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## **Integrated Transport and Land Use Simulation for Zurich**

**Michaela Bürgle, ETHZ**

**Michael Löchl, ETHZ**

**Urs Waldner, ETHZ**

**Conference paper STRC 2005**



# STRC

Transport and Land Use Simulation for Zurich

## 5<sup>th</sup> Swiss Transport Research Conference

Monte Verità / Ascona, March 9-11, 2005

Phone: 0041 – 1 – 633 45 43  
Fax: 0041 – 1 – 633 11 02  
email: buergle@nsl.ethz.ch  
March 2005

Phone: 0041 – 1 – 633 62 58  
Fax: 0041 – 1 – 633 10 57  
email: loechl@ivt.baug.ethz.ch

Phone: 0041 – 1 – 633 30 04  
Fax: 0041 – 1 – 633 11 02  
email: waldner@nsl.ethz.ch

### Abstract

With the collaboration of two ETH Institutes within the Network City and Landscape (NSL), a transport and land use simulation model is currently set up for the Greater Zurich area with a focus on a suburban area north of Zurich, where the airport is located. The idea is to combine the microscopic land use simulation model UrbanSim and a common mesoscopic transport simulation which is based on homogeneous groups and flows. To get the simulation system up and running, a number of data collection and preparation tasks have to be accomplished. UrbanSim, developed in the US, is adjusted to Swiss circumstances through regional input data and manipulations in the source code.

The paper outlines the research methodology and the used simulation software as well as data collection efforts and gives an outlook on further goals within the project.

### Keywords

Integrated land use-transport model – UrbanSim – land use – accessibility – household generation – land use types

## 2. Introduction

The interactions between transport systems, changing accessibility and land use are vital for the dynamic changes of land use and consequently for spatial planning. Throughout the world new land use simulations are being developed like ILUMASS (Moeckel et al. 2002), ILUTE (Miller 2005), and MUSSA (Martínez and Donoso 2001) to quantitatively reproduce and forecast the processes involved, but there is no recent effort for an application in Switzerland.

The project "Infrastructure, Accessibility and Spatial Development" constitutes one facet of the research focus "The Future of Urbanised Landscapes" of the ETH Zurich's network City and Landscape, NSL (NSL 2005). The goal of the project is to develop and apply a dynamic land use and transport model for Swiss agglomerations. Test bed for the project will be the Greater Zurich Area. The resulting simulation is expected to allow for quantitative forecasting of land use and transport development and impact analysis thus creating a solid foundation for long term investment decision-making.

This paper starts with a description of project goals, study area and methodology of the study area as well as topics to be covered by the research project. The second section gives an outline of the simulation software used for the project, UrbanSim, and its model structure. Subsequently, section 4 provides some insight into data collection and processing efforts. We present examples of the kind of work that has to be accomplished in order to meet data requirements of the simulation system. These examples describe a survey of housing prices, the methodology to generate accessibility values, possible approaches to the generation of synthetic households and, finally, an attempt to standardise the manifold Swiss land use types for simulation purposes. The paper closes with a short summary and an outlook on next steps and planned extensions of the simulation.

### 3. Simulation area and input requirements

There is no common and appropriate delimitation of the Greater Zurich area available. Consequently, the simulation area of Greater Zurich had to be defined. Commuter data were aggregated into groupings of municipalities called “agglomerations”. Agglomerations with an outward-commuting percentage towards the city of Zurich of at least 20% of all outward commuters were considered as the simulation area. These are the agglomerations Zurich, Winterthur and Wetzikon. To smooth the delineation of the simulation area, municipalities not belonging to but being (almost) enclosed by those agglomerations have been added. The defined simulation area is illustrated in Figure 1.

Within the simulation area, a focus is placed on the Glattal, which is a suburban area experiencing a very dynamic development not only because of the included airport of Zurich. As such, the area is the ideal setting for an integrated land use-transport simulation. It comprises the eight *glow*-communities Bassersdorf, Dietlikon, Dübendorf, Kloten, Opfikon-Glattbrugg, Rümlang, Wallisellen and Wangen-Brüttsellen as well as Zurich’s two northern city districts, 11 and 12. This area is specified as “study area” in Figure 1 below.

Figure 1 Simulation area (light grey) and study area (dark grey)



Within the Glattal area, case studies of transport infrastructure investments will be chosen in order to show analysis capabilities of the simulation. The intended choice of case studies will cover public and private transport each with one or two projects that are expected to have major impact on accessibility once realised. The projects selected should be in early or advanced planning stage, in order to possibly provide policy consulting opportunities.

The simulation represents processes of land use as well as information concerning transport systems at different points in time. It will integrate those different pieces of information to account for their interactions when making forecasts. A common mesoscopic transport model based on traffic zones will be combined with a microscopic land use model contemplating single households and jobs in a grid of hectares. This combination will allow for meaningful results on a high level of detail while having reasonable set-up and running cost.

As land use simulation software, UrbanSim, a model developed at the University of Washington, USA (Waddell 2002), will be used instead of developing our own model. Still, some efforts will have to be put into the software in order to adapt it to Swiss conditions. For validation purposes there will be simulation runs emulating the research area's development during the years 1990 to 2000. After the successful completion of the validation phase, forecasts will be made for roughly 15 years into the future.

The commitment to UrbanSim also determines data requirements to a certain extent. The model system has to be provided with a predefined series of data sets from exogenous data sources. Examples for such input information are population totals and forecasts for the simulation area as well as job totals per branch or economic sector. Transport infrastructure and spatial information concerning development types are also considered as exogenous input data.

*Endogenous* modelling procedures comprise the spatial distribution of households and jobs, the construction and demolition of buildings, the evolution of land prices and characteristics of transport supply, e.g. travel times between transport zones. The latter information is provided by an external transport model.

## 4. Simulation software UrbanSim

UrbanSim has been applied in several North American cities and regions. It leaves the user a fair amount of choices with regard to the modelled dimensions in space and time. In practice, the eligible unit is that for which sufficient data is available from regional and national sources. For the research project described here, the spatial unit hectare (100 x 100 metres) was chosen along with one model run per simulated year. On those scales the availability of statistical data is more or less satisfactory, particularly for recent years.

Several facts argued for the application of UrbanSim:

- UrbanSim has been applied in practice to a range of northern American cities and regions (e.g. Eugene-Springfield, Salt Lake City, Puget Sound Region, Honolulu) and can therefore be regarded as a stable and approved software
- UrbanSim is constantly being developed and improved at the University of Washington
- Extensive documentation is being provided online by the developers
- UrbanSim is Open Source Software under the GNU General Public License enabling the user to adapt it to his or her own needs without depending on anybody else.

UrbanSim is a system comprised of several autonomous subsystems, so-called „models“. Therefore, UrbanSim might be better described as an urban simulation system, consisting of a software architecture for implementing models and a family of models implemented and interacting with this environment. These models all share a common database by means of which they can exchange information. For calculating accessibility information, an external travel model is linked in order to provide transport supply information (see Paragraph 4).

The database comprises geographical information, type definitions, characteristics concerning households and jobs etc. Each of the subsystems accessing the database represents an actor or a process, e.g. location choice, land price development or development activities. The models therefore calculate events like construction of buildings or relocation of households. For each subsystem an estimation model with associated parameters is given that controls modifications of the base data set in each simulation cycle.

The common database is given externally to start with. It is consequently modified in the course of the simulation process by the different models. The final state of the database after processing the last year cycle as well as the states at the end of each simulated year comprises the simulation results.

UrbanSim allows for the definition of different development scenarios, e.g. regarding population totals, changed development types or changes in regional accessibility. These scenarios make up the mechanism that will bring the case studies into the simulation.



## 5. Data collection and adjustment efforts

The collation of a database for a simulation run can be quite laborious. Not all the data needed is necessarily available in Switzerland or elsewhere. Some pieces of information are available only for parts of the simulation area, other data exist but cannot be obtained, all of which leaves the researcher no choice but to invest in data collection efforts and to make some imputations. Examples for such cases are the percentage of people with home-based jobs or housing prices. Additionally, substantial data processing has to be accomplished in order to obtain the data in the format required by UrbanSim from the raw data available. Examples of such preparatory work steps are exemplified in the next sections.

### 5.1 Survey on housing prices

Rent and land prices have a strong impact on location choice of households as well as businesses. Though land price data is available from administrative offices the level of disaggregation is not suitable for modelling prices at a grid level of hectares. As private institutions like banks or consultancies are rather reluctant to release such data, the missing information on housing markets is collected by means of a new survey. Moreover, the survey serves to fill some other data gaps like the tendency of households to change location or the rate of home-based jobs.

The survey has been posted to 9300 households in 21 municipalities plus additional four districts of Zurich starting in mid-February. The municipalities and Zurich districts belonging to the Glattal area made part of the sample by definition. Moreover, the universe for drawing the sample consisted of those municipalities in which at least 5% of the out-commuter commute to Zurich. Another constraint was to proportionally represent the spatial types defined by ARE (Swiss Federal Office for Spatial Development) in the sample.

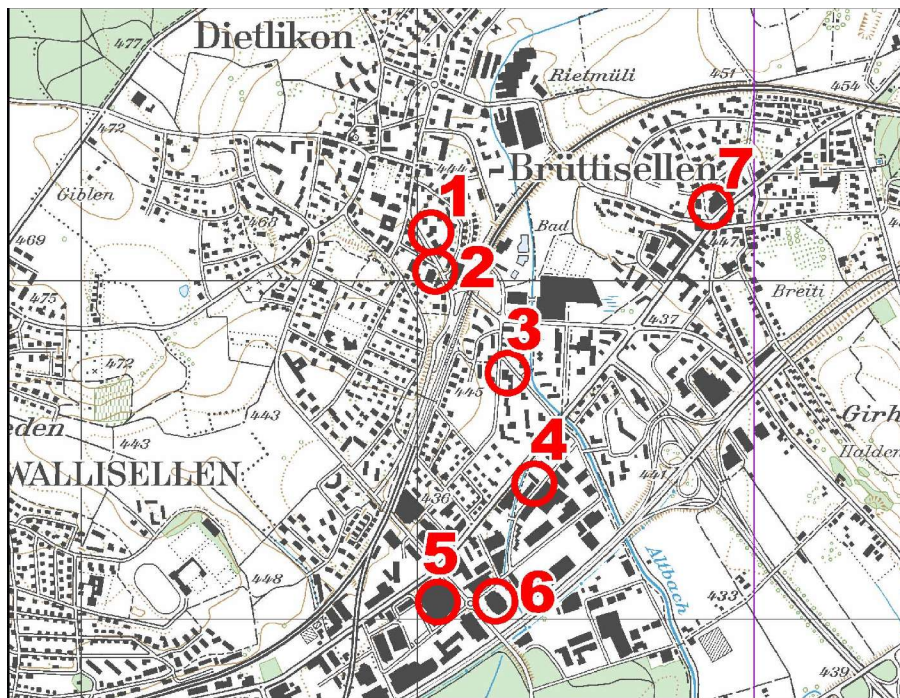
In addition to the 10 municipalities and city district of the Glattal, two more districts of Zurich and 13 municipalities of the cantons of Zurich, Aargau and Schwyz were randomly drawn taking into account the aforementioned constraints.

In 2004, a pretest comprising 300 households was conducted in one city district of Zurich not contained in the main survey sample. As a result of the pretest, some rearrangements, reductions and reformulations took place. It is now expected that the pretest's return rate of 22 percent will be exceeded noticeably, especially as additionally a cover letter signed by the communities' respective representatives could be obtained for about half of the surveyed municipalities.

The mailing is staggered over a period of two weeks. After two weeks those households which will not have answered yet will be sent a reminder, after another two weeks a post card containing a few selectivity questions will follow. This post card will serve to grasp possible response bias among the household which have answered compared to all households.

As regards the content of the survey, most of the questions aim at the interviewees' dwellings' situation and properties as well as the price of housing. Besides characteristics of the house itself, attributes of the building's surroundings matter as well. This comprises e.g. the availability of recreation spaces and shopping facilities in the neighbourhood. To collect data on those two topics, maps were created for each surveyed community. Those coloured maps display a choice of areas or facilities. The survey allows for indicating the frequencies of visits to the given locations. Figure 2 gives an impression of the type of map used for the survey.

Figure 2 Map displaying shopping facilities in Dietlikon as used in the survey



To complement the information about dwellings and their surroundings, some questions deal with socio-economic characteristics like household size, place of work or education of all household's members and mobility tool ownership. This information is needed on the one hand to enhance the explanatory power of the objects' information, but can also serve as a base for response analyses.

As soon as the survey data is available (around May 2005), the results can be used to model land prices by hedonic regression for the entire simulation area. To enrich the data obtained by the survey, geographical coding of the addresses and the use of GIS (Geographic Information Systems) make it possible to add information like accessibility, topography or sunshine duration which can be considered in the hedonic models as well.

The sampled households' data thus facilitate the area-wide modelling of average land prices against factors like location or configuration on a grid of hectares and to draw conclusions on households' location choice behaviour.

## **5.2 Calculating accessibilities**

Accessibility constitutes an important foundation for UrbanSim's modelling of location choice for households and businesses. For specifying regional accessibility, transport supply characteristics from a transport model at traffic zone level and the spatial distribution of households and jobs at hectar raster level are being combined. Within UrbanSim, the translation from traffic zone to grid cells is performed. A travel demand model must be at hand to be able to utilise UrbanSim.

Using the transport supply characteristics of the Canton of Zurich's transport models, like travel time matrices for individual and public transport, it is possible to generate a traffic zone matrix containing logsums which reflect the multimodal travel utility. This matrix is used as input data for UrbanSim's accessibility model, which associates it to the households and jobs located in grid cells. Therefore, the regional accessibility can be calculated simply by multiplying the sum of destinations (households/persons and jobs) by the respective logsum. After having passed through one simulation cycle, the data relating to destinations is updated. The results can be used in the transport model again to update the travel supply characteristics.

UrbanSim also incorporates local accessibility measures as a factor for location choice. They are corresponding to the activities that can be reached within a fixed perimeter (e.g. 600 metres) represented by proximity of retail employment. This information can be gained using spatial queries of the adjacent hectar raster cells of each cell.

### 5.3 Approaches to household synthesis

As in Switzerland there is no statistical data available about households on a hectare level, the households required for running the simulation need to be generated synthetically. There are several options for generating households to use for the simulation.

One possible starting point could be the synthetic population created by Frick (Frick 2004) which could be grouped into households. Attributes of the population that might be relevant for the households to be generated are hectare location, age, sex, income and availability of cars. The population table has been calculated using information from statistics like the Swiss Census and Microcensus by applying IPF (Iterative Proportional Fitting) constrained by marginal distributions at municipality level.

Alternatively, an approach analogous to that of the population synthesis could be elected for creating a set of households independent from the synthetic population: starting from low-dimensional tables with household attributes (size of household, age of head of household, number of children), the multidimensional household table could be calculated, again using community-based constraints. A downside to this approach would be the lack of opportunities to link the insights gained by the simulation project to other research projects at ETH Zurich, as the households used here and the population used by other projects could not be connected.

Such considerations favour the scheme of grouping the available synthetic population into households. A possible procedure to accomplish this is suggested by Moeckel et.al. (Moeckel et al. 2003): A logical order is determined for assigning attributes to generated households. This raises the question, which household attributes form causalities. The age of the head of a household can e.g. be used to determine the size of the household. The background information needed for accomplishing this can be found in available statistics. With household size available, it could then be determined in the same manner how many children make part of the household, how many workers are in the household and, consequently, attributes like household income or number of cars available could be determined.

### 5.4 Formation of land use types

Land use regulation in Switzerland is considerably different from the corresponding US regulation which is the perspective in terms of data requirements in UrbanSim. Those difference can be summarized as followed:

- Zones of mixed use: A balanced mix of different land uses with several mixed types is desired. Fine grained constraints are applied to consider amongst other things the level of noise accompanying firms of different business sectors.

- Federalism: There are three different measurements of use for restricting development density. Each municipality can determine which measurement to use and how to make use of it for their land use regulations.

Those characteristics cause some adjusting work steps to be performed when assigning to each grid cell a *plan type* describing admissible land use and a *development type* considering the current inventory of buildings in the cell. Both assignments are required for UrbanSim's Developer Model.

The procedure for assigning these types in the Swiss context is as follows:

First of all, the three aforementioned measurements of land use have to be standardised. The *Ausnutzungsziffer AZ* (ratio of usable floor space to parcel area) is used as a consistent measure. The *Baumassziffer BZ* (ratio of built volume above ground to parcel area) and the *Überbauungsziffer UZ* (footprint) are converted to *AZ* using two auxiliary measures, *GH* (average height of building) and *HF2* (height of building plus height of ridge/2).

$$AZ = \frac{BZ * 100}{GH} \qquad AZ = UZ \frac{HF 2}{GH}$$

For estimating the auxiliary measurements *GH* and *HF2*, key figures for the Canton of Zurich are utilised (Wachter 2005). Those figures account for the building laws of the cities Zurich and Winterthur and discern three types of height between floors depending on zonal classifications.

- 1: residential zone, commercial zone, mixed residential and commercial zone, zone of quarter conservation, historical core zone
- 2: central zone
- 3: industrial zone

The deepness of land use data in terms of categories was extended gradually from 1991 to 1999, resulting in some figures of land use being available only towards the end of that period. For the early nineties, those figures have to be imputed using the zonal designations. For scarce zonal types like e.g. Residential Zone „W7“, measures of comparable zones can be used. Classifying zones according to their density allows for comparisons.

## 6. Summary and Outlook

Applying an integrated land use - transport model to the Greater Zurich area opens up opportunities to assess consequences of major transport infrastructure projects and land use policies. The same benefits are expected for other Swiss agglomerations. So far, there is no turnkey solution available to accomplish this task. Data requirements are considerable and shouldn't be underestimated. Although the simulation software is ready to use, it requires input data which is not readily available in Switzerland.

The project's completion is scheduled for winter 2006/2007. Until then, UrbanSim will be applied to Greater Zurich to assess the impact of several transport infrastructure projects.

A further goal of the project is to tighten the connection of transport and land use in the simulation system. One approach is the introduction of traffic noise impacts on land prices and location choice. Therefore, a higher level of spatial detail is required, either by using smaller grid cells or by transforming the georeferenced buildings from regular grids in existing and extrapolated building footprint polygons (from hectare to parcel). Moreover, a better representation of transport beyond accessibility is needed. It is planned to set up a full transport model, introducing transport flows and volumes to the simulation system. Consequently, the aim is not only to take into account characteristics of supply but also of traffic flow and speed when modelling location choice.

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