Environmental Modelling & Software 45 (2013) 92–103

Contents lists available at SciVerse ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

Impact of urban planning on household's residential decisions: An agent-based simulation model for Vienna☆

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ARTICLE INFO

Article history:
Received 18 April 2011
Received in revised form
11 November 2012
Accepted 12 November 2012
Available online 8 January 2013

Keywords:
Socio-ecological system
Agent-based modelling
Urban planning
Energy use
Residential mobility
Vienna
Household decisions

ABSTRACT

Interest in assessing the sustainability of socio-ecological systems of urban areas has increased notably, with additional attention generated due to the fact that half the world's population now lives in cities. Urban areas face both a changing urban population size and increasing sustainability issues in terms of providing good socioeconomic and environmental living conditions. Urban planning has to deal with both challenges. Households play a major role by being affected by urban planning decisions on the one hand and by being responsible – among many other factors – for the environmental performance of a city (e.g. energy use). We here present an agent-based decision model referring to the city of Vienna, the capital of Austria, with a population of about 1.7 million (2.3 million within the metropolitan area, the latter being more than 25% of Austria's total population). Since the early 1990s, after decades of negative population growth, Vienna has been experiencing a steady increase in population, mainly driven by immigration. The aim of the agent-based decision model is to simulate new residential patterns of different household types based on demographic development and migration scenarios. Model results were used to assess spatial patterns of energy use caused by different household types in the four scenarios (1) conventional urban planning, (2) sustainable urban planning, (3) expensive centre and (4) no green area preference. Outcomes show that changes in preferences of households relating to the presence of nearby green areas have the most important impact on the distribution of households across the small-scaled city area. Additionally, the results demonstrate the importance of the distribution of different household types regarding spatial patterns of energy use.

1. Introduction

Interest in sustainability assessment for socio-ecological systems of urban areas has increased notably, with additional attention generated due to the fact that by now half the world's population lives in cities (Pagliara et al., 2010). In conceptualizing the biophysical inputs and outputs of a city, the analysis of urban metabolism provides valuable insights into the energy and resource requirements of a given urban area. Departing from energy metabolism as a crucial concept in assessing society–nature interaction and sustainable development (Haberl, 2001a,b), we focus on energy use. Urban energy use can best be understood from a demand perspective, not just for final energy forms, such as electricity or transportation fuels, but for energy services (Lovins, 1977; Jochem, 2000). Research on the factors determining urban energy use is still in its early stages, especially concerning the coupling of different energy systems with each other. Household demand for energy services changes depending on several factors, which can be categorized as economic, demographic and behavioural (Weisz and Steinberger, 2010).

The positive correlation of income and energy use is long established in the traditional energy literature (Vringer and Blok, 1995; Pachauri and Spreng, 2002; Cohen et al., 2005; Wier et al., 2001; Lenzen et al., 2006; Dey et al., 2007; Weber and Matthews, 2008). Demographic factors such as population growth, household size, average household age and migration influence urban energy usage. Household size plays an important role in energy use: above two persons per household, economies of scale can reduce the energy consumed per capita (Pachauri et al., 2004; Lenzen et al., 2004, 2006; Weber and Matthews, 2008). Urban populations may have significantly smaller household sizes than rural populations, due to smaller family sizes and a larger generation gap as well as smaller dwellings, and are thus less likely to shelter extended families or many generations under the same roof. The evidence for age is mixed. The most important impact of age may be through changing household sizes and changing income level.

☆ Thematic Issue on Spatial Agent-Based Models for Socio-Ecological Systems.

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http://dx.doi.org/10.1016/j.envsoft.2012.11.012

In many European cities, demographic growth is rather moderate or even negative and mainly due to migration. The most significant factors affecting urban spatial growth are the growing number of smaller households and the increasing space consumption by households. The composition of household types within European cities changes from a mixture of one-person to more than five-person households to a dominance of single and couple households within the city and an allocation of family households into the suburban area. This process is based on residential location decisions of individual households. Concerning such residential location decisions Dieleman (2001), Coulombel (2010), Knox and Pinch (2010) each give a comprehensive literature overview. Rossi (1980) shifted the focus from an aggregated level to the individual household and its motivation to seek another dwelling and pointed out the influence of the life-cycle on residential decision-making. Wolpert (1965) and Brown and Moore (1970) refined this approach into a stress/resistance model. Various versions of this model exist in the literature e.g. by Robson (1975, p. 33), by Wong (2002) or by Benenson (2004, p. 10). Households may move due to a large number of reasons mainly related to economic, demographic and behavioural causes. Concerning possible classifications of households, Coulombel comes to the conclusion that a “unitary vision of the household keeps on prevailing in the economic literature on housing as well as in applied modelling” (Coulombel, 2010, p. 56).

Residential location modelling is widely acknowledged to be one of the most important challenges in contemporary social science. Urban areas face both a changing urban population size and increasing sustainability issues in terms of providing good socioeconomic and environmental living conditions. Urban planning has to deal with these challenges by considering processes of growth in new areas, decay and abandonment as well as restructuring and rehabilitation. On the one hand households are affected by urban planning decisions. On the other hand households play a major role in urban consumption patterns of energy use mainly depending on the income level (Weisz and Steinberger, 2010). Residential decisions of households may have an impact on the spatial distribution of energy use resulting from the spatial allocation of different household types. In addition, the reaction of individual households in response to urban planning strategies is an important issue in designing a “sustainable” city if we assume that sustainable urban development is among other parameters characterized by a balanced distribution of different socioeconomic structures.

Agent-based microsimulation models have been applied in the past mainly to simulate transportation networks, since it allows for a comprehensive, logically consistent and theoretically sound implementation of two-way interactions between land use/urban form (land development, building supply, location choices, etc.) and transportation (mode choice, travel demand, public transport accessibility, etc.) (Miller et al., 2004, 10). Recently, there have been efforts to extend such models into the area of urban energy modelling (UEM) (Chingcuanco and Miller, 2012).

We here present an agent-based model[1] analysing the effect of residential location decisions of households on the spatial pattern of urban energy use for the city of Vienna. Residential mobility decisions are simulated on the individual household level based on a stress/resistance model considering the residential satisfaction of each household by relating residential preferences of that household to certain attributes of a dwelling and its spatial unit. The main innovations of the model can be considered as the follows: Firstly, the model implements an empirically informed demographic growth model by using existing demographic forecasts. The demographic module simulates event-driven changes in the demography of different household types (e.g. single households, family households, etc). Secondly, the model implements a relocation module which again is empirically informed. Therefore, different studies were used to analyse the motivations of households in Vienna to relocate. Finally, the model integrates the current and planned infrastructure in order to combine population development with the urban development plans of Vienna. Both innovations allow for an empirically based estimation of the city’s socioeconomic structure in terms of household type distribution and the resulting energy consumption allocation over the city. The model is able to simulate future scenarios depending on changes in external framework conditions (e.g. urban planning) as well as on internal decisions (e.g. changing preferences of households).

2. Study area

Vienna is the capital of Austria with a current population of about 1.7 million (2.3 million within the metropolitan area, which represents more than 25% of Austria’s population) living in 23 districts and is located in the north-eastern part of the country, at the easternmost extension of the Alps in the Vienna Basin. The earliest settlement, at the location of today’s inner city, was south of the meandering Danube while the city now spans both sides of the river. In the early 1990s, after decades of negative population growth, the population of Vienna grew by about 120,000 inhabitants between 1987 and 1994. The reasons for this rapid population increase may lie in the new geo-political status of Vienna after the fall of the Iron Curtain, as well as Austria’s accession to the European Union at the beginning of 1995. This also led to a growing demand for housing and jobs. By the end of the 1980s, construction of subsidized flats had dropped to an annual rate of about 4000. The rising demands on the quality of accommodation and increased housing demand in general, also due to the growing number of (single-person) households, were the main factors for the higher need for new subsidized flats Vienna has seen since the beginning of the 1990s. Given these new framework conditions for Vienna, the Vienna city government at the beginning of the 1990s decided to increase the building rate of subsidized housing to 10,000 new flats annually.

In parallel the settlement structure in suburban areas changed visibly. In the last decades the main development took place in the South. The suburban municipalities and Vienna grew together, which has resulted in a coherent settlement zone. Today the main focus of urban sprawl has shifted from the South to the North. This urban sprawl is entirely based on migration, with birth rates already negative as in the city. While in Vienna the industrial sector is very small, a high aggregation of classical industrial locations in the suburban areas takes place. Additionally, these surrounding areas are facing a strong concentration of trade towards the South and in the meantime also towards the North due to the presence of huge shopping malls.

The population of Vienna is expected to grow from currently 1,686,000 people to more than 2 million people by 2050 (Statistics Austria, 2012a). The main scenario of demographic development for Vienna from 2001 to 2050 by Statistics Austria assumes the persistence of a strong international immigration, which is the single most important factor, expected shaping the demographic development in Vienna during the next decades (Statistics Austria, 2012a,b).

Future demand for new housing units will not depend solely on the quantitative development of the resident population but also on changing expectations regarding the quality of housing in terms

[1] The model is programmed in Java using the Eclipse IDE and cannot be made freely available since it uses non-free licensed data.