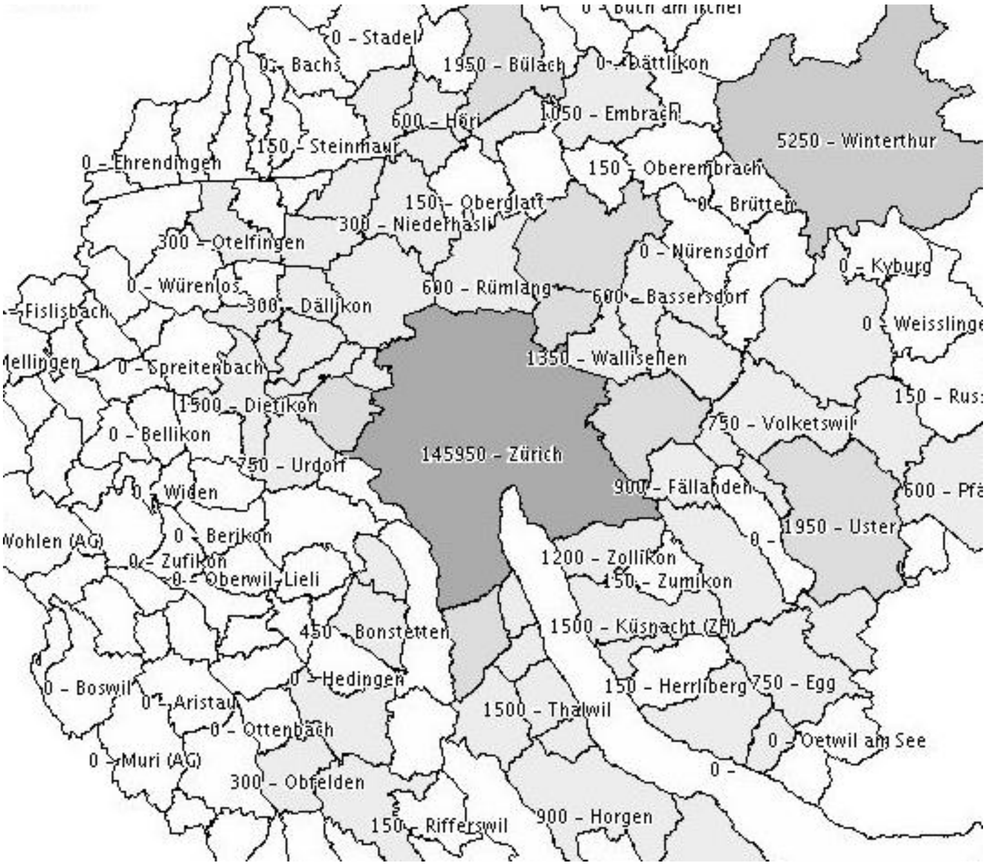


FaLC: Implementation of a Land-Use Transport Interaction Model for Switzerland

BR Bodenmann
BJ Vitins
I Vecchi
A Zeiler
J Hackney
KW Axhausen

Conference paper STRC 2013

12/04/2013

regioConcept AG
Raum + Verkehrsentwicklung

IVT Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Contents

FaLC: Implementation of a Land-Use Transport Interaction Model for Switzerland

BR Bodenmann
I Vecchi
A Zeiler

regioConcept AG
Schmiedgasse 33
9102 Herisau

www.regioconcept.ch

BJ Vitins
J Hackney
KW Axhausen

IVT
ETH Zürich
8093 Zürich

www.ivt.ethz.ch

12/04/2013

Abstract

FaLC (Facility Location Choice Simulation Tool) is an integrated microsimulation system for planning and analysis of urban development, incorporating interactions between land use, transportation, economy and public policy. The aim of FaLC is to develop a tool to answer different questions for scientific as well as for planning purposes. This blueprint gives partners and potential partners a rough outline of the basic elements of the project and, additionally, is a guideline for the development team.

Keywords

land use model, facility location choice, simulation, regioConcept, Herisau, IVT, ETH Zurich

Preferred citation style

Bodenmann, BR, BJ Vitins, I Vecchi, A Zeiler, J Hackney, and KW Axhausen (2013) FaLC: Implementation of a Land-Use Transport Interaction Model for Switzerland, regioConcept and IVT, Herisau/Zurich.

1 Introduction

Spatial planners, transport planners, authorities, real estate developers, investors as well as relocating residents and firms have different questions related to space and transport. These questions may concern only a certain parcel or they cover an area like a city, a region, or even a whole nation. A requirement for spatial and transport planning is an integrated and anticipatory development of the environment.

Indeed, there are some questions to be answered, e.g.: how will the global economy and political climate evolve in the future? How will our society respond to these influences (demographic / firmographic)? And which strategies will authorities and politicians chose to reach their goals? What are the spatial effects (and side-effects) of these changes (e.g. spatial/social segregation, use of resources and infrastructure, climate impact)? This small set of questions is far from being complete and varies strongly for each actor involved.

FaLC (Facility Location Choice Simulation Tool) is a working title for an integrated transport and land use simulation tool (LUTI) developed in a joint project of the Institute for Transport Planning and Systems (IVT) at ETH Zurich[1] and regioConcept[2]. The idea of FaLC is to develop a tool to answer different questions for scientific as well as planning purposes:

> **What are 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).**

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

- **Data**: Simulations on micro-level regarding agents, but data requirements shall be as low as possible. This requires an integrated tool to build synthetic populations.
- **Spatial resolution**: shall be modular and scalable. In a first step 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.

---

[1] Institute for Transport Planning and Systems (IVT), ETH Zurich, Wolfgang-Pauli-Strasse 15, CH-8093 Zurich, Switzerland, www.ivt.ethz.ch

[2] regioConcept AG, spatial and transport planning, Schmiedgasse 33, POB 1112, CH-9102 Herisau, Switzerland, www.regioconcept.ch

- **Models**: shall cover all relevant models to explain spatial long-term location decisions (household and firms with persons involved) and related transport activities.
- **Run time**: shall allow experimental games with on-the-fly results.
- **Costs**: FaLC shall allow to set up a simple land-use and transport model within days and a more sophisticated model within weeks. Special hardware requirements shall be avoided.

In parallel to the implementation of the software, a case study will be set up to test convenience and achievement of the stated objectives. The case study area will cover the whole of Switzerland at the level of municipalities. The implementation of the Swiss Case Study gives the opportunity to have a template for further work in other regions. And, it will be used for the automatization of standardized software reliability tests.

Figure 1 Model of agents behaviour in FaLC

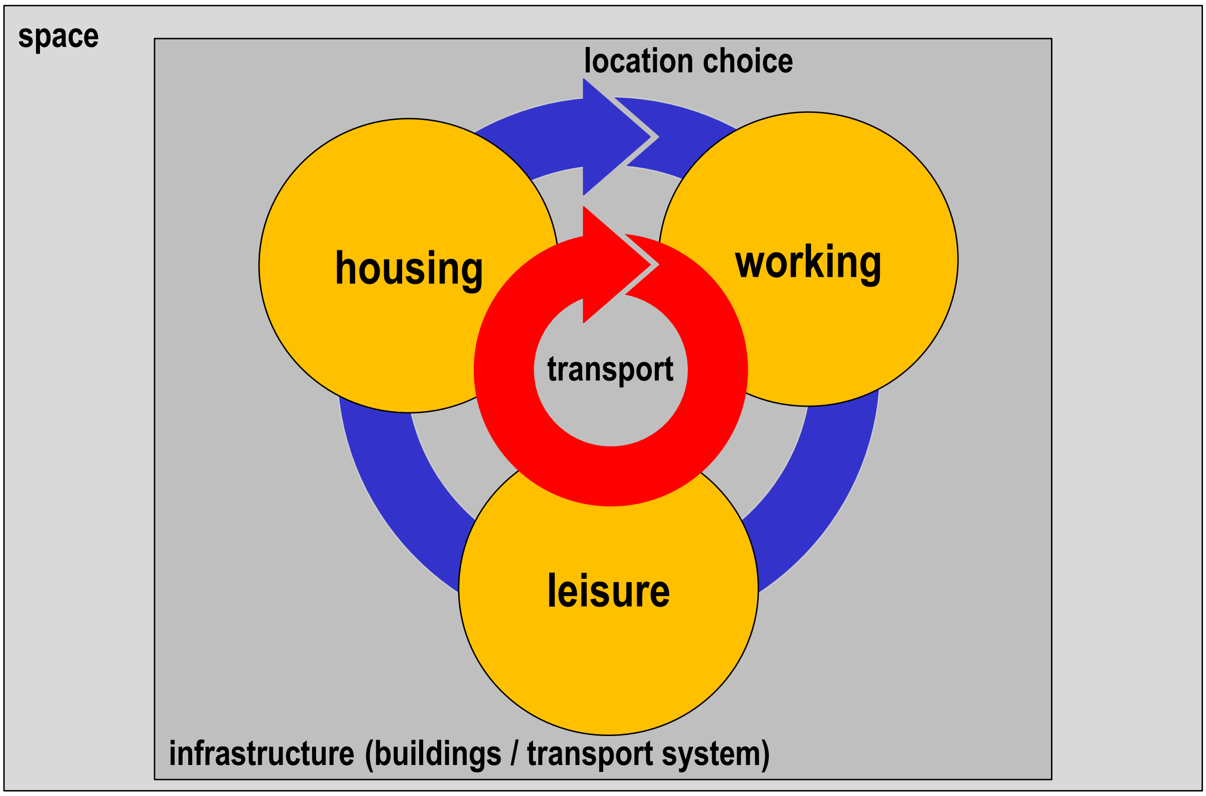


Figure 1 shows the very simplified model of agent behaviour in FaLC: persons move (or stay) in a certain space, comparable to a chess board. In this space, agents use different facilities for different purposes like buildings and transport infrastructure (squares on the chessboard). The different activities of these agents (home, work, leisure) are situated in these facilities. 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.

These two cycles are strongly connected and have to be 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 or maybe half-year. The idea of FaLC is to model daily movements in an aggregated way (e.g. the traditional four step approach to model transport).

Chapter 2 will focus on the goals and use of the FaLC Simulation tool, and also the specification of the software and the interfaces planned. Chapter 3 gives an overview of the FaLC specifications including models and agents included in FaLC. Chapter 4 explains the framework of the Swiss Case Study (template). Finally, chapter 5 and 6 will give an overview to the project organisation and the next steps of the project.

Please note that FaLC provides a) an open source platform for integrated land-use and transport modelling and b) a sample of an integrated land-use and transport model which can be used as a template for other modelling work. In the following, we will strictly distinguish between these two levels:

Generally, the FaLC platform will be discussed. Therefore, text regarding FaLC will not be emphasised.

In contrast, text in borders indicates, that the implementation of the Swiss Case Study is discussed. This is just an example of how the platform can be used. But, the platform allows the implementation of further models and specifications.

Additionally, please note that the project is just starting and its design is still under construction. We invite any partner to join the project and contact one of the authors of the project.

2 The FaLC project

2.1 Aim of FaLC

It is impossible to model all scientific and practical questions raised in the chapter above in one single model. FaLC – like other modelling tools – therefore will focus only on some of these questions:

> **in general, FaLC focuses on local processes (within a certain region or town) and can be influenced by decisions made by actors (e.g. authorities, firms, residents) in this region.**

FaLC is an integrated microsimulation model system for planning and analysis of urban development, incorporating the interactions between land use, transportation, economy and public policy. It is intended to explore the effects of

- decisions and preference changes of persons,
- decisions and strategic changes of firms,
- decisions of authorities and politicians, and
- trends in the (global) economy

on spatial and transport relevant outcomes such as

- demographic segregation and distribution,
- firmographic segregation and distribution,
- land- and housing market (especially land-price and housing affordability)
- use of public infrastructure (e.g. transport network)
- environmental impacts (such as greenhouse gas emissions, protection of open space)

FaLC is intended to be used by researchers as well as practitioners (e.g. planners, authorities). Potential applications are:

- Concept studies for land use and transportation
- Spatial directive plans[3] scenario evaluation
- Spatial labour and demographic changes
- Nationwide transport network studies, like the federal road systems
- Agglomeration programs
- Spatial policy scenarios
- Price regulation evaluation
- Energy consumption prognoses

---

[3] E.g. in Switzerland “Richtpläne”

Figure 2 gives an overview of the fields FaLC could be used – this is a non-exhaustive enumeration. FaLC is suitable for experimental games, optimization Tools and simulations without disaggregated personal data. This work certainly will influence spatial and transport planning and their legal instruments. In fact, results of the FaLC simulations could support political decision-making as well as planning. However, the elaboration of legal instruments itself is not explicitly the aim of FaLC.

Figure 2 Research and practical application

		Innovation	Area of application	
			Research	Praxis
	Planning instuments	+	+	++
FaLC	**Game simulation (Participatory Framework, e.g. Kunze, Halatsch, Scholz)**	++	+	++
	Integrated LUTI Simulation, Optimization Tool (Shape Grammars, Visualization)	+++	+++	++
	Simulation without personal data	+++	+++	+++

Regarding implementation, the developers of FaLC agreed on the following goals: the FaLC-project shall provide

- a modular system
- using just one database (avoiding redundant data) that
- copes with different spatial aggregations;

- an Open Source Software Tool (based on Java) to carry out
- simulations – no estimations – with time periods of about one year; and
- strong connection to MATSim for transport simulations with time periods of about one minute, may seconds;

- a source code without historic ballast that
- allows fast run times for multiple runs needed to test results (reliability, sensitivity, calibration)

- and experimental games;

- an easy to use tool (data import/export, model building, treatments of exceptions/bugs, new extensions, maintenance) with
- reduced need of data (e.g. aggregated data on municipal or regional level), and
- a case study as a template for other study areas.

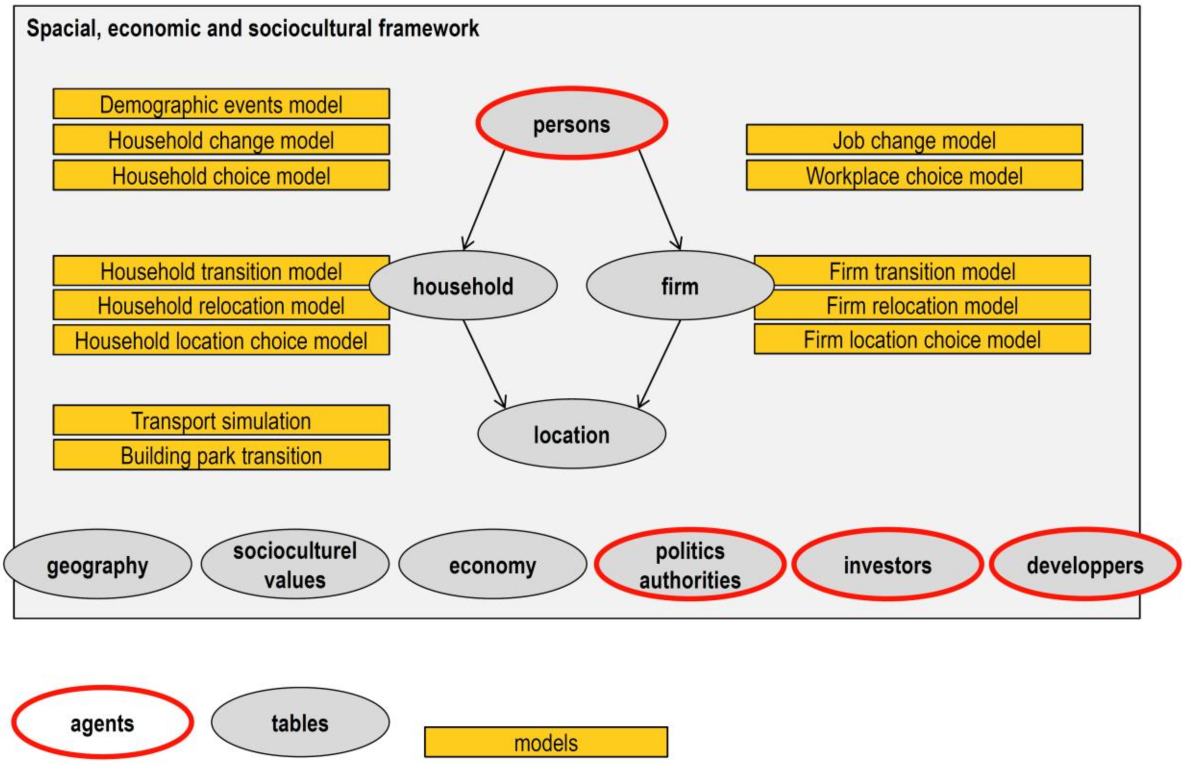
The implementation of these objectives will be tested in a case study for Switzerland. This case study will use as far as possible only data open for public use without legal restrictions. This case study will already focus on different research questions – they will be discussed in Chapter 4.

Specific questions will be discussed in Chapter 0 covering use cases to be modelled with the FaLC Simulation tool and the chosen Case Study. Indeed, there will be a step-wise implementation strategy.

2.2 Design of FaLC

Figure 3 shows the general concept of FaLC. Base of all interactions are different agents located at a location in a spatial, economic and sociocultural framework. Similar to a chess game with a virtual partner, we have the opportunity to influence directly some agents (similar to the 16 pieces in a chess game) or we change rules of the game. The virtual partner reacts in his move to these changes and at the end of each round we face to a new (expected or unexpected) situation. Certainly, there are some mayor differences to chess: modelling land-use and transport involves many more agents (e.g. Switzerland with 8 Mio inhabitants) and not only two colours black and white (e.g. 5.5 Mio. households and 300'000 firms in Switzerland[4]) and game rules could diverge between different regions of the chess board.

Figure 3 Concept (2012)



Basically, FaLC will focus on the relations between persons (possibly aggregated in households and firms) and their location and relocation behaviour. The dynamically modelled decisions are influenced by different external constraints like geography, sociocultural values, economy, and external agents like authorities, politicians, investors and developers. Either, these constraints are fixed during the simulated period, or they change exogenously (e.g. according to different scenarios).

[4] www.bfs.admin.ch

Comparable to real live, the agents essentially are persons. But most of the long-term decisions of the persons are settled within a more or less complex decision process with different persons involved. Examples are households and firms with generally more than one person, but there are certainly other groups involved for certain decisions (e.g. collective decision of site developments with different parties involved: owner, bank, future tenants, etcetera). These aggregated decision makers can be modelled as a conglomerate of agents or as distinct aggregated agents.

In order to attain increased flexibility and accuracy, decisions at the agents conglomeration level can be modelled at the individual level (e.g. as a sum of utilities for each person relevant for the decisions) or on the level of the conglomeration (household, firm, etc.).

FaLC consist of four building blocks: a) a simulation platform consisting of a database with the relevant information of all agents and locations, b) different functionalities to give life to this structure (e.g. transition models, relocation models, location choice models, interfaces), and c) a controller functionality to organise runs, define models and input parameters. And last but not least d) a Case Study to be used as a template to set up FaLC Simulation runs in other regions and for additional questions.

Simulation Platform
The Simulation Platform basically consists of a database containing different tables (e.g. persons, households, firms (agents) and locations (including auxiliary tables like distances and costs). The FaLC platform enables the implementation of modelling tools and their interactions.

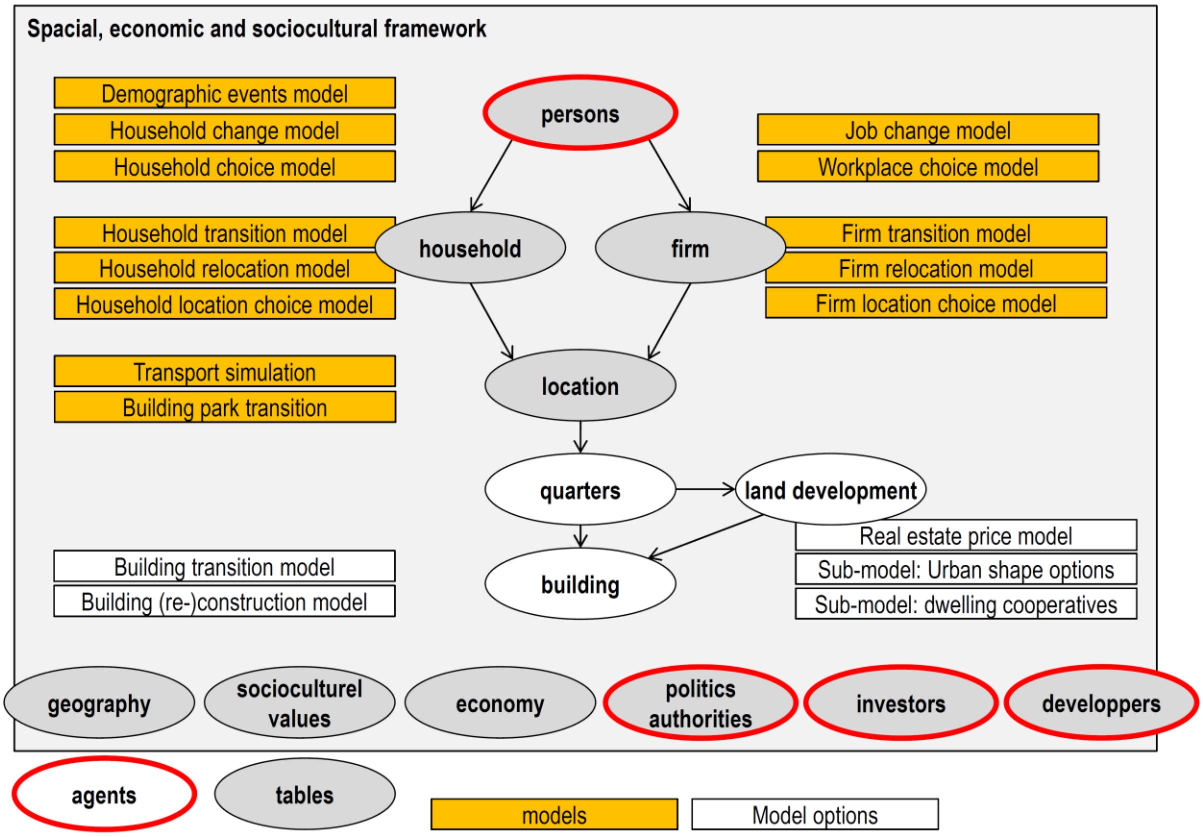
Functionalities of the FaLC Platform
Different functionalities breathe life into FaLC with e.g. transition or relocation choice models for households and firms. Important services are also provided by tools simplifying data import and export as well as result evaluation and visualisation. Apart to the modelling tools, some – in our opinion – important services will be implemented: a controller tool, a tool handling with different spatial aggregation levels and an aggregated transport model (Four-step-approach, including routing capabilities).
Details see Chapters 3.1 - 3.2.

Implementation of Case Study and template
The FaLC Simulation Platform and its functionalities enable simulation runs of specific Case Studies. According implementations strongly depend on their research focus and Case Study Area (and data available). As a proof of concept, a simulation of a Swiss Case Study will be implemented. This simulation framework will can be used as a template for other Case Studies. The implementation as well as results will be published and openly accessible.

The models shown in Figure 3 generally include a) probabilistic models (e.g. a firm has the probability of about 3% to move in year t), b) discrete choice models (e.g. a relocating firm choses municipality x as new domicile), and c) model systems like the transport simulation model. In the first development step, simulation of markets are disregarded. On the long term, FaLC aims to include also markets, namely: land market, housing market, and labour market (including especially wages). Remaining countrywide and foreign economy changes and its parameters are integrated external parameters.

Further options for future development phases are shown in Figure 4. Focus may will lie on modelling land developers, quarters (in contrast to municipalities) and buildings. However, some of these models may are already implemented in a joint venture with TEP Energy.[5]

Figure 4 Options (2013+)



5 www.tep-energy.ch

3 Specifications of FaLC

3.1 Functional requirements: FaLC functionalities

3.1.1 Software functionality

FaLC software functionality is grouped in about a dozen modules. The main modules are:

The **core** module encompasses the basic FaLC objects: person, household, business, location and generalized distance, the latter subsuming a range of generalised cost elements.

Current core implementation handles Swiss municipalities as locations. Additionally, large cities like Zurich or Bern may be split up in different sectors (according to the Swiss Traffic Model; see Vrtic und Fröhlich, 2010).

The **synthese** module provides methods for the generation of synthetic populations based on available data. Due to the wide variety of possible input data, the synthese module is characterized by a high degree of flexibility and encompasses flexible methods for data input, which make the data available to the program without requiring code modifications.

Current synthese implementations create synthetic populations from public available data. Households, businesses and persons are populated and distributed according to statistical distributions and utility functions based on empirical-inductive models. In order to obtain more robust results the tests in the Swiss Case Study will also use synthetic data calculated externally on a wider data-base and method (hierarchical IPF; Müller and Axhausen, 2012) as well as more adaptive activity schedules (MATSim; Weis, 2012).

The **distances** module provides methods and, for the calculation of distances, routings and generalized travel costs. Generalized costs-distances, which can be obtained on the basis of different models-requirements, provide a key input to the synthese, service and rescale modules.

Current distances implementations provide geographic distances and wrapper methods to obtain routing distances from various external packages (e.g. osm2po and MATSim) .

The **service** module provides methods for event-based modelling and simulation of population dynamics. The models are based on regression, discrete-choice methods, and iterative methods for transport modelling purposes. Variability analysis (e.g. Horni, Charypar and Axhausen, 2011) will be implemented in the long term.

Current service implementations provide dynamic discrete-choice migration models for households and business according to statistical distribution rules and utility functions based on publicly available data and empirical-inductive models.

The **geolocations** module provides methods for handling and processing specific geometric/geographic information.

Current **geolocations** implementations rely on open source Postgis and geotools packages for specific geodata functionality.

The **rescale** module provides integrated rescaling implementations for both geographic and population data.

Current rescale implementations provide rescaling and aggregation of Swiss municipalities into larger geosocial entities based on user-defined criteria, aggregating geographical entities as well as the corresponding populations. Rescaled costs/distances for the rescaled aggregations are calculated on the basis of pluggable costs/distances-rescaling implementations, enabling different, alternative weighting/rescaling user-defined models. The current implementation calculates rescaled distances as population-weighted averages of the distances between locations.

The **statistics** module provides statistical functionality (e.g. Monte-Carlo simulation, pluggable random generators, utilities for probabilistic location and grouping assignment).

The **utility** module implements utility functions needed in the generation of synthetic population as well as in the modelling of migration processes.

Current utility implementations provide utility functions for the **synthese** and **service** modules based on publicly available economic and demographical data by sector and population segment.

The **entropy** module implements entropy minimization methods derived from statistical mechanics.

The current entropy implementation provides bare-bones OD-matrix functionality.

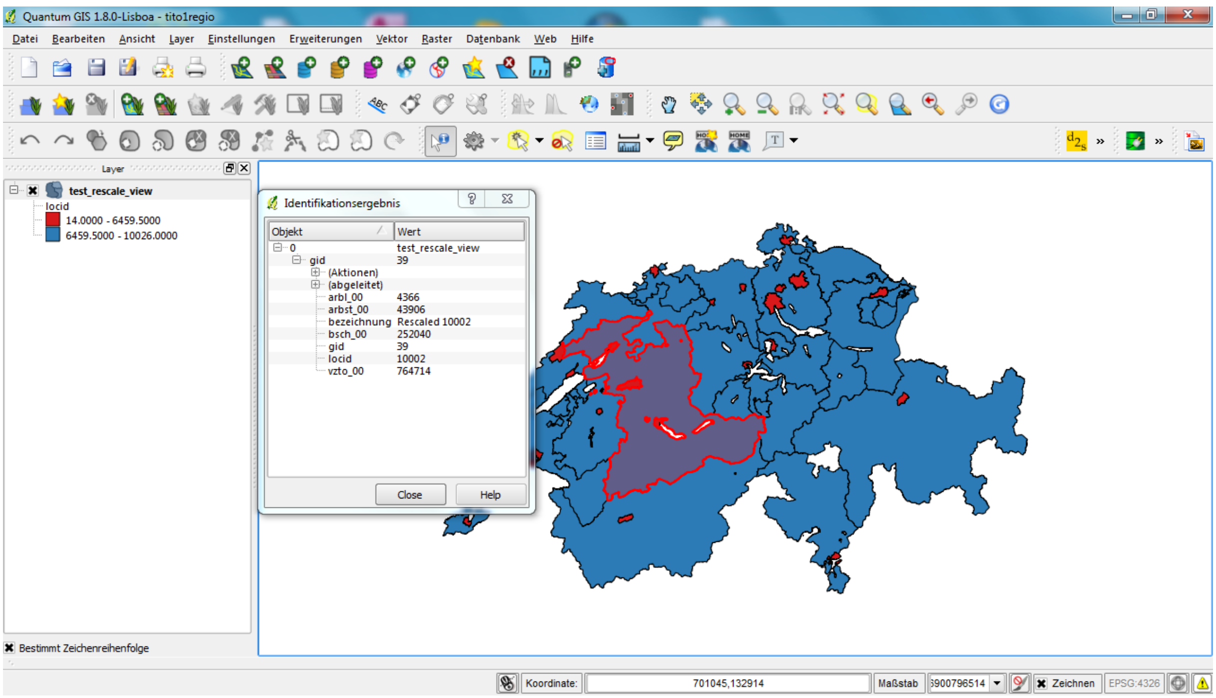
A **visual** module provides simple visualization for specific tasks. In particular, visualisation of input data and results on a map is useful for a first rough check of plausibility. The visual module can be integrated by free open source tools such as QGIS. More sophisticated tests like variations of indicators in time have to be done externally (e.g. in R, SPSS or other statistic software).

The current implementation contains a simple visualisation module for specific tasks, which can be integrated or replaced by free open source tools such as QGIS. Figure 5 and 6 provide examples of such functionality, enabling a first qualitative check of the program’s output.

Figure 5 shows the dwelling distribution of people working in Zürich throughout the Zürich region calculated by a utility-function based test model. Figure 6 shows rescaled Switzerland populations calculated by FaLC rescaling module.

Figure 5 Visualisation for data and results check: an output example of FaLC Visual Tool

Figure 6 Visualization of a rescaled Falc population distribution in QGIS



Beside its functional modules, FaLC contains a **JUnit test module**, which grows with the project and monitors its functionality. The current implementation encompasses about hundred JUnit tests.

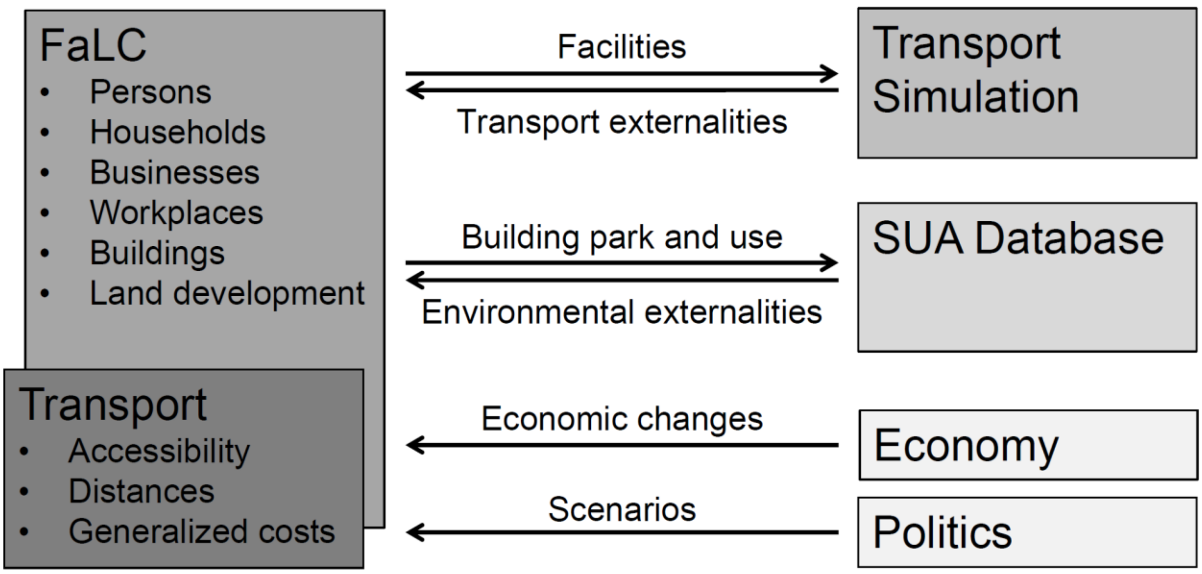
3.2 Interfaces to other Software-Tools

Different interfaces to other Simulation Tools are crucial for Land-Use Simulations and comprehensive research questions.

Transport: As Transport and Land-Use are tightly interrelated, FaLC has an integrated Transport Simulation Tool. Indeed, this tool is implemented to have fast calculations of accessibility variables and rough estimations of traffic flows. Therefore, the Transport Simulation Tool is intended to use just a four-step approach on a more aggregated level. To allow more detailed research, external Transport Simulation Tools such as MATSim (MATSim development team, 2007) or VISUM/VISSIM (PTV, 2011) shall have an interface with FaLC. At least, this will be a possibility of data transfer.[6]

SUA Database: Additionally, a Climate-KIC project “Smart Urban Adapt” (SUA) will implement a database containing data regarding micro climate, pollution, energy consumption, building park and other information regarding sustainable urban development (see www.sua.ethz.ch). Another important goal of SUA is a 3-D visualisation tool to support interactively discussions of authorities, politicians and planners.

Figure 7 Interaction concept



Exogenous models: Different specialised models cover future exogenous impacts on land-use: e.g. models regarding (global) economic developments, international migration flows or (global) climate changes. Usually, these models are from a national perspective and therefore

[6] According to the current level of knowledge, a direct integration of MATSim (and vice-versa an integration of FaLC in MATSim) should be feasible. In contrast, an interface to closed source software like VISUM may only include data transfer.

estimated and provided by national authorities. These models usually are not integrated as such, but as exogenous control totals to be used in FaLC.

Politics: Most of authorities' and politicians' decision to achieve certain goals are impossible to be modelled. Generally, this includes all (spatial relevant) decisions that have an extremely small probability to occur; but, have an extremely high impact on the modelled agents: e.g. new transport infrastructure or tax incentives to attract new inhabitants and firms. These exogenous impacts will be integrated in FaLC using a scenario approach. This approach enables also to compare different options for action for authorities and allows to compare different infrastructure projects.

GIS: Current GIS functionality in FaLC is used for rescaling and visualisation. Further, more detailed geospatial analyses are possible trough external GIS-based tools such as QGIS.

Detailed specifications of the discussed interfaces have to be defined and will be published in due time.

3.3 Other requirements (non-functional and system)

The aim of FaLC is to build up a community actively involved in the implementation of its functionalities as well as simulation runs. This ensues some important requirements – especially regarding source code:

- modular model system
- use of one database (avoiding redundant data)
- clean source code
- easy to use tool (data import/export, model building, treatments of exceptions/bugs, new extensions, maintenance)
- well documented source code with user guide

Most of the simulation tools only provide one simulation result. Indeed, it is very important to know if this result is robust or not. FaLC shall calculate e.g. median, upper and lower quartiles of certain indicators resulting for a specific scenario (e.g. Horni, Charypar and Axhausen, 2011). This requires that FaLC:

- allows fast run-times of the multiple runs needed.

In this respect, scalability will play a crucial role, The possibility of fast runs allows also to arrange experimental games with "real-time" simulation runs within a very short period of time.

3.4 Use cases

FaLC focusses on land-use and (to a smaller extent) transport. The core Use Cases therefore include demography/firmography, use of transport infrastructure, land price/land development and environmental issues. Indeed, the really interesting question is how land-use is affected by different impacts such as changing land regulations and transport infrastructure, political and governmental decisions.

Table 1 Use Cases

Effects on	**Effects of**
UC1: Demography / firmography	UC6: Changing land regulations
UC2: Transport demand: rail /road	UC7: Changing transport PC infrastructure
UC3: Land price, land development	UC8: Changing transport PT infrastructure
UC4: Environment	UC9: Political and governmental decisions
UC5: Effects on economic activities	UC10: Economic changes
…	…

The following Chapters give a rough overview of the most relevant Use Cases to cover major requirements for the FaLC project. Each of these Use Cases will be defined more in detail during the development process.

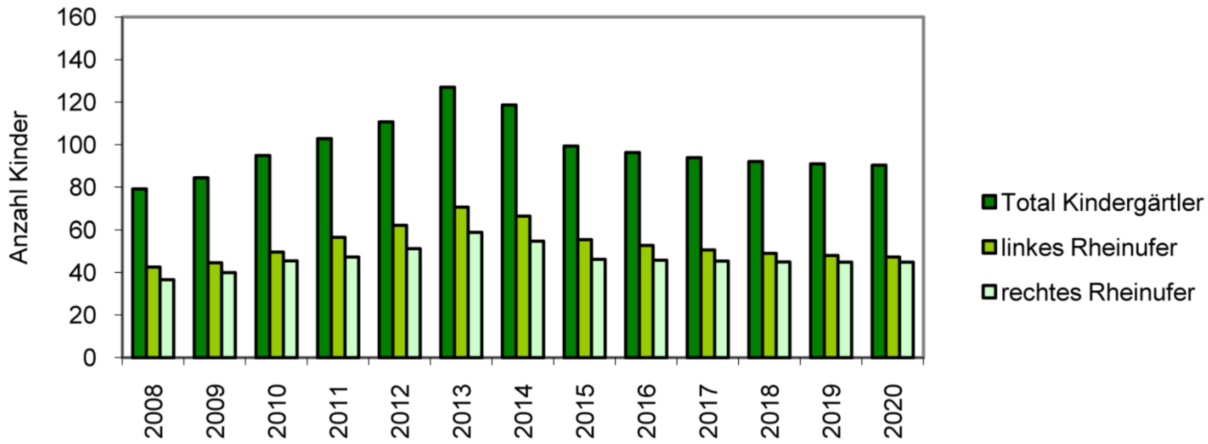
3.4.1 UC1: Effects on land-use: Demography / firmography

Core use case of FaLC is the simulation of demographic and firmographic development. According to the field of application, several questions may are raised. E.g. how will be the future development of:

- inhabitants in a certain area?
- pupils or elderly people?
- number of persons in working age (taxpayers)?
- number of jobs and employees?
- tax income of municipalities?
- use of public infrastructure (e.g. schools)?

In practice, there are several examples for this sort of tasks. One example is the municipality of Eglisau intervening in the land market (Bodenmann et al., 2009). Due to different considerations, the municipal council of Eglisau decided to sell a considerably amount of land assigned as building zones for residential use. Additionally, public transport from and to the city of Zurich has been improved. In the following, the municipal council faced (amongst others) a rising amount of kindergarten pupils. Indeed, the question was, how many children will come and what will be the long-term development of the pupils in the different levels of education. The result was very important to decide how to proceed with additional room and staff. The results of according simulations show a strongly increasing number of pupils until 2013. After this peak, the number of kindergarten pupils will even out on a considerably lower level.

Figure 8 Demographic development on municipal level



Sources: Scenarios for Eglisau: kindergarten pupils 2008-2020 (Bodenmann et al., 2009)

Additionally, this Use Case will cover spatial disaggregation of the results. E.g. in the mentioned example of Eglisau, this municipality is divided in two parts by the river Rhine. Therefore, authorities are interested to have estimations for each side of the river.

The Swiss Case Study will be used to generate populations (residents and firms) for the year 2030 including the connection of home- and workplace (part of the project MATSim 2030), and spatial migration processes due to long-term location choice. An additional task of this project is the disaggregation of data on municipal level on a synthetic parcel level used in MATSim. Additionally, the results will be compared to the official demographic prospect of the Swiss Federal Statistical Office (FSO) to disaggregate these data on municipal level.

3.4.2 UC2: Effects on transport infrastructure: rail /road

The effects of land-use changes on use of transport infrastructure is an important task of all integrated land-use and transport simulation tools. Indeed, developers of a land-use simulation tool like FaLC are well advised to focus on certain questions crucial for the land-use modelling. As shown in Figure 9, this is the calculation of accessibility, input for spatial planners, cost benefit analyses and indicators regarding environment and climate. In contrast, transport planning and simulation are subjects for specialised transport modelling tools like MATSim or VISUM/VISEM.

Figure 9 Modelling Transport in FaLC and Transport Simulation Tools

	Scope	Implement. Effort	Processing Speed	Requirement Data	Standard Proceeding	Market
FaLC	Accessibility	+	+	+	+++	++
	Spatial Planning	++	+	+	++	++
	Cost-benefit Analysis	++	+	+	+++	+++
	Environment / Climate	+++	+++	+++	++	+
	Transport Planning	+++	++	++	+++	+++
MATSim	Transport Simulations	+++	+++	+++	++	++

Therefore, FaLC will provide at the start some interfaces to MATSim and VISUM. Evidently, the variables transferred will vary substantially between the different transport simulations tools.

The Swiss Case Study will focus on two main tasks: the calculation of accessibility variables and the interfaces for MATSim and VISUM. FaLC will provide a possibility to transfer data to these two software tools. Additionally, FaLC shall have the possibility to extract the required inputs from MATSim runs.

FaLC will use an approach similar to the interface between UrbanSim and MATSim implemented in the SustainCity project (Nicolai and Nagel, 2010).

3.4.3 UC3: Effects on land market: land price, land development

The effects on land price and land development will be implemented in a second phase. The Use Case will be defined later.

3.4.4 UC4: Effects on environment: climate impact, CO_2-emission

Interaction effect of land use / transport one side and climate, energy consumption, and CO_2-emissions on the other side are widely discussed but scientifically poorly explored subjects in political discussions. FaLC gives the opportunity to build up research in this field. What are the effects of residents' and firms' locations, building densities, and accordingly commuting distances on

- energy consumption,
- air pollution and CO_2-emissions,
- (urban) heat islands, and
- how can we influence this consumptions and externalities.

FaLC is going to be used for the simulations in a Climate-KIC project "Smart Urban Adapt" (SUA). Interactions with climate and energy-related modules are defined within this project (see www.sua.ethz.ch).

3.4.5 UC5: Effects on economic activities: cash flow

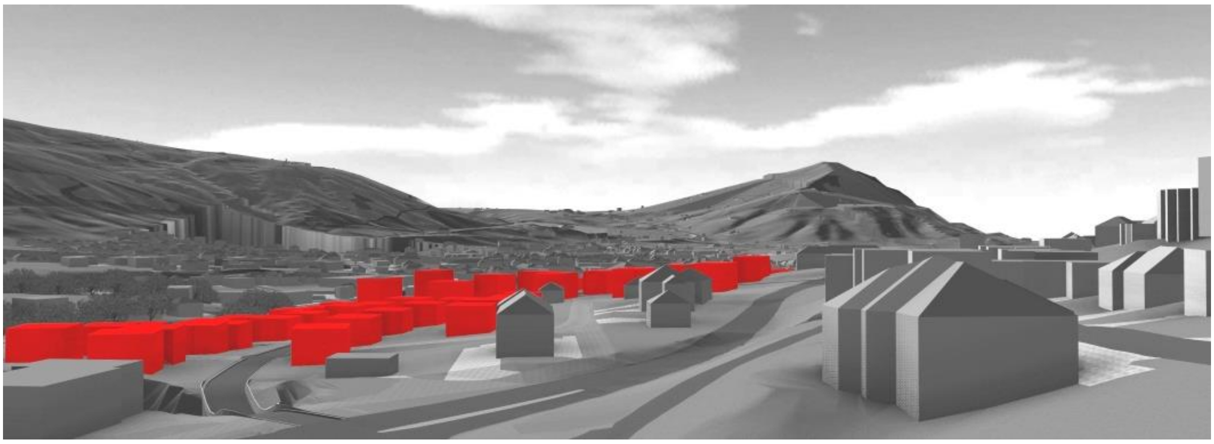
The effects on economic activities such as e.g. (regional) cash flow will be implemented in a second phase. The Use Case will be defined later.

3.4.6 UC6: Effects of changing land regulations

One common option for action in spatial planning are changes of land regulations. E.g. designation of new building zones often is a publicly discussed subject (e.g. Figure 10). But, also freezing the limits of building zones is an option observed: e.g. in the new cantonal directive plan of Zurich. Usually, this strategy is used by spatial planners to density the building park within the building zones. To evaluate and compare effects of these strategies, FaLC will focus on the following questions:

- What are 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?
- What are the side effects on municipal and cantonal budgets, use of infrastructure such as kindergardens and schools?
- What are the effects on spatial segregation of land use?

Figure 10 Visualisation of newly assigned building zones



Source: Grundlagen Siedlungspolitik Appenzell I.Rh. (Bodenmann et al., 2012)

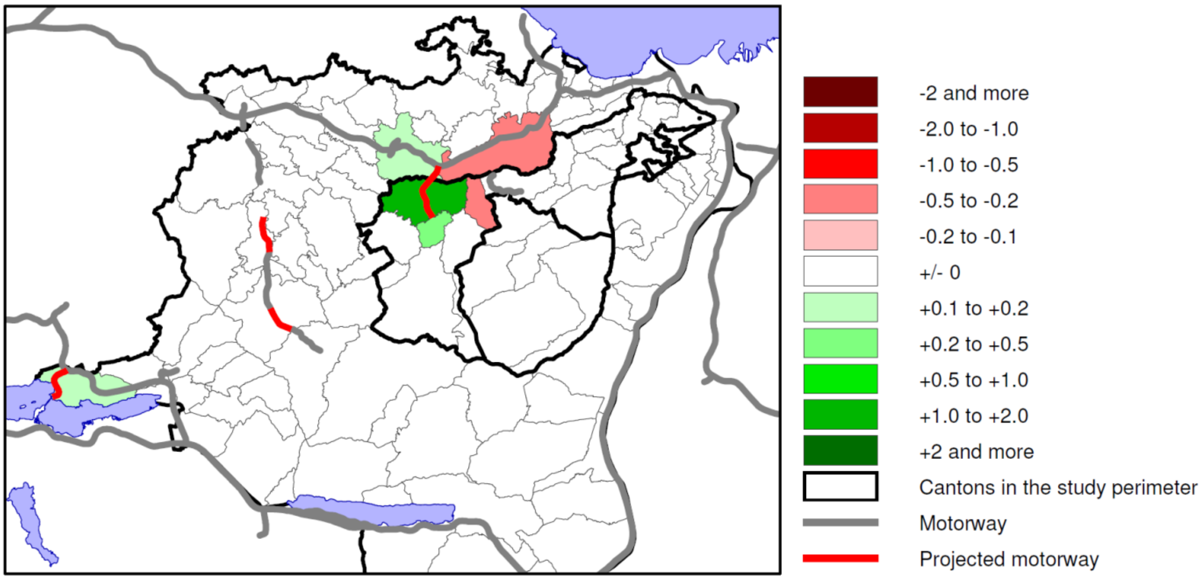
In a first phase, the Swiss Case Study will focus on the first research question regarding demographic and firmographic effects.

3.4.7 UC7: Effects of changing private car (PC) transport infrastructure

Different researchers prove a direct impact of changing transport infrastructure on different land use indicators such as demography, firmography and land price. Indeed, some indirect effects can occur unexpectedly.

An example of the effects of planned new bypasses in the Canton of St.Gallen illustrates such side-effects (Bodenmann and Axhausen, 2011). Figure 11 shows the relocation pattern of firms due to the projected bypasses in Rapperswil-Jona and in the district of Toggenburg, as well as the motorway connection and access highway for the region of Appenzell. The new bypasses in the district of Toggenburg have an extremely small impact. One reason is that in rural areas distances between municipalities are relatively large. Additionally, residential population and numbers of employees in these municipalities are small. In contrast, the new access highway for the region of Appenzell has a considerable impact on various municipalities, as travel time savings affects an area with a relatively high density of residential population and firms. Negative effects can be shown for areas along existing important traffic corridors but – surprisingly – also in the hinterland of municipalities directly concerned.

Figure 11 Firm relocation effects due to improvements in transport infrastructure (PC)



Real projects according to cantonal directive plans (SG/AR/AI)
Source: Bodenmann and Axhausen (2011)

To evaluate and compare effects of improvements in (private car) transport infrastructure, FaLC will focus on the following questions:

- What are demographic and firmographic effects of improvements in transport infrastructure (PC)?
- What are effects on land-market, especially if time-lags are considered

In a first phase, the Swiss Case Study will allow simulations concerning new PC transport infrastructure and its demographic and firmographic effects. Due to some lac of research in the field, the introduction of time-lag will be postponed to a later phase of the project.

3.4.8 UC8: Effects of changing public transport (PT) infrastructure

Also Public Transport (PT) plays a crucial role in land use simulation. Especially, this holds for resident location choice. In general, research questions are very similar to those regarding the private car transport system discussed above.

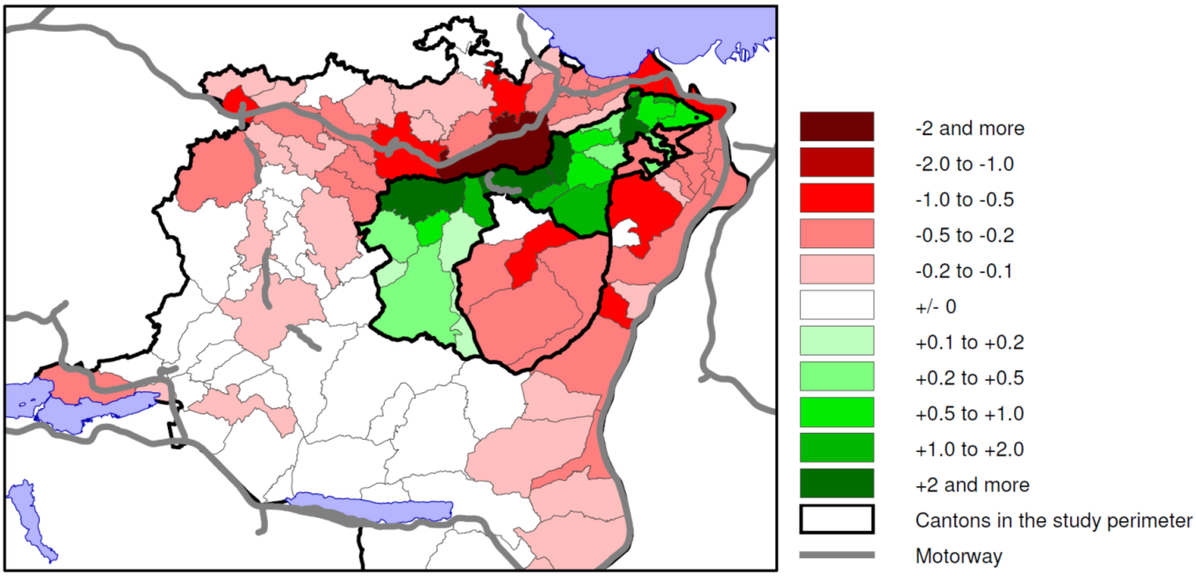
The Swiss Case Study will, in the first phase, focus on modelling and calculating public transport indicators such as accessibility variables. Indeed, this already requires a certain integration of public transport in the simulations.

3.4.9 UC9: Effects of political and governmental decisions

Regarding political and governmental decisions, tax reductions and incentives are well discussed strategies to attract residents and firms. If these instruments are used to develop a whole canton, the effects and also side effects are considerably large.

Figure 12 shows the firm' simulation results of a tax reduction for legal persons in the canton of Appenzell Ausserrhoden (Bodenmann and Axhausen, 2011). Self-evidently, all municipalities of this canton show a gain of immigrating firms. But there are large differences: municipalities with or located nearby municipalities with a larger number of firms benefit with relatively large gains. Not surprisingly, the additional firms in the canton of Appenzell Ausserrhoden have a large impact on the remaining municipalities. First and foremost, the centre of the region, St. Gallen, would have to deal with a considerable loss of migrating firms. But also smaller towns would have considerably negative effects. In fact, negative effects are detectable in towns also over large distances.

Figure 12 Firm relocation effects due to tax reductions for legal persons



Reduction in the canton Appenzell ARh:
-1 standard deviation (CHFk 25) on taxable profit CHFk 1'000
Source: Bodenmann and Axhausen (2011)

Indeed, there are other spatially relevant political and governmental decisions. Apart providing new transport infrastructure (discussed above), possible options for actions are incentives for the establishment of firms, providing good leisure and school infrastructure etc. In this respect, FaLC will focus on the following questions:

- What are demographic and firmographic effects of spatially relevant political and governmental decisions?

- What are the side effects for municipal and cantonal budgets and the use of public infrastructure?
- What are spatially side-effects on adjacent municipalities and cantons?

The Swiss Case Study will basically focus on the effects and side-effects of tax reductions – especially for firms. Analogous to simulation of income, the simulation of tax reductions for residents will be postponed to a latter phase.

3.4.10 UC10: Effects of economic changes

The effects of economic changes such as e.g. the (global) economic situation or money market will be implemented in a second phase. The according Use Case will be defined later.

4 Implementation of Swiss Case Study

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 2. In the following the creation of synthetic population, the modeling of demographic events, households, firms, locations, economies and politics are described.

Table 2 Datasets used

Dataset	**Source**	**Costs**	**Purpose**
Swiss Federal Population Census 2000	FSO	Included in proAbo (CHF 800.-)	Synthetic persons and households
Swiss Federal Business Census 1999	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	Openstreetmap.org	--	Distances
..			

4.1 Creating synthetic data

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. In a first step, roughly calculated synthetic data are used (discussed in the following). This approach will may be used in a template for other case study areas. Later, these data will be replaced by more appropriate synthetic data calculated at IVT Zurich (Müller and Axhausen, 2012a).

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[7] (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[8] (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.

[7] Betriebszählung

[8] Volkszählung

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 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.

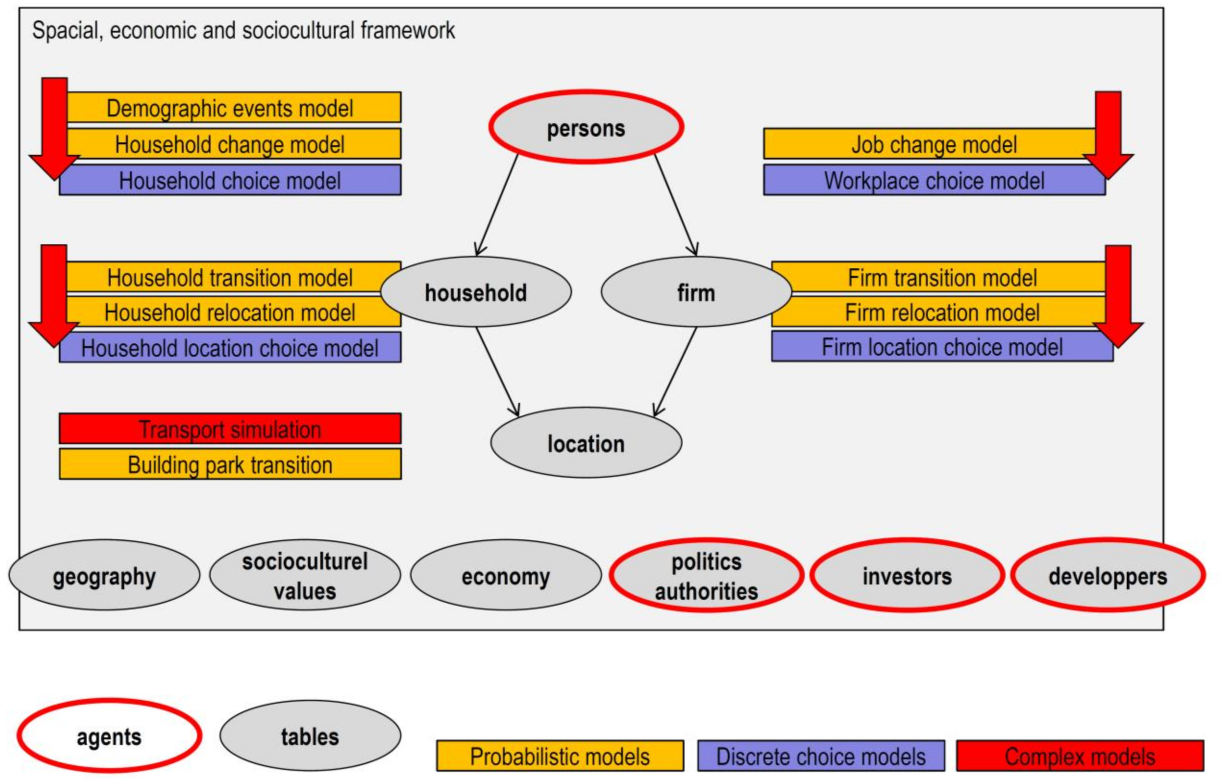
Creating a synthetic household dataset

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.

4.2 Implemented Models

Figure 13 shows an overview of the different models and model types for the Swiss Case Study. In general, three different model types are involved: *probabilistic models* used with the Monte Carlo simulation approach, *discrete choice models* with, subsequently, also a Monte Carlo simulation and more *complex model systems* like transport simulation.

Figure 13 Base models (2012)



Each time step (usually one year), will pass through 5 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 dying or bearing children), the *transport simulation model* (provides distances and accessibilities) and the *building park transition model* (providing room for residents or workplaces). The according results may influence the models of the second step: *household* and *job change models* as well as *household* and *firm transition models*. In step three, the households and firms will be (re-)assembled using the *household* and *workplace choice model*. 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 in step five a new location.

5 Project organisation

The FaLC project – like most of open-source projects – is the answer to different problems and needs of the partners involved. The aim of the pursued collaboration between involved partners of the FaLC project is to possess an integrated land-use and transport simulation tool for a wide range of questions. To keep risks limited, manageable and transparent, the core of the FaLC software shall, as a matter of principle, be joint IP of all partners involved in the project. Indeed, to simplify collaboration and, at the same time, to have a clear legal statement, the core of FaLC will be under GPL-licence.[9]

Basically, the FaLC project is organised in three levels:

- FaLC Consortium and Scientific Board
- FaLC Development Team
- FaLC User Group

After all, FaLC is an open source project, interested persons and institutions are invited to join us on meetings, conferences and other activities of the FaLC community.

[9] This is the state of the discussions between the involved partners. Licencing may change – but FaLC definitely will be published under open source licence.

6 Literature

Amt für Raumentwicklung und Geoinformation AREG (2010) *Kantonaler Richtplan 2010*, Baudepartement Kanton St. Gallen, St. Gallen.

Bierlaire, M. (2003) *BIOGEME: A free package for the estimation of discrete choice models*, paper presented at the 3rd Swiss Transportation Research Conference, Ascona, Switzerland, March 2003.

Bierlaire, M. (2010) *Estimation of discrete choice models with BIOGEME 1.9*, www.biogeme.epfl.ch, July 2010.

Bierlaire, M., D. Bolduc und D. McFadden (2008) The estimation of generalized extreme value models from choice-based samples, *Transportation Research Part B, Methodological,* **42** (4) 381-394.

Bodenmann, B.R. (2003) Zusammenhänge zwischen Raumnutzung und Erreichbarkeit, am Beispiel der Region St. Gallen zwischen 1950 und 2000, *Nachdiplomarbeit,* **37**, Institut für Verkehrsplanung und Transportsysteme (IVT), ETH Zürich, Zürich.

Bodenmann, B.R. und K.W. Axhausen (2008) Schweizer Unternehmen - quo vaditis? Firmendemographische Trends am Beispiel des Wirtschaftsraums St. Gallen, *Raumforschung und Raumordnung,* **66** (4) 318-332.

Bodenmann, B.R. und K.W. Axhausen (2010) Synthesis report on the state of the art on firmographics, *SustainCity Working Paper,* **2.3**, IVT, ETH Zürich.

Bodenmann, B.R. und K.W. Axhausen (2011) Destination choice of relocating firms - A discrete choice model for the region of St. Gallen, Switzerland, *Papers in Regional Science,* **00** (0) 0-0.

Bodenmann, B.R., G. Horvath und T. Mauchle (2009) *Standortbestimmung Gemeinde Eglisau*, Gemeinde Eglisau, www.eglisau.ch/portal/entwicklung, Aug. 2012.

Bodenmann, B.R., T. Mauchle und A. Zeiler (2012) *Grundlagen Siedlungspolitik Appenzell I.Rh.*, Schlussbericht, Bau- und Umweltdepartement, Kanton Appenzell Innerrhoden, Appenzell.

Credit Suisse (2003) Kantonale Wirtschaftsförderung: ein erster Vergleich, *Spotlight,* **2003**, Credit Suisse Economic Research, Zürich.

Creedy, J. und N. Gemmell (2006) *Modelling tax revenue growth*, Edward Elgar, Cheltenham.

de Bok, M. (2007) *Infrastructure and firm dynamics*, Dissertation T2007/5, The Netherlands TRAIL Research School, Delft.

de Bok, M. (2009) Estimation and validation of a microscopic model for spatial economic effects of transport infrastructure, *Transportation Research Part A, Policy and Practice,* **43** (1) 44-59.

de Palma, A., K.W. Axhausen, E. Morand I. Thomas, J.F. Thisse, D. Peeters, S. Proost, S. Gayda, C. Antoniou, K. Nagel, M. Bierlaire, F. Billari, R. Baggio, N. Picard and P. Waddell (2010) *SustainCity Project*, 7th Framework Programme, European Commission, FP7-244557, www.sustaincity.eu, January 2011.

Devereux, M.P., R. Griffith und H. Simpson (2007) Firm location decisions, regional grants and agglomeration externalities, *Journal of Public Economics,* **91** (3-4) 413-435.

Egger, H.R. und J.E. Falkinger (2006) The role of public infrastructure and subsidies for firm location and international outsourcing, *European Economic Review,* **50** (8) 1993-2015.

Finanzdepartement Kanton St.Gallen FD SG (2007) *Jahresrechnung 2006*, Finanzdepartement Kanton St.Gallen FD SG, St. Gallen.

Fröhlich, P. (2008) *Änderungen der Intensitäten im Arbeitspendlerverkehr von 1970 bis 2000*, Dissertation, ETH Zürich, Zürich.

Gatzweiler, H.P., E. Irmen und H. Janich (1991) Regionale Infrastrukturausstattung, *Forschungen zur Raumentwicklung,* **20**, Bundesforschungsanstalt für Landeskunde und Raumordnung (BFLR), Bonn.

Gilgen, K. und B. Aliesch (2004) *Infrastrukturkosten in der Kommunalplanung*, KTI-Projekt-Nr.: 5823.2, Schlussbericht, Institut für Raumentwicklung, angewandte Forschung und Planungsbegleitung (IRAP), HSR, Rapperswil.

Hilber, C. (1999) Standortattraktivität, Liegenschaftspreise und Mieten, *WWZ-Forschungsbericht,* **1999** (4) , Wirtschaftswissenschaftliches Zentrum WWZ, Universität Basel, Basel.

Hoffmann, S. (2006) Biodiversität: Ein wissenschaftliches Konstrukt auf politischem Prüfstand, *FEMM Working Paper Series,* **06029**, Faculty of Economics and Management Magdeburg, Magdeburg.

Horni, A., D. Charypar und K.W. Axhausen (2011) Variability in Transport Microsimulations Investigated With the Multi-Agent Transport Simulation MATSim, *Arbeitsberichte Verkehrs- und Raumplanung,* **692**, Institut für Verkehrsplanung und Transportsysteme (IVT), ETH Zürich, Zürich.

Kanton Solothurn (2004) *Erfolg für Wirtschaftsförderung - Puma nach Oensingen*, Medienmitteilung, Staatskanzlei Kanton Solothurn, Solothurn, www.so.ch, December 2010.

Kleinewefers, H. (2004) Zur Erfolgskontrolle der kantonalen Wirtschaftsförderung - Ein konkreter Vorschlag, *DISP,* **157**, 18-22.

Lufin, M. und D. Nakamura (2010) Spatial social-networking externality and firm location: a simulation model of Chile, *Documentos de Trabajo en Ciencia Regional,* **4**, Universidad Catolica del Norte, Antofagasta, Chile.

Marfurt, I. und M. Domeisen (2010) *Region Winterthur - vielfältig und zentrumsnah: Standortbericht 2010,* Standortförderung Region Winterthur, Winterthur.

MATSim development team (Hrsg.) (2007) *MATSim: Aims, approach and implementation*, IVT, ETH, Zürich.

McFadden, D. (1978) Modelling the choice of residential location, in A. Karlquist, L. Lundqvist, F. Snickars and J. Weibull (eds.), *Spatial Interaction Theory and Residential Location*, 75-96, North-Holland, Amsterdam.

Miller, E.J., D.S. Kriger und J.D. Hunt (1999) Integrated Urban Models for Simulation of Transit and Land Use Policies: Guidelines for Implementation and Use, *TCRP Report*

48, Transportation Research Board, National Research Council, National Academy Press, Washington D.C..

Moeckel, R. (2006) *Business Location Decisions and Urban Sprawl: A Microsimulation of Business Relocation and Firmography*, Dissertation, Universität Dortmund, Dortmund.

Müller, K. und K.W. Axhausen (2012) *Preparing the Swiss Public-Use Sample for generating a*

synthetic population of Switzerland, paper presented at the 12th Swiss Transport Research

Conference, Ascona, May 2012.

Nicolai, T.W. und K. Nagel (2010) Coupling MATSim and UrbanSim: Software design issues, *SustainCity Working Paper*, **6.1**, TU Berlin, Berlin.

Ortuzàr, J.D. und L.G. Willumsen (2011) *Modelling Transport*, 5th edition, John Wiley & Sons Ltd., Chichester.

Planungsamt Kanton Appenzell Ausserrhoden PA AR (2001) *Kantonaler Richtplan*, Departement Bau und Umwelt, Kanton Appenzell Ausserrhoden, Herisau.

PTV Planung Transport Verkehr (2011) *Benutzerhandbuch VISUM, Analyse und Planung von Verkehrsnetzen*, PTV, Karlsruhe.

Schuler, M., P. Dessemontet und D. Joye (2005) *Die Raumgliederungen der Schweiz*, Bundesamt für Statistik (Hrsg.), Statistik der Schweiz: 0 Statistische Grundlagen und Übersichten, **2005**, Bundesamt für Statistik (BFS), Neuenburg.

Siebert, H. (Hrsg.) (1996) *Steuerpolitik und Standortqualität: Expertisen zum Standort Deutschland*, Institut für Weltwirtschaft an der Universität Kiel, Mohr, Tübingen.

Siebert, H. (2000) The paradigm of locational competition, *Kieler Diskussionsbeiträge*, **367**, Institut für Weltwirtschaft, Kiel.

Swiss Federal Statistical Office FSO (2009) *STATINF - Statistical information system*, Swiss Federal Statistical Office (FSO), www.statweb.admin.ch, Dezember 2009.

Swiss Federal Tax Administration FTA (2007) *Steuerinformationen*, Schweizerische Steuerkonferenz SSK, Bern, http://www.estv.admin.ch, April 2007.

Swiss Federal Tax Administration FTA (2009) Direkte Bundessteuer - Juristische Personen - Schweiz: Steuerperiode 2006, *Statistik direkte Bundessteuer*, **2006**, Eidgenössische Steuerverwaltung ESTV, Bern.

Train, K.E. (2003) *Discrete choice methods with simulation*, University Press, Cambridge.

Tschopp, M. (2007) *Verkehrsinfrastruktur und räunliche Entwicklung in der Schweiz 1950-2000*, Dissertation, Universität Zürich, Zürich.

Vrtic, M. und P. Fröhlich (2010) *Nationales Personenverkehrsmodell des UVEK*, Bundesamt für Raumentwicklung ARE, Bern.

Wegener, M. (2004) Overview of land-use transport models, in D.A. Hensher und K.J. Button (Hrsg.), *Transport Geography and Spatial Systems*, 127-146, Elsevier, Oxford, UK.

Weis, C. (2012) *Activity oriented modelling of short- and long-term dynamics of travel behaviour*, Dissertation, IVT, ETH Zürich, Zürich.