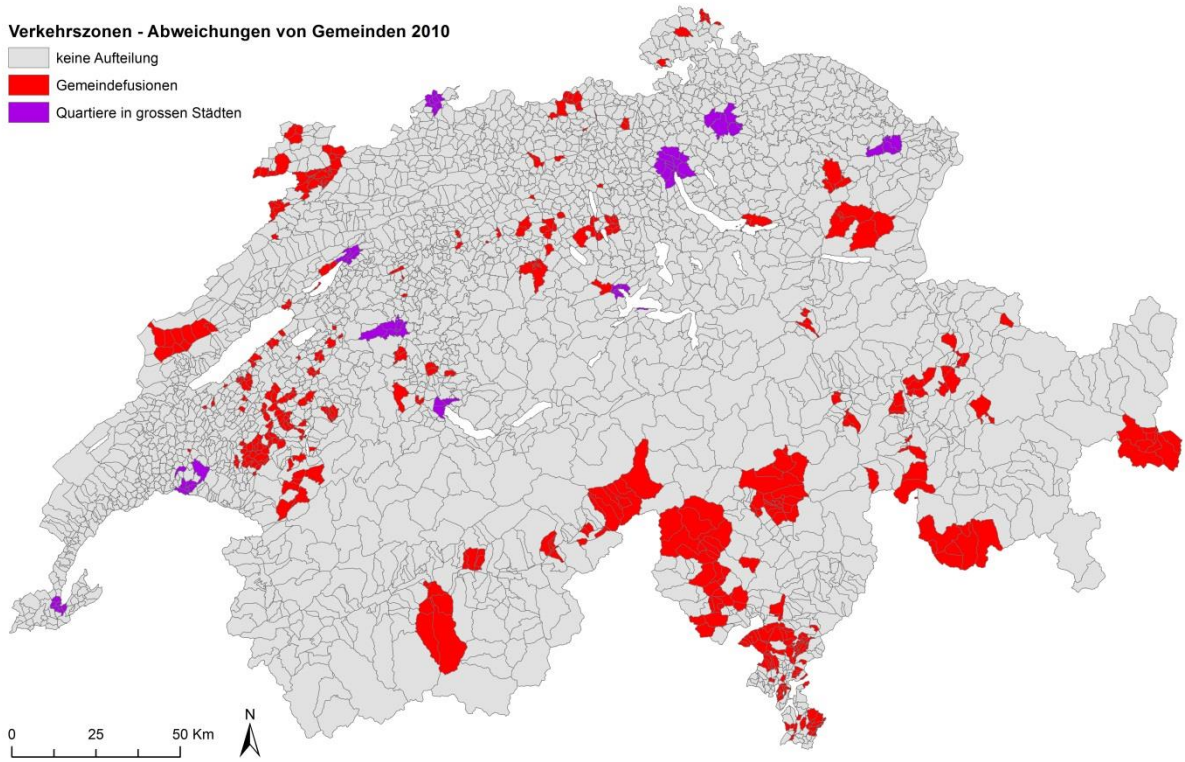
Figure 2 FaLC: general workflow



2.3 Case Study Area

The Swiss Case Study 2013 covers the whole area of Switzerland on a spatial scale of municipalities as of the year of 2000. Additionally, 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 3).

Figure 3 Differences between NPVM zones and official municipalities 2010



2.4 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

Level of service matrices (in this paper, generally referred to as distance tables of Federal Office for Spatial Development 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 is the subject of an according whitepaper (Bodenmann et al., 2014).

3. Validation of FaLC modules

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

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

3.1 General statistics

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

Validation by Relative Weight

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

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

with:

- n number of municipalities i and j
- Y_i number of residents or employees in municipality j (BFS)
- $\widehat{Y}_i$ estimated number of residents or employees in municipality j by FaLC

Validation by R2 (coefficient of determination)

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

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

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

with:

n number of municipalities i

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

Y_i result of FaLC for municipality i

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

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

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

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

Overall validation statistics

With a high level of achievement, both, Relative Weight indicator and R^2 show that FaLC fits quite well for residents and especially well for employees. Generally, the values of the Relative Weight Statistics are lower as the ordinary R^2. The fit of the estimated employees is extremely high with achieving an R^2 of 0.99, but also the fit for residents is very good.

Figure 4 Validation for residents (2000-2010) and for employees (2000-2008)[2]

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

The reason for the better results of employees is due to the fact that the according models have been estimated on a similar spatial level (municipalities), with similar variables explaining the behaviour of the firms. In contrast, the (relocation) models of households have been estimated on a much more disaggregated level (parcel and flats) including more explanatory variables such as; number of rooms, or floor level (Schirmer et al., 2011). The transformation of these models to the level of municipalities cause that not all variables of the initial model are considered in FaLC and, finally, this results in a lower fit.

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

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

3.2 Fit of absolute values by agent groups

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

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

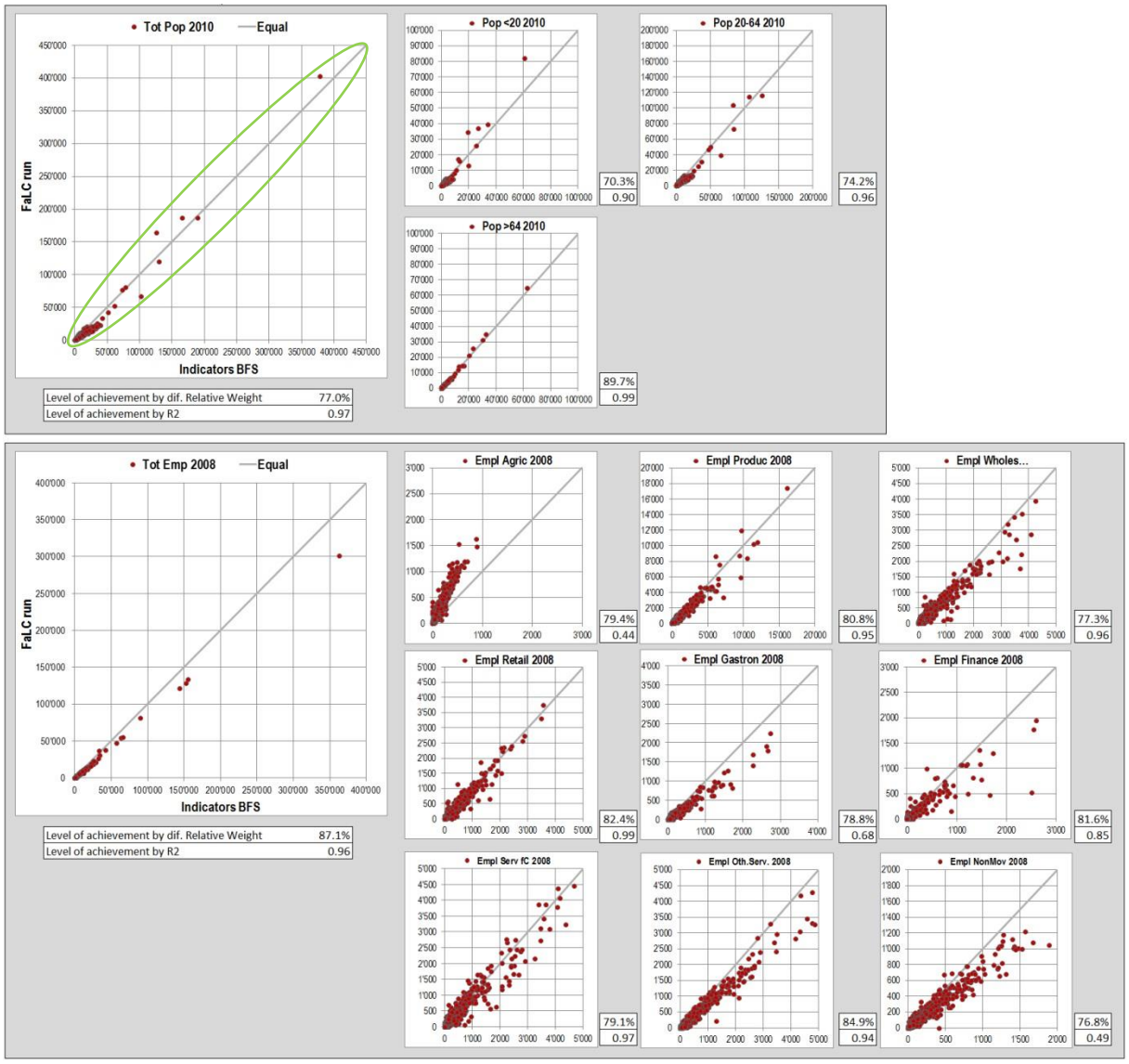
As the green circle in the figure below shows, the more the dots are close to the “equal” line, the better FaLC results fit to reality.

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

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

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

Figure 5 FaLC indicators vs FSO official data for residents (2010) and employees (2008)[3]

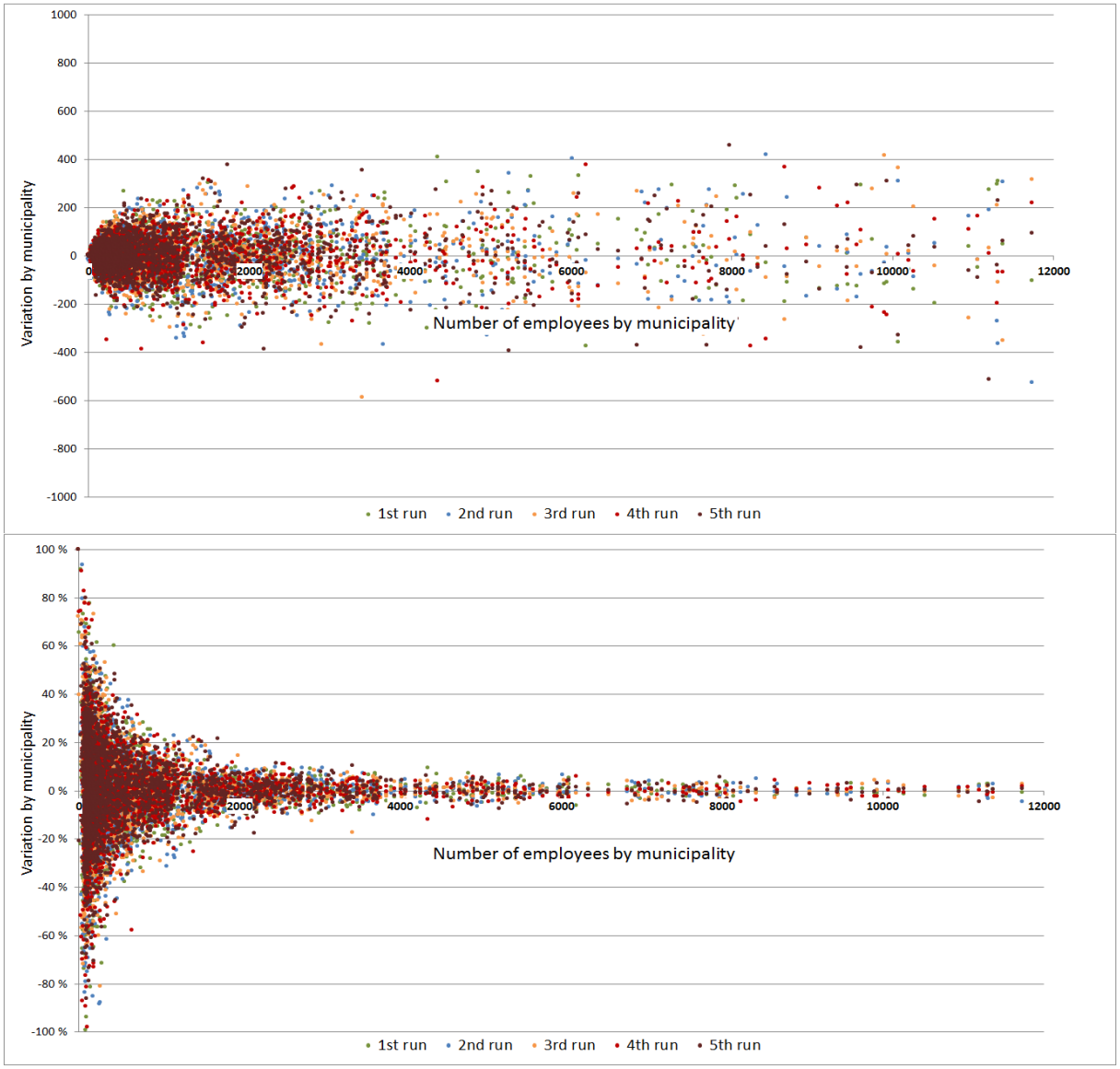


[3] Reference run: "2014-04-24-20-33_ARE_0A_10x_2000-2010_run_average" (ARE Network 2005)

3.3 White noise

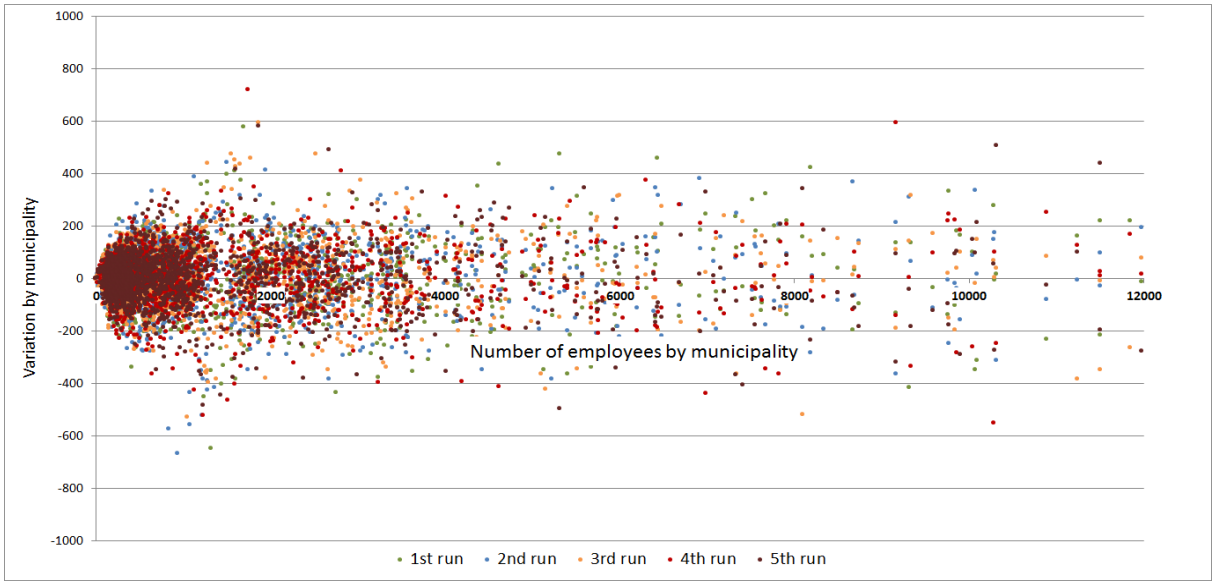
Unfortunately, the outputs of scenarios often do not show unambiguous effects. Comparing the results of the different scenarios, we note that the larger expected effects of a scenario are, the better the results are. Despite the good validation results, we therefore state that effects have to reach a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

Figure 6 White noise for employees after 10 years (5 runs)



Comparing the observed white noise after 10 years (Figure 6) with those after 20 years (Figure 7), we note a much larger noise after 20 years. This is reasonable, as with each Monte Carlo Simulation processed in the model, white noise will increase. White noise seems to grow at least 50% and especially the number of very extreme outliners increased considerably. Nevertheless, white noise does not depend significantly on the size of a municipality – or the number of employees in a certain zone. On the contrary, the white noise in absolute numbers seem to be stable despite of increasing number of employees. For residents, the same result can be noted.

Figure 7 White noise for employees after 20 years (5 runs)



As most of the scenarios only have an impact of several dozens to hundreds of residents and employees over 10 years, it is very important to reach reliabilities of +/-50 residents or employees. Unfortunately, this holds not only for small villages, but also for large cities, as impacts are (or should not be) dependent from the size of a location. To analyse simulation results, we have to focus therefore first and foremost on absolute values.[4]

This leads us to the question of how large confidence intervals for residents and employees are. In Figure 8 and Figure 9 the 95% confidence intervals for residents and employees are shown. The general assumption of a size-independent white noise can't be hold. Instead, the white noise is increasing with the size of a zone with an increasing number of residents and

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

employees until about 10'000 persons. For larger zones, the confidence interval keeps more or less stable. Residents start with a confidence interval of +/-200 for small zones and the interval increases to +/-700 for large cities. In contrast, the confidence interval for employees is between +/-150 and +/-350 employees.

Figure 8 Confidence interval of 95% for residents (after 10 years)

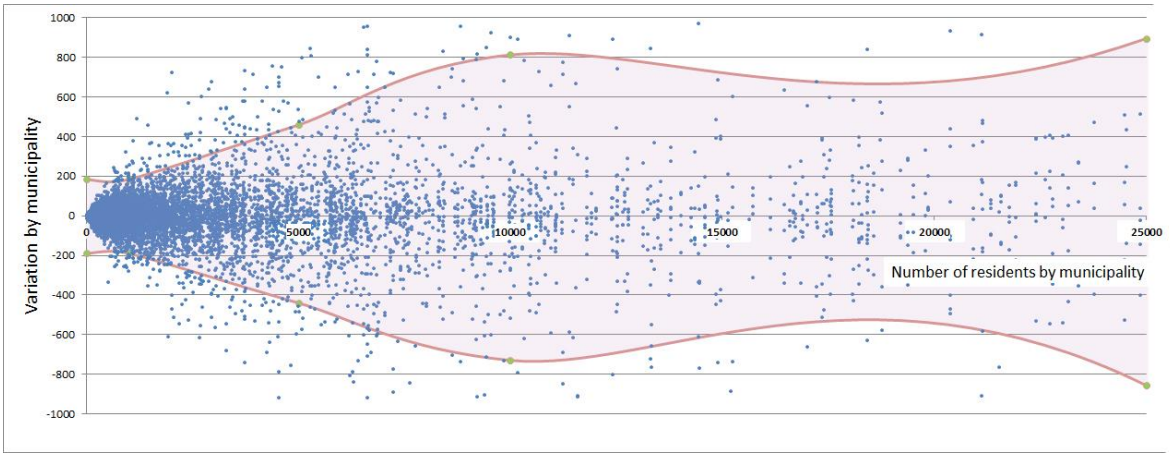
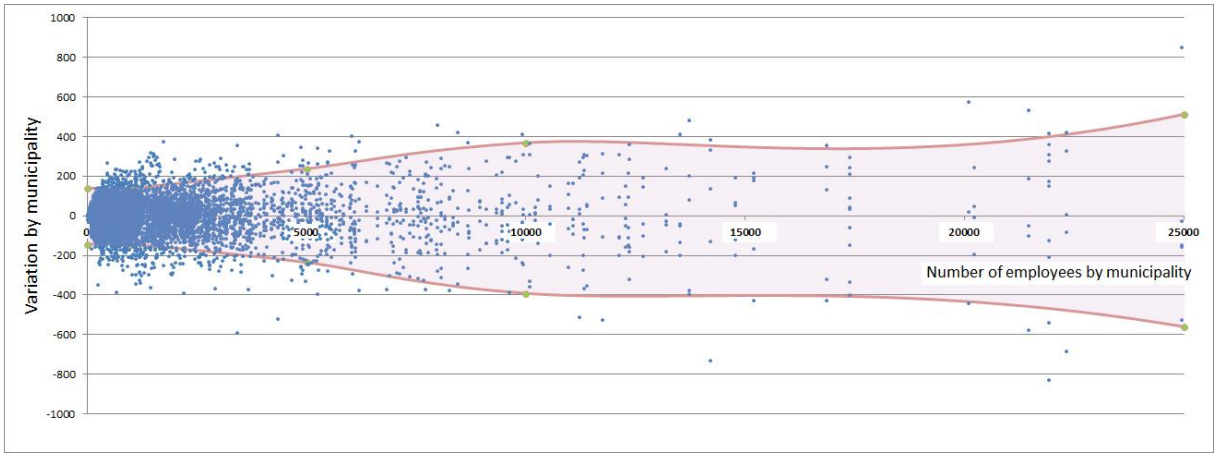


Figure 9 Confidence interval of 95% for employees (after 10 years)



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

Reducing white-noise

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

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

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

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

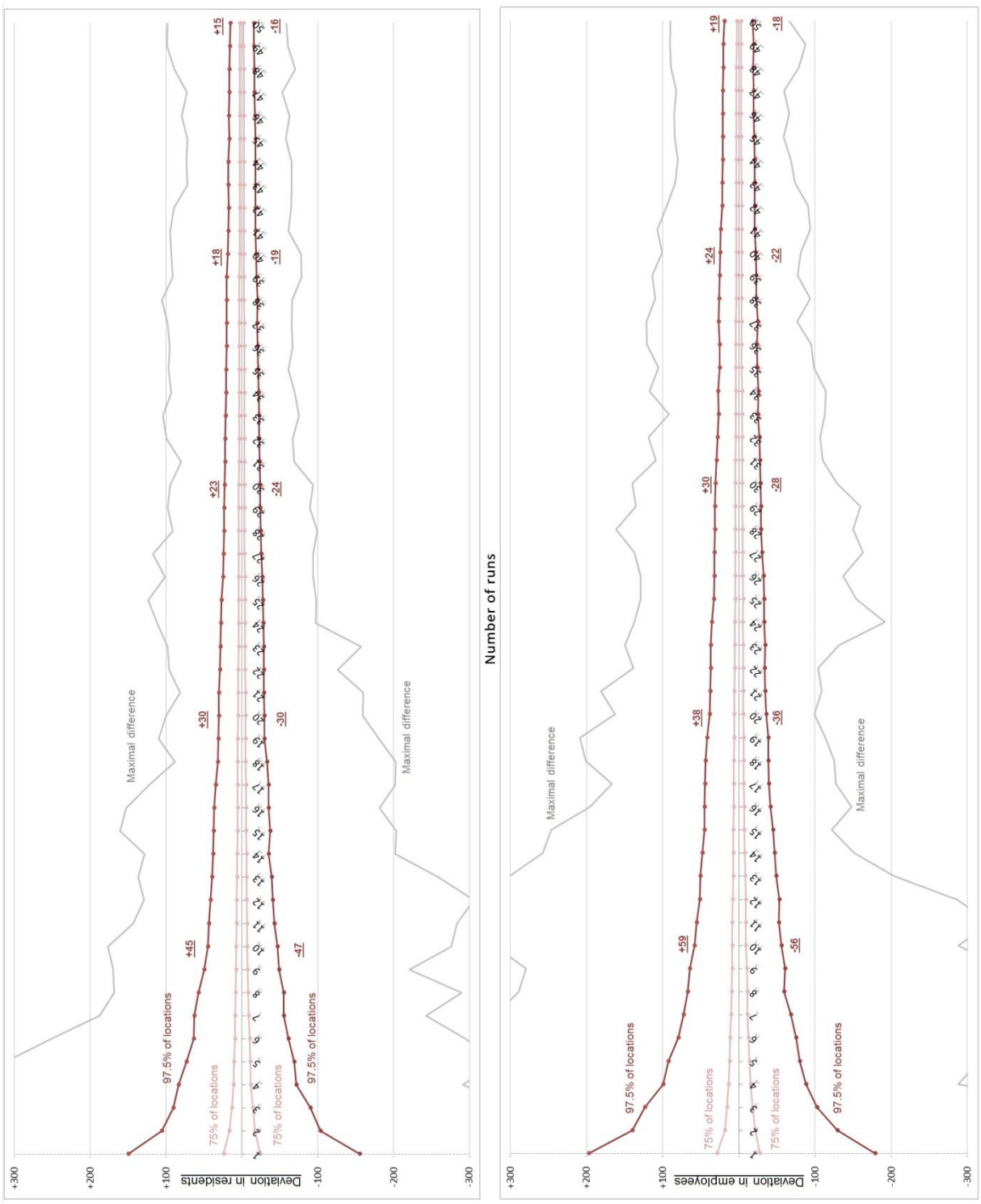
Wolf (2001) gives an overview of different approaches to reduce white noise. A very effective way to reduce white noise is the use of multiple runs. In FaLC, the user/modeller can select how many times will FaLC run a given scenario and FaLC will not only calculate the results for each run, but also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

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

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

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

Figure 10 White noise reduced by using the average of several runs



3.4 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 were kept as they had been derived from empirical work. However, after analysing some simulation results and cause-effects relations, different amendments have been made:

- Amendment of the workflow of the different models to get more randomness in the results – and avoid bias due to the modelling workflow.[5]
- Additionally, growth limitation based on legal land use limitations has been introduced (see chapter 4.3) where no more people are allowed to move into a zone once no more floor space is available.
- In the location choice model of households, we introduced also the distance to the former place of domicile to avoid too many relocations over long distances.
- Finally, different smaller errors and bugs have been detected and fixed. This concerns the FaLC code as well as base data (e.g. the simplified OSM-Network).

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

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

4. Scenario Simulation Results

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

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

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

4.1 Scenario 1: Effects of road network modification

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

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

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

difference of more than 40 residents and employees, we still observe some municipalities affected by white noise.

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

Figure 11 Relocation effects due to new motorway connection

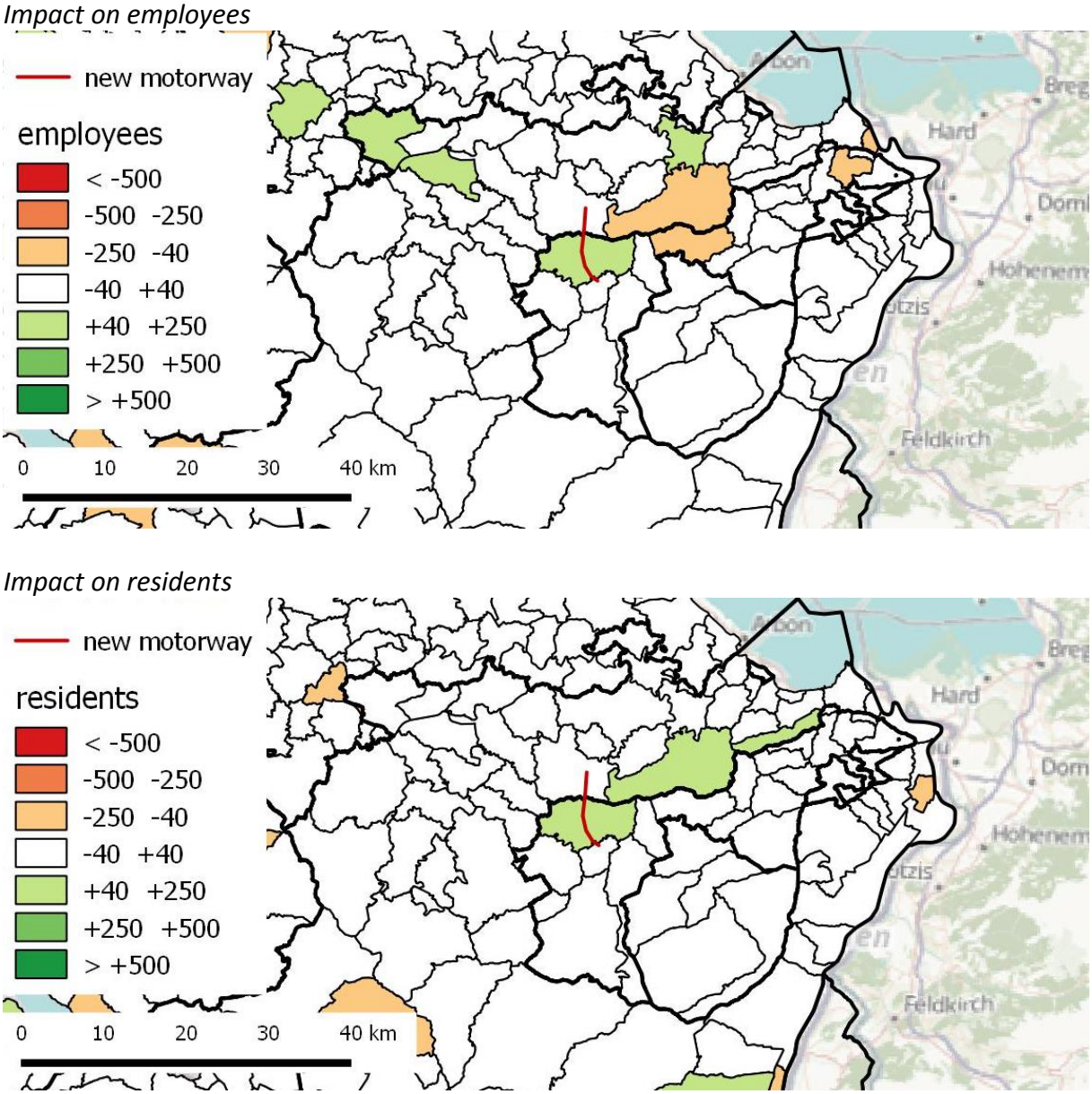
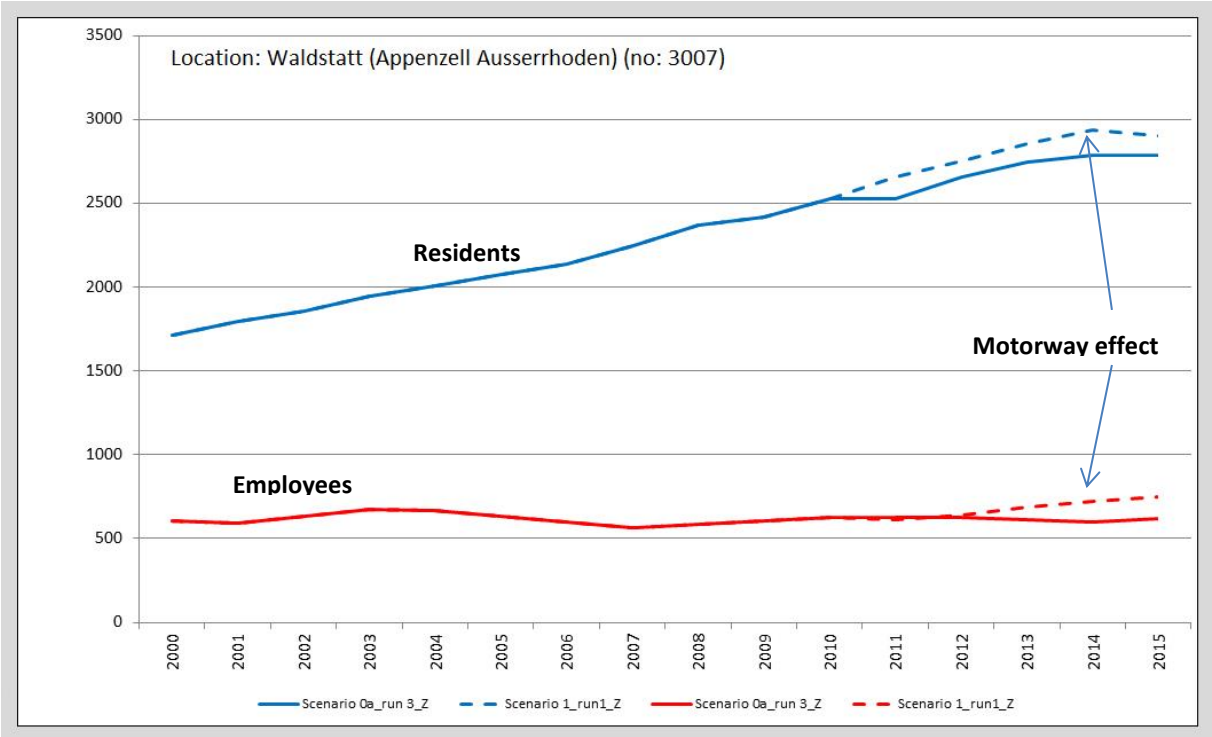


Figure 12 shows the case of Waldstatt in a randomly selected simulation run. The example reveals the evolutionary impact on residents and employees starting in 2010. Astonishingly, the effect of a new motorway access and its higher accessibility of other locations mainly has an impact on residents for the first year. The reason for this is that the new motorway connection re-rates the attractiveness of the locations considerably – this results in a new spatial distribution of residents. As in the following years the model does not receive a further large impact, attractiveness of locations do not change measurably. The resulting changes in land use distribution therefore keeps accordingly minor.

Figure 12 Firm relocation effects due to new motorway connection in Waldstatt



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

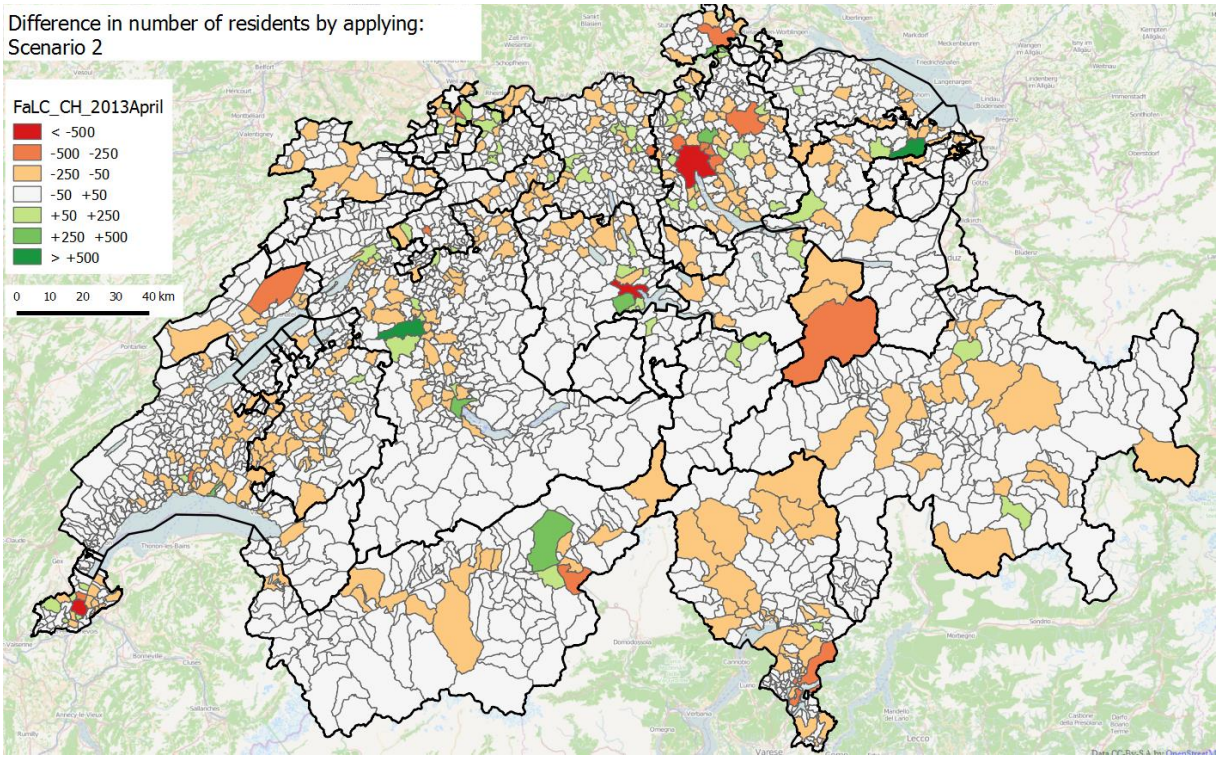
In consequence, the results show that a confidence interval of 95% is still very week to test local scenarios. 100 multiple runs of both scenarios (base scenario as well as the scenario itself) would result in a more appropriate 95% confidence interval of about +/-20. Additionally, in a further improvement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

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

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

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

Figure 13 Relocation effects on residents due to improvements in transport infrastructure

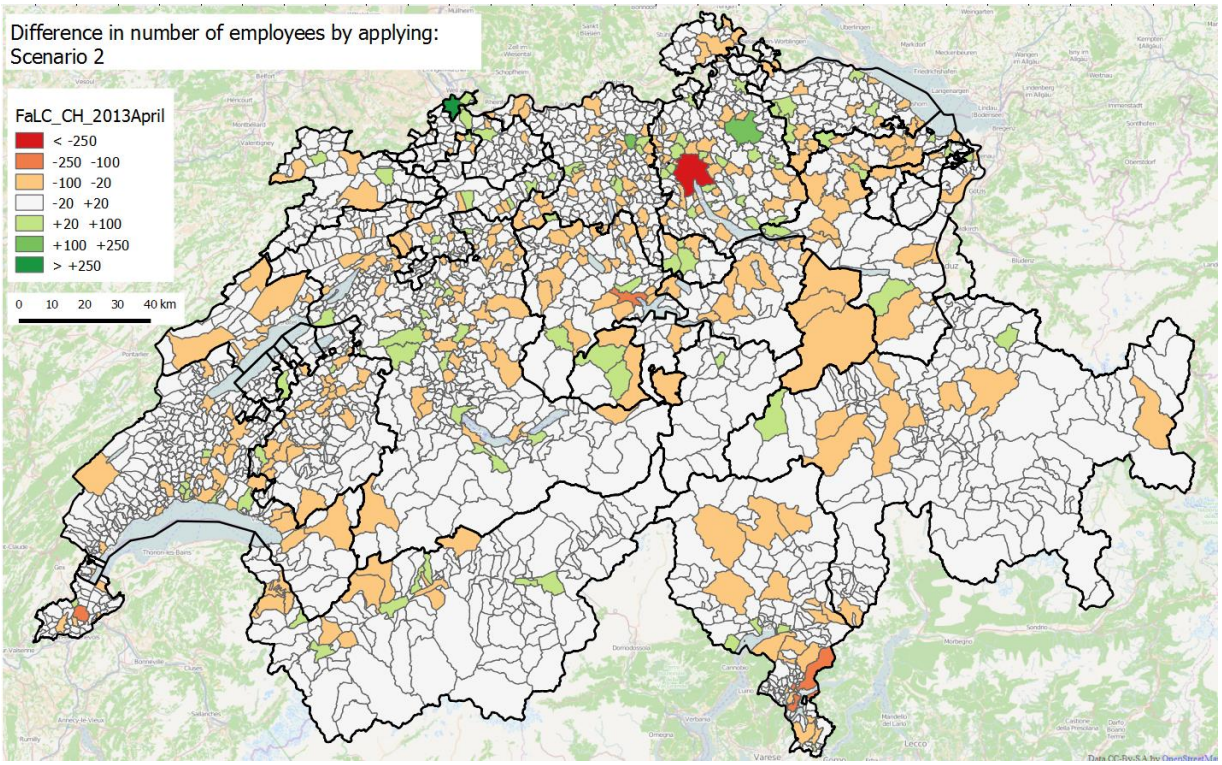


In the following map we see the effects on the spatial distribution of residents in Switzerland. In general, a decrease of residents in rural areas is noted. But in some in peri-urban areas, population tends to increase (e.g. near Zürich and in Aargau). These areas become better accessible and, consequently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

and Bern profit of changing accessibilities, whereas first and foremost Zurich and Geneva seem to loose attractiveness and therefore residents.

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

Figure 14 Relocation effects on employees due to improvements in transport infrastructure

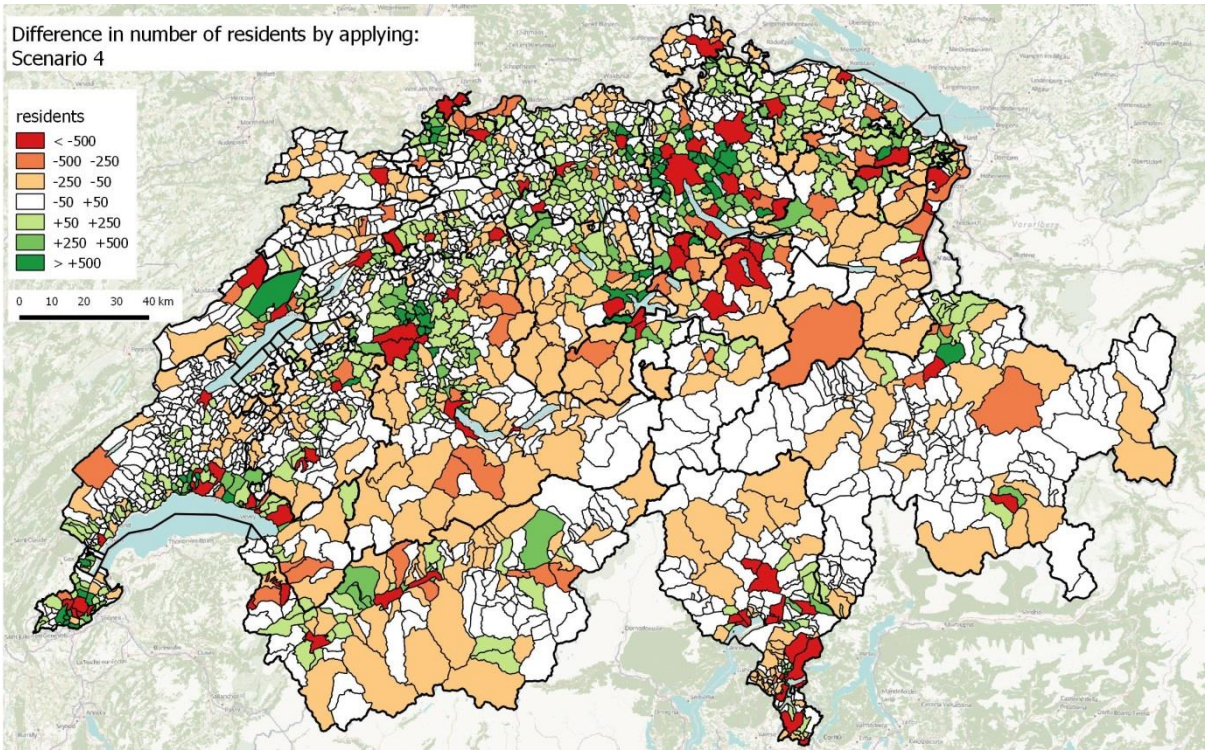


4.3 Scenario 3: Effects of land-use regulation modification

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

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

Figure 15 Resident relocation effects due to land regulation modification

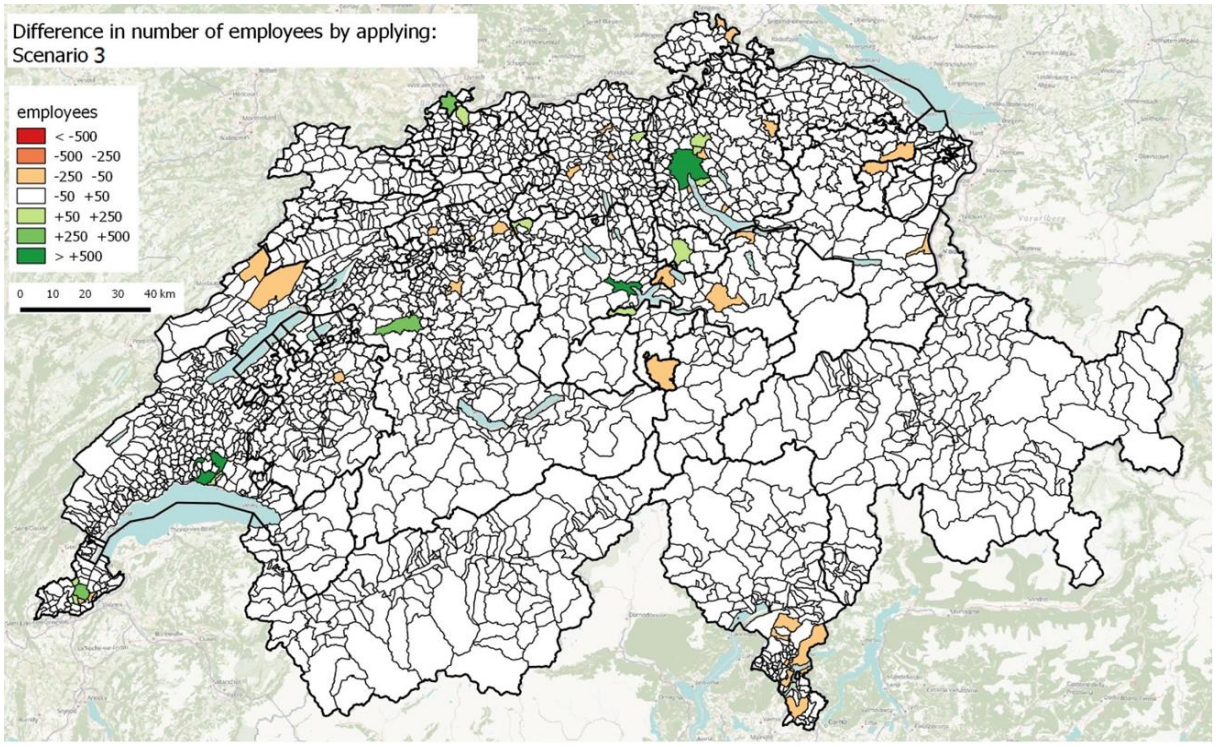


As we can see in Figure 16, the impact in large cities and adjacent suburban areas is much stronger than in rural areas. In general, agglomerations tend to become considerably denser. But – at first sight astonishingly – the results show a restructuration in the core of the agglomerations: households leave the core area and in return, firms move in the core of the agglomeration. This is due to the composition of the utility function, where firms react stronger on additional capacities in building zones. But, this results are in line with the

approach of von Thünen. Transfering the rings of von Thünen to cities, we would also assume that especially firms (of the third economic sector) tend to move to the city.

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

Figure 16 Employees relocation effects due to land regulation modification



5. Conclusion

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

The results of the Swiss Case Study show that – despite of the sometimes very simplified models – the estimations in FaLC are quite accurate. 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.

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

To test sensitivity of FaLC, different scenarios were calculated. The results show that especially powerful effects (e.g. increasing the Utilization Factors in all municipalities of Switzerland) deliver correspondingly strong and plausible results. Scenarios with weaker and more local effects (e.g. the motorway connection) tend to remain invisible in the white noise – and therefore need means to reduce white noise in the results. But, with multiple runs, it is possible to show also local effect like a single motorway connection (see scenario 1). Stronger impacts like the future road network 2030 (scenario 2) and changing land-use regulation in whole Switzerland (scenario 3) result in appropriately distinct effects on land-use.

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

Software

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

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

Revision of the models and model parameter

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

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

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

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