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SustainCity
Micro-simulation for the prospective of sustainable cities in Europe

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Contents

1 Executive Summary

The objectives of the SustainCity research are to advance the state of the art of urban simulation models, to develop an European-adapted version of the urban micro-simulation tool UrbanSim, to implement it in three European case studies (Paris, Zürich, Brussels), and eventually to improve the diffusion of the urban simulation models among planners and decision makers.

The modelling platform adapted for the context of European cities will be based on the existing software UrbanSim, which was originally developed for cities in the United States. (In the project reports, the adapted platform is referred to as “UrbanSim-E”.)

UrbanSim-E, developed within SustainCity, provides the means to evaluate the impacts of policy measures in European cities. With the sustainable development objective in mind, UrbanSim-E will provide a quantitative assessment of the trade-off between economic, environmental or social objectives.

The goal of this project was to address the modelling and computational issues of integrating modern mobility simulations with the latest micro-simulation land use models. The project intended to advance the state-of-the-art in the field of the microsimulation of prospective integrated models of Land-Use and Transport (LUTI). On the modelling side, the main challenges were to integrate a demographic evolution module, to add an environmental module, to improve the overall consistency and, last but not least, to deal with the multi-scale aspects of the problem: several time horizons and spatial resolutions were involved.

The SustainCity project includes also three case studies to take advantage of the achievements of the other tasks in order to undertake an empirical analysis on three European agglomerations (Ile-de-France, Brussels and Zurich). The simulation results of the three Use Cases show that UrbanSimE provides the means to evaluate the impacts of policy measures in European cities. With the sustainable development objective in mind, UrbanSimE provides a quantitative assessment of the trade-off between economic, environmental or social objectives in the development of cities.

2 Summary description of project context and objectives

SustainCity – Micro-simulation for sustainable cities in Europe – is part of the 7th Framework Programme for Research of the European Commission (January 2011 to July 2013).

Increasing concerns about sustainable development and the growth of urban areas have brought forth in recent years a renewed enthusiasm and need for the use of quantitative models in the field of transportation and spatial planning. This project proposes to improve urban simulation models and their interaction with transport models. Unified operational models that favour a microscopic approach, such as UrbanSim and ILUTE (Integrated Land Use, Transportation, and Environment Modelling System) have recently gained a lot of interest both in the land use and transport communities. Nevertheless, in their current forms these models still require further development to support a comprehensive analysis of the main environmental and socio-economic questions of the sustainability of urban growth and the relevant public policies.

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The project has been divided in different Work Packages (WP). WP2 already has been concluded in summer 2010 by publishing different working Papers focusing on the State of the Art of demographic issues, agent behaviour, firmographics, econometric models, and other subjects regarding land use modelling. Based on this work, WP3 to WP6 focused on the development of a software tool modelling demographic events (WP4), econometric and other empirical issues (WP5), and the coupling of UrbanSim (urban simulation model) with MATSim (travel model) (WP6). These work packages led to the implementation of the three Case Studies. According scenarios were designed to reach further policy insights towards sustainable cities. An important Work Package addresses Dissemination and Valorisation (WP9), this involved the organisation of different workshops in Athens, Berlin and Zurich. Aim of these workshops was to introduce a wide range of researchers in the application of UrbanSim, MATSim and METROPOLIS – particularly also researchers not involved in the SustainCity project. Additionally, the consortium organised also an academic conference as well as a final policy oriented conference on land use and transport to increase attendance.

One of the main outputs of this project is the development of a modelling platform adapted for the context of European cities. This platform is based on the existing software UrbanSim, which was originally developed for cities in the United States. Besides identifying new modelling approaches that could be used to improve the existing modelling platform, this review also aims at identifying geographical, social and economic characteristics of European cities that are taken into account in the platform (called UrbanSim-E)

Apart of the software development, large work was contributed to set-up and to implement the three Case Studies. The work scheme for each case study was divided into the following tasks:

- Data collection and analysis
- Model calibration
- Scenario simulations

The first period, which covered a period of 18 months, was mainly dedicated to the data collection, the estimation of the models and general calibration. The second period, which covered a period of 24 months, was dedicated to the refinement of the estimation, the model calibration and the scenario simulations. An additional task dedicated to spatial issues was treated in parallel as it was not exactly on the critical path to the scenario simulations.

At the end of the project, each case study had developed a comprehensive UrbanSimE model. It is worthwhile reminding that, in this project, the three case studies were starting at different stages of calibration; consequently, they also reach different calibration/validation levels. The Paris team started from an existing detailed model and has therefore developed a more operational model than Brussels and Zurich teams, which started from more basic models (a very prototypical model for what concerns Brussels and a basic model implemented on a grid-cell version of UrbanSim for what concerns Zürich). However, the three case studies were able to simulate different policy scenarios, which was the main technical goal of the project.

The models developed for Brussels and Zürich are nevertheless not as operational and as user-friendly as what was initially planned. This can among others be explained by the underestimation of the technical difficulties (e.g. in the case of Brussels and Zürich setting the interface between land-use and transport models required much more time than planned), long runtimes that are a limiting factor for extensive testing, and the fact that UrbanSim is a microsimulation software implying very large databases (in microsimulation models, each individual of the population is explicitly modelled, which leads to databases with millions of data). But nevertheless, all three case studies were able to show further insights in urban processes by means of the different implemented scenarios.

These results show that UrbanSimE provides the means to evaluate the impacts of policy measures in European cities. With the sustainable development objective in mind, UrbanSimE provides a quantitative assessment of the trade-off between economic, environmental or social objectives in the development of cities.

3 Main S&T results/foregrounds

The project SustainCity addresses the modelling and computational issues of integrating dynamic mobility tools with the latest microsimulation land use models. It proposes to advance the theory and the practice in the field of the microsimulation of prospective Land-Use and Transport Interaction models (LUTI). The 12 partners of the project extended the OPUS/UrbanSim platform (Open Platform for Urban Simulation) to take into account relevant specificities of the European context. Several key developments were achieved:

- An extensive (and critical) review of the state of the art of the literature on integrated transport and land use models was made.
- Seven theoretical models relaxing restrictive assumptions in the current version of UrbanSim were developed. These improvements aim at reflecting European specificities.
- A specific micro-simulation demographic model was constructed and integrated. Such tool describes individual and household behaviour in the context of urban development models.
- An econometric guidance was used for the application of the UrbanSim software for the three case study areas: Paris area, Zurich and Brussels.
- Two travel models (MATSim and METROPOLIS) were integrated with UrbanSim. These travel models produce realistic generalized travel costs, including congestion and schedule delay costs, as well as accessibility measures, which play a key role in land-use models.

The extended OPUS/UrbanSim was consistently renamed as UrbanSimE, for UrbanSim Europe and tested for the three case study areas: Paris, Zurich and Brussels.

3.1 State of the art (Work Package 2)

In order to better identify the modelling approaches to be implemented in the project and to prepare for potential issues to be found, a review of the current state of the discipline is needed. Work Package 2 consisted in an extensive (and critical) review of the state of the art and the literature for integrated transport and land use models. The work package was subdivided in seven tasks, each of them dealing with a main subject or theme within the land use modelling and microsimulation literature:

Initial objectives

The original objectives are listed theme-wise and following the Work Package (WP) structure that was used in the project.

Task 2.1: Demographic and micro-simulation models, had two objectives: (1) Understand and describe the state of the art in demographic models, focusing specially in the topics of dynamics of birth and death, household formation and dissolution, effect of macroeconomic variables in demographics and changes in the composition and characteristics of households. (2) Understand and describe the state of the art in microsimulation models, focusing in the topics of activity based travel demand models, multi-agent models and dynamic traffic assignment and equilibrium models.

Task 2.2: Behaviour of agents, with the main objective of undrstanding and describing the state of agent behaviour modelling, focusing on two topics: 1) individuals and household and 2) stake holders in real estate.

Task 2.3: Firmographics aimed two objectives: (1) Understand and describe the state of the art in firmographics (life cycle of firms). (2) Make a synthesis of the various strands of literature which are developed in various disciplines about firmographics (regional science, economic geography, economic theory and econometrics).

Task 2.4: Econometric models aimed to understand and describe the state of the art on econometric models used in UrbanSim and other similar software. Highlight their strengths and flaws, and select a list of econometric models which could be efficiently used in the project.

Task 2.5: Software (UrbanSim and other tools), had the objective of understanding and describing the state of the art on land-use and integrated modelling software.

Task, 2.6: Descriptive and geographical data, aimed to identify the differences between the descriptive and geographical data required (and available) to properly model US and European cities.

Task 2.7: Social and Economic attributes, was going to identify market and other economical characteristics of European cities, as well as characteristics of European households that should be considered when developing the new modelling platform.

Achievements

Following the objective defined for each of the work packages, 9 working papers were written: Working Paper 2.1a, b, 2.2a and b, 2.3, 2.4, 2.5, 2.6 and 2.7. They are publicly available for download at the project's website: www.sustaincity.org

Relation with other work packages

The working papers were used as a guiding tool and starting point for the ensuing tasks of the project. Many of the working papers were later improved and converted into chapters for the SustainCity Handbook.

Summary of most important results

The literature review allowed identifying the modelling methods that were later used in the model implementations for Brussels, Paris and Zurich. The analysis allowed identifying the main shortcomings of the available tools and potential ways to overcome these difficulties, together with relevant modelling aspects to be taken into account. Some of these include:

- The relevance of having a synthetic population and to simulate its evolution over time
- The different ways to model location choice and what attributes should be used to better characterize household behaviour
- The particular characteristics the life cycle of firms and how this affects their (re)location
- The technical difficulties to estimate complex econometric models that include both time and space as relevant dimensions
- The role of social housing and home owner associations as stakeholders in the real estate market.
- The technicalities of land use microsimulation models and their explicit connection with agent-based travel demand micro-simulators.

In general, a set of methods, agents to model and open research questions was identified, therefore generating a guiding set of knowledge that was useful in more advanced stages of the project. This work, however, was further developed on other stages of the project and will see a final state in the book that will be published as part of Work-Package9.

3.2 Theoretical developments (Work-Package 3)

In the theoretical development section, a total of seven theoretical models have been developed, which will relax restrictive assumptions in the current version of UrbanSimE. The major concerns of the developed models were to improve the assumptions behind real estate investments, location and real estate decisions within couples, equilibrium mechanisms, real estate stake holders and firmographics.

Initial objectives

In this Work-Package, we consider the following directions for developing economic models that relax restrictive assumptions in the current versions of UrbanSim: real estate investments, location and real estate decisions within couples, equilibrium, stake holders in real estate and firmographics.

Achievements

Two Working Papers have been written in the context of real estate investments. In Working Paper 3.1 (de Palma and Prigent, 2012), the portfolio choice and the investment on housing of an investor over his life span are analysed when this household is facing exogenous random shocks. As illustrated by Kraft and Munk (2011), house prices and labour incomes are highly correlated and labour income risk can vary with age. The investor has the flexibility to decide how much to invest on financial assets, on housing units owned as well as on perishable goods. The initial problem was formulated on the basis of simple portfolio optimization. Then, it was expanded to take into account independent and exogenous random shocks. Three basic cases were considered: the household totally ignores the random shocks and optimizes investments as if no shock can occur in the future (myopic behaviour); the household is informed about the future consequences of the shock (perfect foresight); the household is rationally adjusting its behaviour taking into account the distribution of shocks which may occur later on (rational expectation). The solution for each case is provided and it is proved that the financial shares are not affected while the consumption ratios are reduced when the household is significantly risk averse (under the hypothesis of relative risk aversion). In this paper, the authors introduced another source of risk corresponding to exogenous random shocks, which are independent from the financial and real estate assets. They can correspond to a sudden loss of employment or other events such as divorce.

Working Paper 3.2 (Lapparent, de Palma and Picard, 2012) proposes a theoretical microeconomic model to analyse residential choices of households in a dynamic context with perfect information. The decision maker is a household. Intra-household negotiation between members was not considered. The paper addresses simultaneously economic choices of residential location, dwelling and tenure and their dynamics (in a two period model) while accounting for interaction with transportation market, with demand for local amenities, and with financial investment constraints. This simple model is then illustrated using real data collected in the large Paris area.

In Working Paper 3.2, the authors considered that, the household lives in two periods. At the beginning of each period, household is endowed with a per-period utility function that depends on the level of amenities, the level of floor space, and the level of consumption of a composite good. It is faced with continuous and discrete decisions: choices of optimal quantity of floor space and consumption level of an outside composite good, and choices of residential location, tenure and dwelling types. These choices are subject to budget and other technical constraints. It is assumed that, interest rate is higher when borrowing for a dwelling than when saving/borrowing on the money market, and that transaction costs apply to real estate. Moving cost is considered whenever changing home location in second period and transportation cost affects the choice of household.

The current version of UrbanSimE does not distinguish between individuals and households. The theoretical model in Working Paper 3.3 (Chiappori, de Palma and Picard, 2012) considered the case of households with husband and wife. The bargaining power of the household members is considered as an important factor for the decision of selecting residential location. The spouse are both active and have different residential location, which explains that each spouse may prefer a specific residential location. In the Working Paper 3.3 it is shown that it could have important consequences in economic analysis (for example, neglecting the bargaining power within couples may change significantly the value of time). A new method has been suggested to calculate values of time in the context of couples. It is shown that age of the women as well as nationality of men play a crucial role in determining bargaining power.

In Working Paper 3.4 (de Palma, Proost and Van der Loo, 2012), the role of the equilibrium mechanism has been studied. The paper investigates the role of anticipations in the housing market and the possible interplay with transport investments. The key agents in this model are the government, and the housing entrepreneurs (besides households, and firms). A simple two region model was used where one region is subject to an unanticipated productivity shock that increases the demand for labour in that region. The demand for labour can be met by additional commuting, by more housing or by additional investment in transport. The result depends on the expectations of the developers, when there is no transport investment. Depending on the specific expectation of the agents (myopic, perfect foresight, imperfect) over- or under investments in transport infrastructure has been observed. The model is a simplistic two region model with only one mode of transport.

Regime switching models has been developed and applied on real estate market in Working Paper 3.5 (Maurin de Palma and Picard, 2012). This technique allows taking into account the existence of different regime which explain housing prices. The regime and the switching probabilities have been determined endogenously. The study was based on data from Paris region. The authors have twin their model with a standard hedonic regressions model. The proposed technique allow for better prediction of the distribution of the future housing prices.

Working Paper 3.6 (Zöllig and Axhausen, 2012) is about the qualitative study of real estate developers in the canton Zurich. The working hypothesis is that heterogeneous developers are present and that their characteristics help to explain development events. The literature review concludes that there is a lack of knowledge in respect of the supply side of land development, that heterogeneity among real estate developers is shown in previous studies and that there is no established typology. This paper tests the hypothesis that developer types do have an influence on the development events that eventually occur. The study was based on a survey where 11 real estate developers are interviewed. The authors found that the behaviour of developers varies in terms of decision criteria, considered information base, search space and fulfilled tasks.

Paris Region is one of the most important metropolises in the world with 11.7 million inhabitants and over 5 million jobs (de Palma, Motamedi, Picard and Waddell, 2005). A clear understanding of the behaviour of establishments over time is crucial in forecasting the development of the region, and related land use and transportation is-sues. The changes in business units affect the spatial distribution of jobs and economic activities in the urban area. Working Paper 3.7 (Buczkowska de Palma Picard and Motamedi, 2012) focuses mainly on modelling firmographic events in Ile-de-France including the differences by activity sectors. To describe the life cycle of the establishments, the authors propose a threefold firmographic model which explains the disappearance, evolution and location choice of the business units. They also compute the creation rates across various activity sectors and all counties of Paris Region to get possibly the most detailed overview of changes of the business units.

Relation with other Work-Packages

The theoretical models are used in the new version of UrbanSim which is UrbanSimE. The new models are tested for each case study teams: Paris, Brussels and Zurich. Therefore, Work-Package 3 is related with Work-Packages 6 and 7.

Limitations and future research

Some of the theoretical models are still needed to be updated or extended. Especially the model in Working Paper 3.2 needs to be extended to a $T > 2$ periods inter-temporal maximization program. Also the assumption in Working Paper 3.2 about perfect information and perfect foresight of market variables has to be called into question. Working Paper 3.3 used census data from 1999 which could be updated in future.

The model in Working Paper 3.4 is a simplistic two region model with only one mode of transport. Interesting extensions include the consideration of the introduction of regional governments that can tax income and commuting flows, decide on the building permits etc. Working Paper 3.6 considers the qualitative parts of the in-depth interviews taken with the developers. Estimation of discrete choice models based on the data are left for future research.

3.3 Demographic model (Work-Package 4)

A demographic module was added to UrbanSim, in order to produce information on households' structure and its evolution. That is consistent with a projection of individual demographic behaviour which leads to household change. Based on a microsimulation of individual behaviour, a yearly dataset of population with individual characteristics, including household membership was produced, and used in UrbanSim-Europe (UrbanSimE).

The usefulness of microsimulation has long been proved (Orcutt, 1961, Burch, 1979), especially to study household composition and family links (Ruggles, 1987, Zaidi and Rake, 2002), but its implementation needs much effort and programming efficiency (Bacon and Pennec, 2007).

Initial objectives

UrbanSim used a micro-simulation database containing households and persons. Households are summed to meet aggregate control totals by sampling and duplicating existing households. This was not adequate, however, for a good modelling of the spatial-temporal dynamics in the housing market and labour market arising from on-going demographic change.

The demographic module explicitly simulates annual dynamics of birth, death, household formation, household dissolution, etc., all the individual demographic events that impact the composition and characteristics of households. The predictions are based on a microsimulation model that can explain births, deaths, marriages and other unions, divorces and other union disruptions, children leaving their parents' home, as well as immigration, and emigration.

This module was planned to allow interactions and retroactions with the other modules: the above-mentioned demographic events may be influenced by labour supply, local or regional economic conditions and improve the modelling of the influence of the regional demographic evolution on the other modules in UrbanSim.

Achievements

A specific demographic model has been derived from an analysis of the state-of-the-art in demographic behaviour microsimulation (Morand, Toulemon, Pennec, Baggio and Billari, 2010), based on an overview of the issues concerning the integration between demographic modelling of individual and household behaviour, and urban development models (Turci, Pennec, Toulemon, Bringé and Morand, 2011).

A specific demographic module has been built, using the MODGEN language developed and maintained by Statistics Canada for creating microsimulation models.

It was developed as an independent module and used to simulate the evolution of the population and households in the Paris region, for which available data were found and used as a basis for estimating the parameters of demographic models.

Many individual demographic events were simulated, based on annual transition probabilities (Turci, Bringé, Pennec, Toulemon, Morand and Baggio, 2012): exits from the population by death or emigration; entries by immigration or birth of a child; exits from the parental home, union formation, marriage, and dissolution; entry into a household (home mates) and exits from complex households; entries in and exits from communal establishments. All these transitions were dependent on sex, age, and specific additional covariates for which parameters estimates were produced; education attainment and labour force participation were also simulated, allowing using enrolment and working status as optional covariates for demographic behaviour; micro simulation methods allowed using specific rules of mate matching.

The model produced as an output a yearly file of individual and households with their characteristics derived from family status of individuals: children, couples, “isolated” adults living alone, in the same household than a family, or in a non-family household. For each individual, sex, age, and all the covariates used in the microsimulation are available, and can be used to build specific variables at the household level. Complex households hosting “isolated adults” living together or with a family, as well as communal establishments, were also produced as outputs from the demographic module. Yearly estimates of population and households could then also be used by the other modules, based on the individual data file.

Relation with other Work-Packages

Within UrbanSimE simulation, yearly results from the demographic module are introduced as inputs for the other modules (household location, job location, etc.). It was envisaged to introduce a retroaction between household location models, labour market, and the demographic model. Technically it would be possible to include location and job variables as covariates in the demographic module, in order to introduce such retroactions in UrbanSimE. The demographic behaviour of individuals and households, as well as in- and out-migration of individuals and families were considered by the other modules as exogenous, and not related to household location, local markets, and regional attractiveness.

Summary of most important results

The most important result was the description of the trends in the distribution of households by size and family structure in a consistent and explicit way, dependent on assumptions on individual demographic behaviour.

In the Paris region, between 1999 and 2049, the number of households increases much faster that the population size (7.3 per 1000 per year vs. 3.3), due to a decline in household size. Furthermore, the increase in the number of households was entirely due to an increase in the households with no couple and no child. The first category includes households where a person lives alone: a young adult, a man of middle, old adults living by themselves after the death of their partner. The second category includes complex households, made of unrelated housemates or individuals living with (but not within) a family (mostly young adults).

On the contrary, the number of households with a couple is stable, with a decline of couples with children on the short term, due to the current delay in the birth of the first child.

Limitation and future research

Due to memory limitations in MODGEN, we had to run several populations for the Paris region and to merge them. An improvement using a 64-bit operating system is currently being tested. The software developments are not fully open access because of the need to use visual Basic in order to run the programme. The executable file is open access and can be run freely.

It was decided not to develop a Python version of the module to be embedded in the UrbanSim software, but to develop and use a specific demographic module. This has two advantages. On the one hand, the demographic module can be used and tested out from UrbanSim; on the other hand, UrbanSim could use other simulated populations and households. The main shortcoming is the need for a data entry specific interface within UrbanSimE.

The implementation of the demographic module needs a lot of data as input, because all demographic transitions must be estimated, as well as the impact of covariates on these transitions. As always when using microsimulation, a sensitivity analysis is needed and calibration can be performed in many different ways. For instance in order to increase the number of couples in the population, you can increase union probabilities, or decrease disruption rates, but also increase probabilities to leave parental home or introduce lower mortality for people living as couple. The calibration was not difficult for the Paris region, as its current demographic structure is close to the equilibrium (with an on-going decline in household size). Due to lack of data and of time, Brussels case study team could not use the module.

3.4 Econometric and other empirical issues (Work-Package 5)

Initial objectives

The initial objectives of Work-Package 5 focused on a number of econometric improvements to be made in respect to the existing estimation or calibration of models on which UrbanSim is based:

- Household location model should be consistent with variable size of potential locations, husband's and wife's respective preferences and constraints (current and potential labour place); the location decision should be modelled simultaneously with the decisions to live in a house/a regular flat/a low-price (social) housing (e.g. HLM in France), and to buy or rent the dwelling;
- Consider firms rather than jobs as the decision unit for jobs location; decompose the evolution of the number of jobs at a given place in: variation in the number of jobs in each existing firm; firms relocation; births and deaths of firms;
- For the land use model, instead of estimating transitions probabilities from one usage to another, develop and estimate a model of generation of projects of a given type and size, and estimate a location model for these projects given the constraints imposed by their type and size.
- Work-Package 5 would also investigate the possibility to estimate interrelated decisions entering different work packages (For example, life cycle effects in the car ownership and location decision process). However, difficulty to access the needed panel data will add to the difficulties raised by the theory of dynamic decisions.

Achievements

Following up on the analysis of the econometric models that are being used in UrbanSim (performed within Work-Package 2 and summarized in Deliverable 2.4 (Picard, Antoniou and de Palma, 2010), econometric guidance was developed for the application of the UrbanSim software in the three case studies that are considered in this project (namely Brussels, Paris and Zurich), and most of the models developed in the econometric guidance were used in at least one case study.

- A version of the household location model consistent with variable size of potential locations was implemented in UrbanSim relying on importance sampling methods. The joint decision to buy or rent a dwelling, live in a house/a regular flat and residential location is ready to implement in UrbanSim, relying on log-sum computations.
- The firmographic model was successfully introduced in Paris case study.
- A simple model of projects generation and projects location model was also implemented in Paris case study.
- This econometric guidance is intended as a guideline helping UrbanSim users specifying the econometric models underlying the predictions of all variables endogenous in a Land-Use Transport-Interaction (LUTI) model.
- We pay particular attention to constraints imposed by data restrictions and availability. We illustrate various model application possibilities based on the three case studies considered in the SustainCity project: Paris, Zurich and Brussels. Suggestions for diagnostic tests and the presentation of model results are also provided.

Three original models were developed and estimated to illustrate new behavioural insights.

A joint residential location-job location-job type model enhances the need to define an individual-specific accessibility measure. Because individuals have different values of time and different preferences (or opportunities) for different job types, they are not attracted by the same workplaces. For example, a district with numerous manager positions is an attractive workplace for highly educated people, whereas a district with numerous blue collar positions is an attractive workplace for low educated people. One step further, a district with easy access to attractive workplaces for highly educated people has a good accessibility for highly educated people, whereas a district with easy access to attractive workplaces for low educated people has a good accessibility for low educated people (see Chiappori, de Palma, Inoa and Picard, 2013).

A joint model of tenure status, dwelling type and household location shows the importance of borrowing constraints in residential location choices, and the implication of such constraints on the local social mix of the population and on residential segregation. An important policy implication of this model is the prediction that alleviating the borrowing constraints would have strong implications not only on tenure type, but also on household location and residential segregation (see Dantan and Picard, 2013).

A joint model of couples' residential location and spouses' workplaces shows that the usual estimates of the spouses' values of time are biased when not correct for spouses' bargaining powers. When the household locates closer to the wife's workplace than to the husband's workplace, it is partly because her value of time is larger than the husband's value of time, and partly because she has a larger bargaining power (see Inoa, Picard, de Palma, 2013).

Policy brief (D5.2) provides new behavioural insights into the developed models, as well as estimations results for selected case studies.

Relations with other Work-Packages

Due to its nature, Work-Package 5 interacted considerably with other Work-Packages in the SustainCity project. In particular, input from the case studies was initially collected. This input related primarily to the data availability and limitations of each case study (Work-Package 7). Furthermore, policy requirements from WP8 were also requested early on and considered explicitly in Work-Package 5. The guidance and main directions of Work-Package 5 have been extensively exploited within other Work-Packages, primarily 6 (Software), 7 (Case studies) and 8 (Policy insights and insights for sustainability).

Summary of most important results

The most important results of Work-Package 5 include the guidance to the Case Studies, which was used to achieve consistent results across the case studies. Even though the nature of each case study is very different, in terms of city characteristics, level of aggregation for running UrbanSim (i.e. zone or parcel), and availability of data, Work-Package 5 provided a set of "standardized views" which were used to present the model results. Following these templates, it is possible to have a coherent view of the outcome of the case studies. This becomes particularly important in the context of developing policy assessments based on these outputs. It is expected that these "standardized views" and the experience gained through this process will be valuable beyond SustainCity.

Furthermore, a number of "lessons learned" from the runs of the case studies have been formulated, which can both assist others in designing and performing similar studies in a better way, but also prevent them from making some of the more common missteps. One of the main findings of the econometric modelling aspect was that considering spatial models has a great potential in improving the accuracy of land use and transport interaction models. Preliminary results, estimated outside of UrbanSim, provided very interesting results.

Limitations and future research

Even though the SustainCity consortium was very well designed, it still became apparent that data can be a challenge. While it was still possible to develop these models for three large and well-developed European cities, it is still open to consider how one might be able to develop similar, "data-hungry" models in regions of Europe, where data are harder to collect.

Integrating some of the advanced econometric models (such as spatial models or modelling of intra-household decisions) that were estimated outside of UrbanSim in this research, into UrbanSim could provide a considerably boost for Land Use Transport Interaction modelling in the future.

3.5 Software development (Work-Package 6)

The main focus of Work-Package 6 was to better integrate travel model results into UrbanSim. The travel model uses the population and land use information from UrbanSim, generates travel demand from it, and assigns it to the network. The main purpose of this exercise is to come up with realistic network-oriented travel times, including congestion effects. The results from the travel model are fed back into UrbanSim, where they are taken into account in the land use decisions. Two different models have been introduced MATSim and METROPOLIS. They have been separately integrated with UrbanSim.

Initial objectives

Major challenges included that travel models typically use a large amount of computing time, and that the microscopic information that would be conceptually most straightforward to use by UrbanSim is too large to be fed back directly. An additional challenge was to achieve a robust coupling between UrbanSim and the travel models (METROPOLIS and MATSim).

Achievements

Robust coupling of MATSim to UrbanSim as a travel model plugin

UrbanSim is written in python while MATSim is written in Java. For python there exist both C/C++-based and Java-based implementations, but UrbanSim is bound to the C/C++-based implementation because of some underlying libraries. Thus, C/C++-based python needed to be coupled with Java.

The coupling was achieved using the standard file-based approach. In order to make the coupling more robust, an XSD (XML Schema Description) was developed which is used both on the UrbanSim and the MATSim side (Nicolai and Nagel, 2010). Thus, when the communication channel between the two packages is modified in an incorrect way, the communication will fail with a clean error message rather than, say, interpreting data in an erronous way but continuing the computation. In addition, a sizeable number of regression tests were written and installed both on the MATSim and on the UrbanSim side.

Development of an interface between METROPOLIS and UrbanSim

In the case of METROPOLIS, we have opted for the solution of interface. In this case there was no need to modify neither of models and the interface was as much as possible independent of the future evolution of both of them. The data exchange is made by the intermediary of cache files that are directly read by two models. The independent interface makes possible to include future developments in travel demand computations. The interface is developed in such a manner to be able to manage the models run on different remote servers.

The interface has three major tasks: (1) manages the integrated simulation and data exchange between models as well as running them, (2) compute the necessary OD matrix to feed METROPOLIS from UrbanSim results for population and employment distribution and (3) compute necessary accessibility measures as needed in UrbanSim from METROPOLIS outputs. The interface is designed to take advantages of all possible micro-data available in modelling process, in particular the workplace of the individuals. In this case the OD matrix for home to work and work to home trips is based on known workplace information.

Computing times

An important step was bringing down the computing times for the accessibility computations (see next). Hot start brings the necessary number of MATSim iterations down from about 100 to about 30, thus reducing the travel model computing time to about 30% (Nicolai, 2013).

Accessibility computations and feedback to UrbanSim

The original UrbanSim implementation assumes that a so-called travel data table is returned to UrbanSim, which contains, for each pair of zones, elements such as the travel times. This is a large table, which is in consequence slow to write and read. To reduce the computational resources needed for production of accessibility measures, it was accelerated using techniques such as shortest path trees, aggregation of workplace opportunities to the nodes of the transport network, caching of computations, and interpolation of accessibility values to the parcel level. Overall, it was possible to make the computation time much smaller than the overall runtime of the travel model, while maintaining a high resolution of 100 metres.

The accessibility measure was tested comparing accessibilities by car (uncongested) with accessibilities by car (congested), by bicycle, and by walk. As expected, the results clearly demonstrate that accessibilities by car on the uncongested network are by far the best, but once the network becomes congested, accessibility by bicycle becomes similar in urban regions. Accessibility by walking is always worst except for the innermost urban cores. More details are reported by Nicolai and Nagel (submitted, 2012, 2011).

In the case of METROPOLIS, the interface feeds directly the relevant accessibility measures to UrbanSim. The interface permits to introduce different relevant accessibility measures with strong microeconomic theoretical bases like is the case in METROPOLIS development.

Matrix-based public transit simulation

The two pre-existing approaches to model public transit in MATSim were a very simple model which obtains public transit travel times from multiplying uncongested car travel times by a factor, and a rather complex model which reads and uses the full schedule(Nicolai and Nagel, 2013).

METROPOLIS can be integrated with different public transit models like VISUM that performs schedule based assignment to compute travel times.

Relations with other Work-Packages

The main interaction was with case study teams. For Zurich and Brussels case studies, MATSim was used as the travel model plugin, and thus the work of Work-Package 6 was instrumental in order to support this.

The Paris case study used METROPOLIS (see Saifuzzaman, de Palma and Motamedi, 2013 and Saifuzzaman and de Palma, 2012). The application of METROPOLIS in Paris case has been developing during a long period.

Summary of most important results

A file-based coupling of MATSim as a travel model plugin to UrbanSim was achieved, and as long as the regression tests keep running on both sides, it should remain functional beyond the end of the project. The same is the case for METROPOLIS by limiting the exchange to the necessary and relevant data and feeding them directly in UrbanSim cache database.

It was demonstrated that high-resolution accessibility computations, with a resolution of 100m×100m, using the transport network for the computation of the generalized cost of travel, and taking each opportunity into account separately, is computationally feasible, and provides better insights and thus better modelling input than conventional accessibility computations that aggregate over zones.

Both travel models were run successfully for the case studies. In the case of Brussels the model includes a matrix-based public transit model. The introduction of a cordon toll resulted in reduced car mode shares across the cordon. Accessibility inside the cordon improved because of reduced congestion. At the same time, the cordon toll showed up as reduced accessibility outside the cordon, since for those households the toll for destinations inside the cordon is added into the generalized cost of travel which thus becomes larger. (As of the writing of this text, the status of the Zurich case study is not yet known.)

In the Paris area case study, the transport model is calibrated based on 2009 data including the coded network and initial peak hour OD matrix. The parameters are estimated based on regional travel survey (EGT, 2001) and MADDIF survey for dynamic behavioural parameters. The model is calibrated against traffic count on more than 200 stations over all network essentially the freeways. Also, we have used observed travel times for about 120 extents over the area. We obtain an R^2 of 84% for the goodness of fit. The integrated model has been used in evaluation of different transportation policies including the Grand Paris project. The results are explained in Paris case study section.

Limitations and future research

Coupling Java-based with python, C and C++ based software packages remains problematic. Quite some time was invested in order to achieve an architecture that is still less than optimal – in particular, it is impossible for deliberating “persons” in UrbanSim to query the MATSim model directly. Since there is also no clear reason to move the whole community either to python, C and C++ or to Java, this means that there will be separate streams of software that will remain difficult to integrate until technology improves.

The computation of high resolution accessibilities proved rather fruitful, and it is intended to use this in the future for various scenarios and also for various trip purposes. This should, for example, help with the identification of regions which may be underequipped with certain services.

The frequency of update of congestion information in UrbanSim need to be more explored. Also, the use of disaggregate information available via Web (price of land, travel time, GPS position system, etc.) could be considered as future development challenges.

3.6 Case studies (Work-Package 7)

3.6.1 Paris (Ile-de-France) area case study:

Among the three case studies, Ile-de-France is the largest application of UrbanSimE with a total surface of more than 12,000 km² and more than 5 million households and jobs. It also benefits from the richest database, including exhaustive individual data. Most of the theoretical developments presented in WP3 have been estimated and applied in this case study. The results of this case study have already been disseminated and used successfully in practical studies and socio-economic analyses such as the Grand Paris project.

Initial objectives

- Data collection and analysis
- Work on spatial issues: geographical units (Department, Commune, IRIS, Ilot, Ilot MOS)
- Integration of demographic model, improving real-estate price model, implementation of firmography model, improve the residential location choice model
- Calibration: transport model, UrbanSim and integrated model, tool evaluation
- Simulation of scenarios and policy evaluation, socio-economic analysis

Achievements

Data collection and analysis

All the data needed to run UrbanSimE were collected. It covers demography, population (exhaustive census data), firms and jobs (exhaustive Regional Employment Surveys), yearly real-estate prices in the largest 300 communes, land-use and many other marginal data sources. All these data have been carefully checked. All variables used in UrbanSim were computed and organized, as reported in deliverable 5.1 (Picard and Antoniou, 2011).

Work on spatial issues

A comprehensive study has been performed on geographical units to be used in analysis, simulation and presentation of the results. These units range come from district (8 in the area) to Ilots (over 50,000 in the area) or 500m*500m grid cells (nearly 50,000 in the area), with 1300 communes ad 5200 IRIS as intermediary levels.

A variance analysis was performed for some key variables used in UrbanSim at three relevant geographical levels: district, commune and grid cell. Globally, most of the variability in accessibility measures is captured at commune level, whereas the variability in environmental variables mainly holds at the smaller grid cell level.

Our results on a first series of simulations revealed that it is more relevant to run simulations at the intermediate IRIS level. In addition, since some communes have less than 100 inhabitants or jobs, we used a hybrid unit that aggregates very small communes to have units with a minimum reasonable size (in terms of population), which leads to 725 pseudo-communes.

Integration of demographical model

UrbanSimE takes advantage of endogenous demographic evolution model. In this case we are able to keep track of the household moving and location behaviour. Household members' age is updated in the model, so the aging of the resident population can be explicitly modelled. The lifecycle events affect the moving probability to obtain more realistic results. Last but not least, the household location choice history is taken into account, especially through a dummy variable (which happens to be the most significant in household location choice model) indicating that an alternative is located in the same county as the previous residence.

Improving real-estate price model

We have clearly established the need to estimate different price models for different real-estate types and the correlation between the prices estimated in the different real-estate types is not very high (between 50% and 80%). We have improved these models based on panel data for the real-estate prices observed over the period 1998 to 2010. We are currently working on a more comprehensive study on a regime switching price model on the real-estate price indices for the period 1980 – 2010. The models are estimated but not yet implemented in UrbanSim.

Implementation of firmography model

Four sub models have been estimated and implemented in UrbanSimE. The estimates are based on individual business data available in two cross sectional databases provided by regional employment survey conducted on 1997 and 2001. The model treats the establishments in 11 separate activity sectors.

Improvement of the residential location choice model

The access to exhaustive census data for Paris area gave us the opportunity to develop and estimate elaborate models developed in work packages 3. See the section related to work package 5 for details. These models were developed in the perspective of being implemented in UrbanSimE and are ready for that, although some of them were not yet implemented.

Chiappori, de Palma, Inoa and Picard, 2013 have elaborated a joint residential location-job location-job type model and defined an individual-specific accessibility measure, which varies significantly across individuals, and explains residential location better than the usual universal accessibility measure. Dantan and Picard (2013) developed a joint model of tenure status, dwelling type and household location enhancing the importance of borrowing constraints in residential location choices, and the implication of such constraints on the local social mix of the population and on residential segregation. Inoa, Picard and de Palma (2013) have elaborated joint model of couples' residential location and spouses' workplaces and shown that the usual measures of the spouses' values of time from household location choices are biased up to 20% when the spouses' bargaining powers are neglected.

Calibration of UrbanSim and integrated model, tool evaluation

The UrbanSim models have been calibrated separately against observed data in particular the household and individual population data and employment data by activity sector. To present the results and calibrate the model, we have used an aggregated zoning with 50 zones over the region. These zones are designed to be compatible with urban policy zones and also transportation analysis zones. The compatibility with the urban policy zones permits us to introduce some calibration constants that represent the effects of policies that are not explicitly modelled. The UrbanSimE and integrated model results have been calibrated against the census data for the period 2006 – 2008 for population and employment.

Relation with other Work-Packages

A great interaction has been carried out between this case study and all other work packages. Concerning theoretical developments, the working papers 3.3, 3.5 and 3.7 are directly based on Paris case study data and are ready to be implemented in the UrbanSimE. The demography model has been initially tested and calibrated for the Paris case study and is directly integrated in Paris case study simulations. The Paris case study estimations provided a great part of insights in the econometric guidance. The implementation of frimography and interface with METROPOLIS constitute the major software developments related to Paris case study. Policy evaluation indicators have been used in policy evaluation of our case study.

Summary of most important results

This case study has proved that it is possible to develop and run a European version of UrbanSim which is consistent with all the specificities of the European context, and which provides an operational tool for policy evaluation, as illustrated in the Grand Paris project. It is a major public transportation and urban development project in Paris area. About 160 km automatic subway will be added to the existing subway network in majority around the Paris city and in near suburbs. 75 new subway stations will be constructed. In comparison with currently active 220 km subway lines and 303 stations, the project is a considerable evolution in the public transportation system of the area. The total project's investment is estimated at about 30 billion Euros over more than 20 years (up to 2035). UrbanSimE simulations provided key inputs for socio-economic analyses which show that the future benefits will largely exceed the initial investment.

Limitation and future research

Two major limitations of our research deserve attention. The first one is related to the lack of relevant data, especially panel data, which made it impossible to estimate and implement in UrbanSimE the complex dynamic models which could explain, measure and predict life cycle effects in car ownership or residential location decisions. The second one is that the advanced econometric models (such as modelling of intra-household decisions) estimated outside of UrbanSim are not yet implemented into UrbanSimE. This defines motivating future research and the results of this research will clearly could provide a considerably boost for Land Use Transport Interaction modelling in the future.

3.6.2 Zurich case study

Here we report about the implementation of a parcel level UrbanSim land use model which interacts with another microsimulation for transport simulation, MATSim, and a microsimulation model of demography. The study area is the Canton of Zurich in Switzerland. The implementation comprises a substantial effort of collecting data, which is needed for the creation of a highly detailed base year definition and the estimation of adequate choice and price models (Schirmer, Zöllig, Müller, Bodenmann and Axhausen, 2011). The model estimation was successful and three policy scenarios were finally run. The first scenario is a cordon road pricing applied to the City of Zurich. The second scenario modifies land regulation such that higher densities of built space are allowed in central areas. The third scenario is the combination of the two previously mentioned. The results show the sensitivity of the model to the measures. The expected effects of car travel time reduction in the road pricing scenario are confirmed. Travelled distance decreases accordingly. The reductions in the model originate from adapted mode choice of the travelling agents.

Initial objectives

The initial objectives for the case studies were to collect and analyse data, estimate the necessary models, calibrate sub-models and the overall model, simulate baseline and policy scenarios, evaluate policies by running environmental and socio-economic indicator modules and identifying practical limitations and difficulties of UrbanSimE.

Achievements

A full parcel level land use model of UrbanSim is implemented in the case study Zurich. The level of detail of the model has been enhanced by adding living units as independent entities. The household location choice model benefits from this new data structure because of the now available living units' characteristics. Calibration of the land use model has been done to some extent by fine tuning the base year data. This included correction of plan type data and adjusting non-residential vacancies.

The land use model is coupled with an equally detailed micro-simulation of transport and a demography model. For the transport simulation we use the new interface to MATSim to simulate commuting travel. Unfortunately, it has not been possible to integrate other important trip purposes such as leisure or shopping. The evolution of the population in the study area is simulated using the demography model. Numerous Switzerland specific transition parameters were collected for its application. The model is calibrated to reproduce the overall population development in the study area by adjusting the number of immigrating and emigrating households as well as mortality. The individual records of households and persons generated with the demography model are then used in the land use and transport simulation.

A car ownership model and an income model are added in UrbanSim to maintain important attributes for the household location choice model.

Four scenarios are simulated, including the baseline. The baseline is the “do nothing” scenario. The population is given by the demography model, job numbers are given externally and we assume relocation rates for households and jobs. The simulations start in 2000 and end in 2030. Every fifth year a transport simulation is performed to update accessibility values of parcels and travel related indicators of persons such as chosen mode and travel time.

Relation with other Work-Packages

The case study benefited directly from the demography model (Work-Package 4) and the MATSim interface developed (Work-Package 6). Parcel based accessibility computation within MATSim is delivered as part of the MATSim interface. The policy scenarios have been evaluated with the indicator tool (Work-Package 8).

The theoretical work and discussions as part of Work-Packages 3 and 8 have been stimulating for the case study application. The transfer to the case study model is not easily possible because of data, time and software constraints.

Summary of most important results

A cordon road pricing for the city of Zurich is the first policy simulated. A monetary payment of 5 euros is imposed on travellers crossing the cordon towards the city centre from 2015 onwards. The results show 4% reductions in car mode choice and consequently time and distance decreases for car travel by 1.5% and 1%, respectively, for the whole simulation area. In terms of land use we see attraction of jobs and reduction of households respective to the cordon area.

The second policy scenario assumes higher allowed densities of floor area in central locations. The policy is again applied in 2015. Car mode choice reduces by 1%, which reduces car travel time by 1% and travelled distance by 0.7%. Allowing higher floor area ratios in central locations of settlements leads to more built space in these areas. As a consequence about 18% more households locate in central areas.

The third policy scenario is the combination of the two previously described. The results show that the combination of road pricing and densified land use reduces car travel most. Overall travel time and distance reduction is almost 2%. Reduction in car mode choice is also about 4%. There is no notable deviation in the number of households within the municipality of Zurich. It seems like the effects of both policies balance themselves in the region where both policies are applied. There are about 4% more jobs locating in the municipality of Zurich compared to the baseline. This is less than in the densification scenario, which shows that disadvantages of road pricing are more than compensated by advantages of central locations.

Limitation and future research

Calibration of all main models (Demography, transportation and land use) could be improved. A thorough methodology to calibrate a composite model is still lacking.

The transport model only simulates commuting trips from home to work and back home. The integration of further trip purposes such as leisure and shopping would improve the transport simulation substantially.

In respect of road pricing the transport simulation would benefit of adding choices about trip making, carpooling and other modes. The simulation of public transport does not include additional costs with more demand. This leads to a mode share shift towards public transport which is not realistic and substantial costs are neglected.

The relocation decision of households does not depend on the simulated situation. One would expect higher probability of relocation for policy affected households.

The land development model would benefit from a coupling to real estate prices and simulated economical assessments of construction projects. An appropriate model would need a more consistent reproduction of sub-markets which also requires additional price models.

All models implemented represent rather simplified models that would benefit from further optimization in terms of data used for estimation, definition of model variables and the estimation or modelling methodology. Especially the workplace choice and employment location choice models are lacking observations for estimation and had to be estimated using the distribution in the census data. In most cases models had to be estimated using the base year data which represents the current distribution and not the location choice.

3.6.3 Brussels case study

The Brussels case study consists in the development of an UrbanSim-MATSim model for an area covering the Brussels urban agglomeration and the suburban area (3 million inhabitants).

Initial objectives

As for the other case studies, the objectives of the Brussels case study were manifold: (1) collect the required data, estimate the submodels, and develop a comprehensive UrbanSim model; (2) simulate a set of policies with the model; (3) calculate indicators to assess the policies and compare the assessment with results of previous land-use/transport models; (4) assess the performances of the tool, notably on the following aspects: difficulty of the calibration, performance of the reconstitution of the past evolution, and evaluation of elasticities.

At the beginning of the project, there was an existing UrbanSim model of Brussels, but this was a pure prototype model, developed using very aggregate data and not able to provide meaningful results.

Brussels as many other European cities undergoes an out-migration of middle class families to the suburban areas, yet for several decades, which causes urbanization of previously open spaces, commuting by car and traffic congestion. In reply to this, the Brussels Capital regional authorities implement policies to improve the residential attractiveness of the Region. As another topical point, the three Regions committed themselves to drastic reductions in their greenhouse gas emissions. This objective appears to be reachable only if it is supported by strong land use and transport policies. Some topical issues that the city is currently facing are the following ones: 1) the housing supply to be developed to meet the needs of the demographic growth foreseen for the next decades, 2) the densification of office districts and namely of the European institutions district, 3) the possible implementation of an urban congestion pricing scheme, 4) the funding of the development of the public transport network and services (including the funding of the Regional Express railway Network to be fully implemented by 2025). Consequently, from the very begin of the SustainCity project, the policy scenarios which were envisaged to be simulated with UrbanSim were: densification policies and urban road pricing (note that these policies are at the top of the agenda in many European large agglomerations). These policies were simulated as planned.

Achievements

Data collection

The study area covered by the case study has been defined according to functional and transportation criteria. It is much larger than the urban agglomeration, and corresponds to a set of 151 municipalities (“communes”) around Brussels. The central part of the morphological agglomeration corresponds to the Brussels-Capital Region, one of the three Regions making up the Belgian federal state. The study area is roughly the area which will be served by the “RER” (regional express railway network). It includes about 3 million inhabitants, which is much larger than the Brussels Capital Region (19 communes – about 1 million inhabitants).

Data were collected in the following fields:

- data on the population (from the last national census dated 2001 and from the annual population registers)
- data on the employment (from the national Social Security databases, for employees and self-employed persons, from an annual national survey on home-to-work trips and from a private-sector database)
- data on buildings, dwellings, housing real-estate prices, land plots (from the national Land Register)

- data on land-use (building permits)
- data on the home-to-work relationships (notably from the 2001 census).

These data were collected for the year 2001 (base year of the model, against which it was calibrated). The main population and employment data were also collected for the year 2007: the year 2007 was used for validation purpose, i.e. the situation 2007 simulated by the model starting from 2001 was compared to the actual observed 2007 situation.

Other global parameters required by the model were also estimated from the available data, such as dwelling and office vacancy rates, household and job relocation rate.

All these data were of course organised in database and processed into formats useable by UrbanSim.

Development of a "synthetic population"

A "synthetic population" was developed. The basis of the UrbanSim model is a population (as UrbanSim is a multi-agent micro-simulation model), as close as possible to the actual base year (2001) population. To get that population, the first idea was to request data at an individual level from the 2001 Belgian census. However, the Belgian administration refused to provide these data, because of privacy issues. Consequently, it was decided to build a "synthetic population" based on distributions according to one variable or two crossed variables, at the level of the municipalities or at a finer spatial level (statistical sector level).

Spatial issues in LUTI models

The representation of space by LUTI models raises some problems. The sources of geo-statistical biases in econometrical analyses are for example: the definition of the urban agglomeration, the Modifiable Areal Unit Problem (M.A.U.P.), the border effects and econometrical issues that deal with spatial autocorrelation, endogeneity and sampling. Using the three SustainCity case studies, implications of these biases in operational applications were highlighted, and practical examples were provided, showing how these biases can influence the behaviour of UrbanSim for a given case study, and make the comparisons between the case studies difficult.

Within-case study issues were mainly illustrated using Brussels, and include: influence of the definition of the study area on model estimates, M.A.U.P (as expected, estimated parameters of econometrical sub-models are affected by a change of the size of the BSU or basic spatial unit – a strong attention must be paid to this, when interpreting parameter values). Location choice parameters, in particular, may vary with the scale.

Further to that, inter-case study issues were based on an empirical comparison of Paris, Brussels and Zurich: comparison of the study areas (size and content), comparison of the city structures, and conclusions on the difficulty of comparing the modelling results.

Development of the UrbanSim model

The following models were calibrated: 1) household location choice model (multinomial logit model), 2) job location choice model (multinomial logit model), 3) housing real-estate price model (hedonic model), 4) real-estate development and location choice model.

Validation of the UrbanSim model on the period 2001-2007

The simulation results obtained with the model for the year 2007 (in terms of population and employment per commune) were compared to the observed data for validation purpose.

Development of the MatSim model

In particular, we compared some indicators produced by the MATSim model (travel times) with indicators produced by another traffic model developed by Stratec with the Saturn software. The similarities and differences were however rather difficult to be interpreted due to the fact that the methodological frameworks of MATSim and Saturn are rather different.

In spite of some remaining weaknesses of the MATSim model, due to a lack of data and resource to fully calibrate it, it was enough satisfying to be used together with UrbanSim for the research purposes of this project.

Scenario definition

The following policies were simulated in the Brussels case study: business-as-usual scenario (horizon 2020), cordon pricing scenario, densification scenario. The latter scenarios are further detailed here below.

Cordon pricing scenario: The cordon is located just outside the Ring road (orbital highway) which surrounds the Brussels-Capital Region and some adjacent communes. Every car entering the area inside the cordon, during the morning peak period (i.e. between 6 am and 10 am), has to pay an additional cost of 5€.

Densification scenario: The objective of this scenario was to test the effects of household and job densification in the zones defined as having a high accessibility. The population densification was implemented by increasing the housing supply in the zones having a high accessibility. These zones "highly accessible" were located in 36 communes classified as the "centre" and the "agglomeration" according to Van Hecke et al. The job densification was focused on the tertiary sector and was implemented by increasing the available office floor space located in the zones having a high accessibility by public transport. The selection of the zones highly accessible was based on the "ABC policy" approach, coming from The Netherlands.

Each scenario was simulated from 2001 to 2020 and compared with the business-as-usual scenario. Both land use and transport indicators were computed. The key indicators used to assess the effect of the policies were as follows:

- number of households in the Brussels-Capital Region
- number of households located inside the cordon (for the cordon pricing scenario)
- number of households located inside the target area for densification (for the densification scenario)
- number of jobs in the Brussels-Capital Region
- number of jobs located inside the cordon (for the cordon pricing scenario)
- number of jobs located inside the target area for densification (for the densification scenario)
- average modal shares (car, public transport and walk) for the all day and in the morning peak hours, for the whole study area and the Brussels-Capital Region
- average travel time (all modes, car, public transport and walk)
- average home-work travel distance.

The Social Welfare Function was also calculated for each scenario.

Relation with other Work-Packages

The achievements of the Brussels case study have required interactions mainly with two other work packages:

- Work-Package 6 – software development (responsible: TUB), as TUB developed a MATSim model for Brussels
- Work-Package 8 – socio-economic policy evaluation (responsible: KUL), as the Brussels case study provided indicators to WP8, to carry out a socio-economic assessment of the policy (global social welfare).

Furthermore, within Work Package 7, the Brussels case study team also had interactions with the teams of the two other case studies, Paris and Zürich, on the modelling strategies, the encountered difficulties, the interpretation of the simulation results, etc.

Summary of most important results

The main achievements of the Brussels case study are the development of an UrbanSim model and the simulations which were made with the model. Although the UrbanSim and MATSim models still have weaknesses, the case study shows that, provided that data are available, a land-use/transport model can be calibrated. However the model is not fully operational, among others because the resulting elasticities (magnitude of the policy effects) have not been really validated and in some cases are difficult to be interpreted.

Another important result is that the Brussels case study points out some fields requiring improvements and further research, namely model calibration and validation.

It is worthwhile reminding that, in this project, the three case studies were starting at different stages of calibration (Brussels started with a purely prototypical model); consequently, they also reach different calibration/validation levels at the end of the project.

Limitation and future research

Future research should be carried out in the field of the calibration and the validation of the models. In SustainCity, and in particular in the Brussels case study, all the models (household location choice, job location choice, hedonic price model,..) have been estimated with observed data, in which correlations may exist (and probably exist). It is therefore difficult to estimate with accuracy the effect of a given x explanatory variable on the y independent variable. One solution would be to estimate the parameter values using “stated preference surveys”, i.e. surveys were scenarios are presented to the respondents, with uncorrelated variables, so that the effect of each variable on their choices may be derived with much higher accuracy. The collection of such data could provide an important improvement to the calibration of the UrbanSim submodels, particularly the location choice models, were variables such as price, surface, number of rooms, etc., may intervene, all being correlated in the reality.

More generally further research should be dedicated to the issues of correlation and endogeneity in the calibration of these models.

Another field requiring further research is the validation of the models, e.g. by plausibility analysis, back-casting, inter-city comparisons, inter-models comparisons, etc.

Other more technical improvements also should be required, such as a reduction of the computing time, to allow a better exploration of the stochastic variations (in microsimulation, each run provides a different result and a whole set of runs is necessary to provide an average result).

3.7 Policy insights and insights for sustainability (WP 8)

The development of urban areas is holistic and therefore difficult to grasp. The policy makers are expected to improve the economic, environmental, transport and social performance of their city. This is difficult for two reasons. First, these indicators interact in a complex way and there is often a trade-off between them. Second, the policy maker has to decide between alternative developments that differ in many dimensions: some parts of the city may do better (say within a toll cordon), others worse (say outside the toll cordon), some income groups do better than others when city center is revitalized, there may be a short term gain (by making an area greener and safer) but a long term loss (this may cause a loss of social integration in the city). The SustainCity model helps to understand the complex relations between the different policy dimensions and helps to translate the effects of policy actions into outcomes. What is lacking is the operationalization of the complex SustainCity model into policy inputs and policy outcomes.

Initial Objectives

The initial objective of this work package was a unified and integrated framework to evaluate policies in UrbanSim and propose a set of policies that can be applied on three case studies, Paris, Zurich and Brussels.

Achievements

A unified framework has been constructed that trades off social, ecological and economic objectives. These trade-offs are conveniently expressed in terms of a social welfare function. Such a social welfare function also allows us to incorporate equity issues by allowing. The social welfare function computes indicators such as: the utility of the residents which is amongst others a function of the housing, transport costs and income, the utility of commuters and non-residents, the value of the local stock at the end of the horizon, the implementation costs and the collected revenues. The social welfare function is computed as the discounted (weighted) sum of these six components. Policies can then be evaluated by comparing the social welfare outcome when the policy is implemented with the business as usual scenario. This approach has been operationalized by an extra module integrate with UrbanSim.

The three policy packages that have been selected and implemented in the three case studies (see work-package 7 for the exact implementation and results) are the following. The first policy concerns road pricing, this can be a cordon pricing or parking fees in the inner city. A cordon toll around the inner city or an increase in parking fees in this zone will decrease the number of trips to the inner city and one can expect a reduction of congestion, accidents and emissions, together with an increase of the modal share of public transport. In the long run we can expect changes in housing prices and location of businesses and decentralization could occur. The second policy is a large investment in either the road network (such as a bypass) or public transport network. The effects of an investment in the transport network will largely depend on the pricing of the new infrastructure. Building a bypass will lead reduce inner city congestion and improve air quality. If the bypass is not tolled, the additional road capacity will attract higher traffic volumes. In the long run we can expect relocation of businesses which could affect the location of business centres (decentralization). An investment in the public transport system will also increase the use of public transport and reduce congestion.

In addition, average trip length may increases (for both car and public transport) leading to city sprawl. We can also expect that large investments will influence housing prices due to better accessibility and relocation of households. Investments in public transport are also likely to boosts the benefits of road pricing. The last policy is a land-use regulation reducing the density of the city. The expected of densification is that it will reduce commuting times, although the link between residential density and travel distance is not as strong as it appears at first sight.

Relation with other Work-Packages

There has been close interaction with the cases study teams (Work-Package 7).

Summary of most important results

The most important results are the definition and operationalization of a consistent urban sustainability assessment module. Moreover a set of test policies have been proposed.

Limitation and future research

The major limitation has been that the UrbanSim models were too complex and not really ready to test extensively the sustainability policies that have been proposed. Future research should focus on a more simplified model that is available for more extensive policy testing.

3.8 Dissemination and valorisation (Work-Package 9)

In order to share the results and lessons learned during the project, a series of dissemination instances were programmed and developed: scientific conferences, training sessions for software and the edition of a book.

Initial objectives

The urban models are not yet well formulated and easy to use for the professionals as well as for academics. In this project, we will bring it to use of the modelling community. To do so, at first, we propose necessary tools and modelling guidelines for our modelling platform. At last, we organise the training sessions and scientific meetings with two different target publics: the academics and the local authorities and stakeholders.

Achievements

The following events were organized: Two conferences - SustainCity Conference on Integrated Land-Use and Transport Simulation, Zurich, April 17-18 2013, and SustainCity Seminar at the 51st ERSA Congress 2011, Barcelona, September 2 2009

Training sessions: UrbanSim Workshop. Athens, July 4-6, 2011 ; MATSim Tutorial and User Meeting. Berlin, April 4-8, 2011 ; METROPOLIS User Meeting. Zurich, May 22, 2010 ; UrbanSim User Meeting and Tutorial. Zurich, May 17-20, 2010 and MATSim Tutorial and User Meeting, May 17-20, 2010.

A handbook is currently under preparation, edit by Professors Michel Bierlaire (EPFL), André de Palma (ENS), Ricardo Hurtubia (Universidad de Chile) and Paul Waddell (UCB). The handbook describes the modelling efforts, methodological contributions and results of the SustainCity project. The analysis is focused on the theoretical contributions that resulted from the modelling effort, the simulation results of each case study and the practical aspects of the use of microsimulation models as policy evaluation tools. Additionally, a web site (www.sustaincity.org) was implemented, in order to inform of the events and to publish research results to a wider audience.

Relation with other Work-Packages

The conferences presented an opportunity to receive feedback from the scientific community outside the SustainCity team and allowed for a more informed development of the methodological and modelling work packages. The training sessions allowed preparing members of the consortium to work with the modelling tools that were used in the case studies. The chapters of the book are the result of the work performed in Theoretical Developments, Demography, Econometric Issues, Software, Case Studies, and Policy Insights for Sustainability.

Summary of most important results

The conferences and the website were used as a platform to socialize the methodological findings and lessons learned from the project. The book will serve a similar, more long-lasting, purpose and it should provide a good starting point for future research in the field.

The tasks performed in the context of Work-Package 9 allowed showcasing the project and have already triggered interesting discussion, sowing the seed for new networks and collaborations with other researchers in the field.

3.9 Conclusions

We have met the main objective of this project: elaborate a LUTI model perfectly adapted to the European specificities, and apply it to three case studies. We have developed and run a European version of UrbanSim consistent with the specificities of the European context, which provides an operational tool for policy evaluation. Several lessons were learned.

Data: One major issue in the model was data acquisition and validation. We all know that a major issue in transport and urban modeling is data collection, storing, and updating. We were ale to overcome usual difficulties in this type of task (1) update the model in spite of imperfect (or incomplete) data (2) share data between different models and (3) develop a common set of MOE (Measure of Effectiveness) to compare the results of the different models. These measures are based on effectiveness, equity, individual costs, social cost and external effects. They are either individual specific or aggregate (geographical or temporal aggregation).

Team work: Several important tasks are involved: modeling, econometrics, calibration and running. Some division of labor is needed since no researcher can have the different necessary skills. However, efficient coordination is needed, essential and should not be underestimated. The planning of the timing was difficult, since different unexpected issues may arise: problems with the data, or problems with the software, requiring some programming, debugging, etc. Support is absolutely essential. The idea was to have two free software: MATSim and UrbanSim, and one software protected, METROPOLIS. Although these software were indeed free, neither MATSIM nor UrbanSim could be used without serious support from a team of computer scientists and engineers.

UrbanSimE: We spent considerable amount of time to adapt UrbanSim to the European specificities: general geographical cells versus grid cells, taking into account of budget constraints, and introducing family decisions (for example for residential location).

Consistency: It plays an important role in modeling. Several issues, central to the projects, were discussed. They include the micro-economic foundations of agent behavior (households and firms). We highlighted the micro-foundation of the different models to makes the welfare analysis more consistent.

Double counting: The standard example concerns travel time saving and land value. Consider a given infrastructure improvement. If the increased value of property is included in the cost-benefit analysis, it is not necessary to include the value of the travel time saving induced by this change of infrastructure. Such double counting was avoided in our CB analysis.

Dynamics: Different agents have different speed of adjustments: households, firms, governments; and different levels of information (information is necessarily asymmetric). This topic was briefly explored in the theory, but much remains to be studied in more depth, before some implementation can take place. More research has to be done to better understand and guide urban development.

4 Potential impact of the project

The project has important impacts in the scientific as well as in the policy domain.

The scientific achievements are well described in section 3. They take the form of working and conference papers but will also be published in peer reviewed journals as well as in an extensive handbook. Besides the publications the project has also allowed to constitute a small community of scientists that will remain active in the field of land use modelling and its integration with transport. This community is multi-disciplinary as it contains geographers, land use planners, transport engineers, econometricians as well as demographers. Finally, the project has allowed to produce several Phd's with a deep understanding of the field and these will be active in the field in the next 30 years.

The results of the project have been presented at dedicated conferences. There have been two conferences to present the results of the project (SustainCity Conference on Integrated Land-Use and Transport Simulation, Zurich, April 17-18 2013, and SustainCity Seminar at the 51st ERSA Congress 2011, Barcelona, September 2 2009).

In order to dissiminate the results to the community of land use planners, also 5 training sessions have been organised and these were open for the general public (UrbanSim Workshop. Athens, July 4-6, 2011 ; MATSim Tutorial and User Meeting. Berlin, April 4-8, 2011 ; METROPOLIS User Meeting. Zurich, May 22, 2010 ; UrbanSim User Meeting and Tutorial. Zurich, May 17-20, 2010 and MATSim Tutorial and User Meeting, May 17-20, 2010).

The ultimate goal of the project was also to reach out to the policy community and to improve the foundations of city planning and transport. An important part of the resources of the project was reserved for case studies in Zurich, Paris and Brussels. The project has allowed to build new operational models for the three agglomerations and assess the effects of a series of policy scenarios. These policy scenarios included measures with a long lasting impact on urban form and development of the cities. The effects concern as well the expected location of economic activities by type, the expected immigration, location of new housing as well as the expected traffic flows by mode and the impact on different environmental indicators. The effects are measured in quantity terms but also in value terms and can be aggregated in state of the art social welfare measures.

If we take the example of Paris, the project has allowed to compute the effects of a major public transport infrastructure scenario (Grand Paris, a 30 billion Euro investment in a new heavy urban rail ring) as well as pointing out the corresponding needs in terms of transport and housing policy. This case study work is integrated in the planning process of the Paris region and the added value of this case study can, in itself, already justify the investment in the

Sustaincity project. The other case studies are also used in the local planning process and will pay itself back in terms of better land use, infrastructure and transport policies. As land use policies have by definition a long lasting impact, they justify a deeper understanding of the different causal processes at work. For this reason, the construction of a new generation of complex land use and transport models is a research investment with an important social return.

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