Conceptual approaches to regional residential location choice model for Wallonia

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Abstract

The aim of this discussion paper is the evaluation of conceptual approaches to residential location choice model at the regional level with its possible application in Wallonia in Belgium. The main question is the following: should this model be "completely regional", where the crucial parameters are set at the regional level, or might it be a regional "umbrella" of local models, which are elaborated at local scale? The study compares the existing state-of-the-art simulation frameworks with a current Belgian project and proposes the regional "umbrella" approach. The conclusion is that the alternative multi-scale approach is more flexible, though it needs more detailed data on demographic predictions and residential location preferences.

Keywords: residential location choice; residential relocation, logit, regional model; Wallonia

1. Introduction

This is a discussion paper focusing on the micro-simulation of residential location choice. While many advances in this field have been obtained with integrated modelling of land use and transportation, in this paper we deal with its land use component. The aim of the study is the evaluation of conceptual approaches to residential location choice model at the regional level with its possible application in Wallonia in Belgium, which experiences a profound regionalisation.

The applicable methodologies are referred to discrete choice and include random utility models: multinomial logit and nested logit. Multiple regression analysis is usable in auxiliary models supplementing residential location choice.

The main question approaching in the paper is the following: should this model be "completely regional", where the crucial parameters are set at the regional level or might it be a regional "umbrella" of local models, which are elaborated at the scale of particular cities and other areas?

In the geographical context of this paper, it is important to distinguish among the multi-level and multi-scale concepts (see e.g. Wagner and Wegener, 2007). The multi-level concept represents the relationships between a bigger level, for example the whole-European level, and smaller levels, for example urban levels, because a particular urban area is only a part of Europe. The multi-scale concept refers to the same area geographically represented with higher or lower degree of spatial resolution, for example a territory can be covered by zones or gridcells. Wegener (2011) suggests to work towards a theory of balanced multi-level urban models, where for each modelling task there is an appropriate level of conceptual, spatial and temporal resolution.

For a description of history of urban development and commuter movements in Belgium, see Verhetsel *et al*. (2010). Among the well-known problems in Wallonia are a continuing suburbanisation and an increasing daily mobility generating unsustainable effects on society and environment (Carpentier *et al*., 2011). Ageing of population influences individual and household daily behaviour and their residential location choice. In this reality, we find very actual the following general questions asked by Wegener (2011) in the context of energy scarcity: ‘‘Will there be a renaissance of public transport, walking and cycling?'', ''Will suburbanisation be halted or even reversed? '', ''Will there be a social divide between those who can maintain their mobility and those who must give up their cars?''.

The next section is a brief review of some literature sources on urban simulation, in particular about the random utility methodology, spatial resolution and regional modelling approach. Section 3 compares the existing state-of-the-art urban simulation frameworks UrbanSim and ILUTE with the Belgian project MOBLOC. Section 4 describes our proposals of the regional "umbrella" approach. The final section concludes.

2. Literature review

Among human-induced impacts, land use is second only to climate in its effects on the functioning of terrestrial and aquatic ecosystems (Grimm *et al*., 2008; Irwin, 2010). The models of urban and urbanised land use and transportation are widely used to simulate long-term urban development analysing the consequences of the existing tendencies and policies relating to land use, transport and environment. The ability of a land use model to capture market demand-supply interactions and to determine market prices endogenously is an issue of fundamental importance.

Such crucial elements of land use and transportation modelling as residential mobility and residential location choice should be regarded in complex with one another, even if empirically each one can compose a separate sub-module. For the conceptualisation of the complexity of the household's housing decision-making process, see Wong (2002). Typically, in the state-of-the-art micro-simulation systems, a decision to move and location choice are modelled separately by sequentially executed sub-modules: the first one identifies proportions of households to move and the latter sub-module allocates them among geographical units (Lee and Waddell, 2010).

Lee and Waddell (2010) in their literature review (which includes, among other studies, Clark and Huang, 2003) highlight the following three groups of household characteristics influencing mobility rates: life cycle of an individual (young adults in their twentieths and thirtieths are the most mobile population segment), significant life course events (the acts of household formation and dissolution and changes in education and work opportunities very often coincide with changes in residence), and housing size and tenure (the rates are lower for households in larger homes and home owners). Discussing recent research in transportation and land use modelling, Lee and Waddell (2010) note that there is a considerable list of studies on residential location choice, but a few contributions on residential mobility, e.g. Habib and Miller (2008) and Eluru *et al*. (2010). The latter study estimates the joint model of the reason for residential relocation and the duration of stay at a location.

In random utility models, choice alternatives are selected by individuals (or households) applying the utility function of alternative's attributes and individual's (or household's) characteristics. A random component is introduces to account for unobserved attributes and other sources of errors. Multinomial logit (MNL) proposes a consistent estimation of choice models applicable for residential location choice (see McFadden, 1978 and Ben-Akiva and Lerman, 1985).

Kim *et al*. (2005) is among recent applications of a Nested logit (NL) model to estimate the indirect random utility functions of the intention to move and residential location choice. Lee and Waddell (2010) apply a tow-tier NL model of residential mobility and location choice with random sampling of alternatives and sampling bias correction procedure. The nested structure includes a binomial mobility choice of stay or move at the top level and a multinomial location choice at the bottom level. Since the standard NL model does not ensure consistent estimation due to its divergence from the Independence of Irrelevant Alternatives assumption, Lee and Waddell (2010) address this problem applying a sampling correction procedure.

Data scale and resolution issues are in the core of vital discussions in the field of urban simulation. Historically, operational urban land use and transportation models have tended to be quite aggregated spatially, but the current trend is towards a finer spatial scale (Hunt *et al*., 2005). Usually land use and transportation modelling frameworks apply small spatial units for land use modules and bigger spatial units for transportation model. The highest spatial resolution is represented by gridcells, usually of a 100 by 100 metre size, as e.g. in ILUMASS (Wagner and Wegener, 2007) or UrbanSim (Waddell *et al*., 2003), or by land parcels, as in UrbanSim. At the upper level(s), traffic analysis zones (TAZs) and/or municipalities are modelled. In transportation model, both TAZs and municipalities can be used composing thus two levels of transportation analysis, as in ILUMASS. For some reasons, mainly due to the lack of detailed geographical data, land use models can use municipalities or other zones instead of gridcells or parcels. UrbanSim proposes a possibility to use any of the three levels in its land use modules: gridcell, parcel, or zone.

According to Hunt *et al*. (2005), an ideal model should be conceptualised at a very fine level of representation of actors and processes so as to maximise “behavioural fidelity”. In the discussion of Miller *et al*. (2004), a more disaggregate approach to modelling socio-economic processes such as travel behaviour and residential location is named as generally desirable as reducing model aggregation bias, enhancing its behavioural fidelity, etc. (Goulias and Kitamura, 1992). Waddell (2011) argue that the fact that the data are aggregated might make the models run faster, but does not avoid the messy data problem, obscuring the underlying errors. Instead, he suggests finding effective ways of using disaggregate data by imputing missing values.

The argumentation of Wagner and Wegener (2007) concerning why micro-simulation models are not a universal solution includes *the empirical limits*, when the marginal costs of obtaining micro data are larger than their added value, *the practical limits*, when the computing time of the models is too long, and *the ethical limits* to the collection of data about private lives. They suggest that future urban models will be multi-level in substance, space and time.

Wegener (2011) in his recent paper observes a trend towards increasing conceptual, spatial and temporal resolution stimulated by improved data availability, higher computer speed and better theories about mobility and location individual behaviour. However, he concludes that disaggregation has a price and that the principle ‘the more micro the better’ may be misleading. Among the mentioned problems are *the theoretical limits* to calibration and validation of micro-simulation models due to the stochastic variation of their results. Wegener (2011) underlines the relevance of the problems as new challenges, such as energy scarcity and climate change, will force modellers to focus more on basic needs and constraints. According to him, the future of urban transport and land use modelling is not refinement and detail, but the identification of the appropriate level of conceptual, spatial and temporal resolution.

While markets represent ‘‘the basic organizing principle for most interactions of interest within the urban area’’ (Hunt *et al*., 2005), it is important to delineate the geographical boundaries of these market areas and endogenous and exogenous elements of the processes.

The purely regional approach is not very often used in land use simulation. One of the examples is that of Oregon with its wide area, but only 3.9 million inhabitants. A Transportation Land Use Model Improvement Program was begun in the late 1990s, to provide the Oregon Department of Transportation with better information for state-wide policy decisions on transportation, land use and other issues. The micro-simulation model built on TRANUS framework is state-wide (Weidner *et al*., 2007). In the Toronto application of the ILUTE framework, an urbanised region of 5 million people is covered (Miller *et al*., 2004). A Belgian example is the project MOBLOC for modelling transportation and land use for the whole Belgium at municipal level (Carpentier *et al*., 2011).

According to Hunt *et al*. (2005), the components of urban production and consumption processes that are endogenous to urban areas should be modelled endogenously, while the model should be sensitive to such macro exogenous elements as interest rates, national migration policies, etc. Chang (2006) mentions demographics, regional economics, government policies and external effects as exogenous factors. The modelling frameworks MEPLAN and TRANUS are built around a regional input-output model; MUSSA takes output totals from a regional input-output model (Hunt *et al*., 2005). In most of other land use and transportation modelling tools, regional economic data are exogenous.

On the one hand, modelling larger areas has its advantages, taking into account such actual tendencies as increased mobility, longer daily trips and the development of a regional job market. On the other hand, the geographically spread uniformity creates inconveniences. For example, according to Carpentier *et al*. (2011), residential moves in Belgium are often short distance: for almost half of movers the distance between the previous and the new municipalities is less than 10 kilometres, and only for 10% of movers this distance is 50 kilometres or more. Nested logit methodology resolves this regional-local dilemma only partly, because the same model is used for the whole region.

3. Comparison of existing alternatives: UrbanSim, ILUTE and MOBLOC

In this section, we compare the existing state-of-the-art urban simulation frameworks UrbanSim and ILUTE with the Belgian project MOBLOC focusing on residential location choice (Table 1).

Table 1. Comparison of residential location choice models in UrbanSim, ILUTE and MOBLOC

Parameter	UrbanSim	ILUTE	MOBLOC
Territory covered	Urban agglomeration, metropolitan statistical area	Urbanised region (Toronto)	Belgium
Spatial resolution	Gridcell, parcel, zone (municipality)	Gridcell, building	Municipality
Unit of analysis	Household	Individual and household	Individual
Sample for estimation	10,000 households	No information	2,000,000 individuals
Residential relocation (propensity to move) model methodology	Monte Carlo simulation	No information	Binary logistic regression
Residential location choice model methodology	MNL, NL	Hybrid approach: rule-based search + random utility-based models (MNL, NL)	NL

UrbanSim's disaggregate nature is recognised in urban simulation literature (see Hunt *et al*., 2005; Iacono *et al*., 2008). In UrbanSim (Waddell *et al*., 2003), synthetic population is represented as households created on the base of household survey. Each household should contain the information about e.g. the number of persons, age, employment status, income, number of cars, etc. Strictly speaking, households in UrbanSim do not correspond to the concept of agents, because in this framework there is no such an element as behaviour, necessarily presented in agent-based models. The framework includes estimation and simulation. Regarding the household location choice model, the principle of modelling is as follows. In estimation, the known geographical distribution of households, which takes place in a base year, is explained with a Multinomial logit model or, in a recent version of UrbanSim, with a Nested logit model. UrbanSim proposes to estimate model with a random sample of 10,000 households. For simulation, exogenous demographic data for future years are necessary, these are population control totals. Annually, newly created households as well as some percentage of existing households (extracted by a household relocation model with Monte Carlo simulation) are spatially allocated using the model already estimated for the base year (Waddell *et al*., 2003). In multiple UrbanSim applications, often in interaction with transportation models, a metropolitan or an urban agglomeration level is addressed. Three approaches to geographical resolution are proposed by UrbanSim: each household resides in either gridcell or land parcel or zone (which can be e.g. a municipality). Buildings are also applied, but they are not geo-referenced, each building just belongs to some bigger territorial unit, e.g. zone.

ILUTE (Integrated Land Use, Transportation, Environment) is a fully agent-based, integrated micro-simulation model of urban system (Miller *et al*., 2004). Its land use modelling components include not only the evolution of the built environment and location choices of households and firms, but also the demographic evolution, both in response to endogenous population changes (fertility, mortality, household formation and dissolution) and to migration into and out of the region, and the simulation of the internal economy of the urban area (the labour market, the import/export and the internal exchange of goods and services). Individuals, households, businesses and establishments, which are all the primary agents, play their "roles" and make a variety of decisions. In the residential location choice model, both individual persons and households are the agents. ILUTE requires full information about every person in each synthesised household (age, sex, employment status, education level, role in the household, etc.), household vehicles, household dwelling unit and employment data (employment location, occupation, income). Moreover, ILUTE uses both households and families in its class design. The model operates on a "100% sample" (i.e. the entire population) of agents who, in the base case, are synthesised from disaggregate sample data together with aggregate data, such as census tables. In the ILUTE project, a hybrid approach has been adopted for choice models. Rule-based search processes are used to reduce large "universal" choice sets to a relatively small set of alternatives. Random utility-based models are then used to choose the alternative with a maximum utility. Two parallel approaches to spatial representation are being investigated by ILUTE: a grid-based (a 30 metre square) and a building-based. In the latter case, each building is geocodeed. With micro-simulation approach, ILUTE models market demand-supply interactions, particularly within the residential and commercial real estate markets. The framework investigates how to micro-simulate market interactions on an agent-by-agent basis rather than solve for aggregate market equilibrium conditions (Miller *et al*., 2004). As in UrbanSim, a path-dependency is implemented in ILUTE.

The MOBLOC project team (Carpentier *et al*., 2011) has created the modelling framework of residential location choice (with propensity to move model), transportation demand and accessibility for the whole Belgium with municipal spatial resolution. The propensity to move model is a binary logistic regression, this part of MOBLOC is more comprehensive than that of UrbanSim. Carpentier and colleagues use the BIOGEME logit model (Bierlaire, 2003) to evaluate the utilities of each of 589 Belgian municipalities as potential destinations for residential relocation. Nested logit is explored. The residential location choice model is estimated with two million individuals, which compose around 15% of country's population. The on-going SimBelgium-NAXYS project continues the approach of MOBLOC and simulates the population dynamics over a 30-year period using a virtual population for the complete Belgian territory, whose synthetic individuals belong to synthetic households.

In the next section, we discuss the proposal of the so called regional "umbrella" of the local models of residential location choice and its possible application in Wallonia.

4. Regional "umbrella" of local models

For simplicity, in this section we consider households as a unit of analysis. The demographic model should account for all the elements of demographic change: births, deaths, immigration and emigration. The dead households and those who are emigrating outside the analysed area, must be selected, randomly in the simplest case, and deleted. The relocation model selects households for relocation. The location choice model spatially allocates these relocating households and newcomers. We imply the application of Multinomial logit.

Regional level seems to be too large to capture market demand-supply interactions and to determine housing market prices. Market interactions and price formation processes are better pronounced at the levels of cities and rural areas. To simulate the consequences of policy changes in housing, infrastructure development, road pricing or parking issues, it is better to focus on local level. At the same time, many spatial interactions and regulations take place at regional level.

The idea is to combine a regional model of household relocation and location choice with the local models of the same types. Consider a region divided by zones. The description of the “traditional” approach and our proposals of the regional “umbrella” of local models are presented in Table 2.

Table 2. Regional “umbrella” of local models

Condition	Resulting location choice model	
	Traditional approach: The regional relocation model is run only for zones with unknown local control totals for population	Proposed approach: The regional relocation model is run for all zones
Local control totals for population are known in all zones	No regional location choice model, only a group of local location choice models	The regional location choice model distributes only relocating households
Local control totals for population are unknown in all zones	No local location choice models, only the regional location choice model	
Local control totals for population are known in part of zones	The regional location choice model is run only for the zones with unknown local control totals	The regional location choice model is run for all zones, but differently: - for zones with known local control totals it distributes only relocating households; - for zones with unknown local control totals it allocates relocating households and newcomers

If control totals for population, i.e. population in simulated years, are known in each zone, there is no need for a regional location choice model; and local relocation models and local location choice models can simulate the allocation of households *within* zones (provided the available local data). This is the approach, which we call “traditional”. We propose to apply the regional “umbrella” model even in this case in order to find relocatied households (and to ignore newcomers). It is demonstrated in Figure 1, where the selection of households by the regional relocation model as those relocating at regional level is shown with dashed lines. These relocating households compose the regional “pool”, which is then distributed among zones by the regional location choice model; this process is represented in Figure 1 with solid lines. These relocated households should not change the control total of each zone; they just give their attribute “relocated this year” to existing households, which can be randomly selected. Thus, we will know which households in each zone are recently relocated from other zones of this region. This information can be useful for relocation models and location choice models at both regional and zonal levels for future simulated years.

If local control totals for population in simulated years are unknown in all zones, it is the case of the “traditional” regional location choice model that will allocate the relocating households and newcomers, while it is impossible to run local models. In case of negative demographic dynamics a specific model is needed to select and delete the dead households and those emigrating outside the region. Figure 2 illustrates this process showing with thin solid lines the allocation of relocating households and with dotted lines the allocation of newcomers. There is no difference among zones regarding these two flows. Note that if only regional control totals are known, model validation at the local level is impossible.

If local control totals for population are known in part of zones, then according to the “traditional” approach, the regional location choice model can be run only for the zones with unknown local control totals. We propose to run the regional model for all zones, but differently for zones with known and unknown local control totals (Figure 3). For zones with known local control totals, the regional "umbrella" can distribute only relocating households (thin solid lines), which will not change zonal control totals, but will give their attribute "relocated this year" to existing households in zones with indices from 1 to *i*. For zones with known local control totals (zones with indices from *i*+1 to *N*) the regional model can allocate the relocating households and newcomers (both thick solid lines and dotted lines). Note that in the latter case it can be necessary to select and delete the dead and emigrating households.

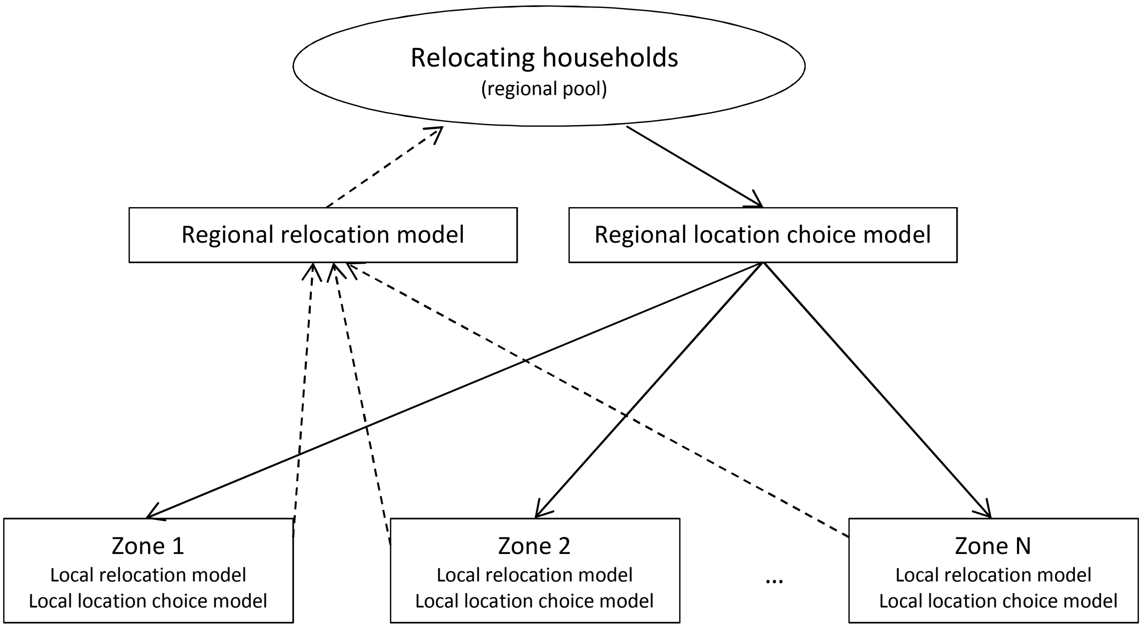

Figure 1. Regional "umbrella": local control totals are known in all zones

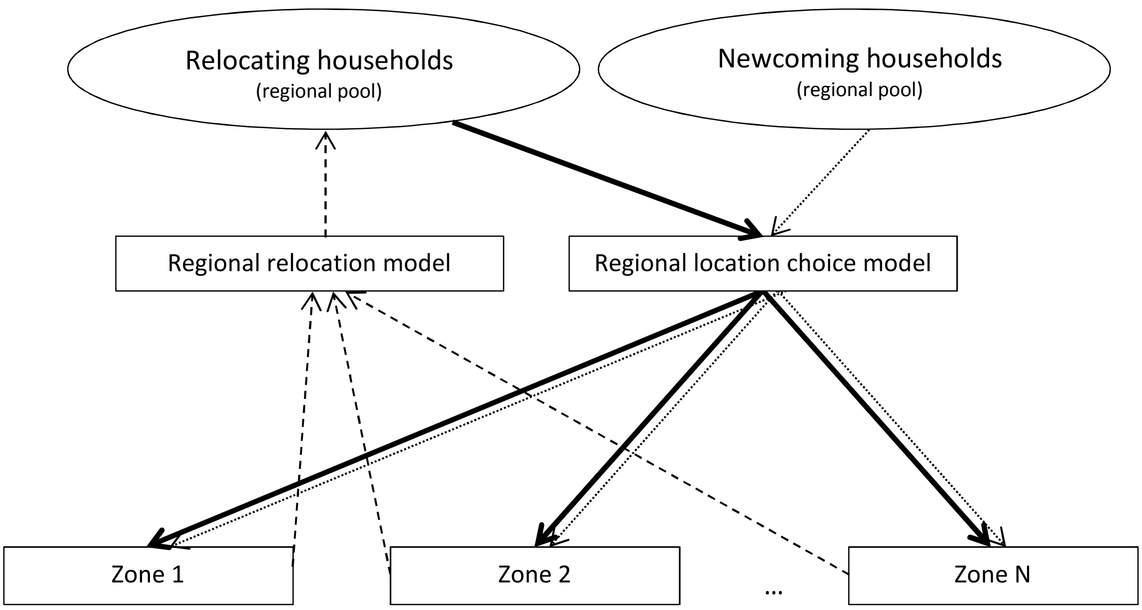

Figure 2. Traditional regional model: local control totals are known in all zones

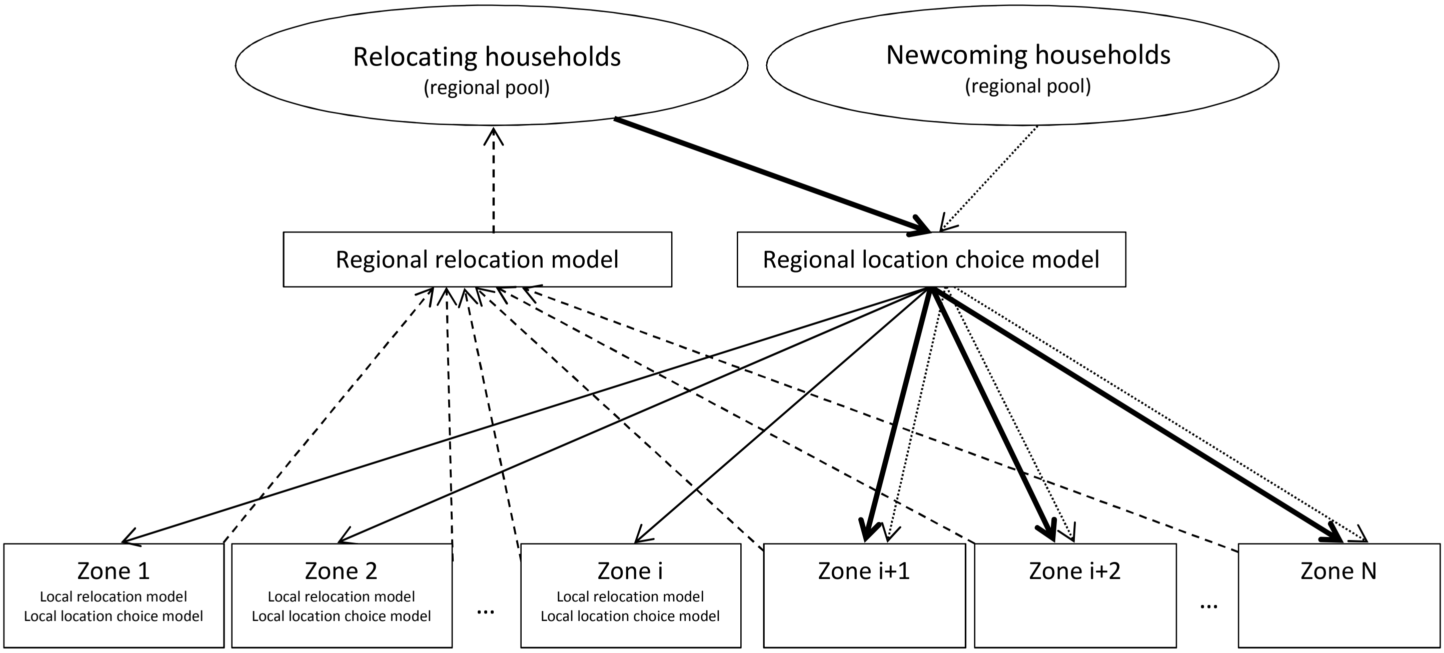

Figure 3. Regional "umbrella": local control totals are known in part of zones

The proposed multi-scale structure includes the three cases of interaction between the regional "umbrella" and zonal level. In all the cases, we will know which households recently relocated from another zone of the same region. This information can be accounted for in both local and regional models.

This "umbrella" approach provides an additional flexibility, as it can be applied simultaneously in areas with known control totals for population as well as in areas, where these data are absent. In the Walloon context, it is an important possibility to treat in different manner the areas, for which more demographic data exists (first and foremost these are urban areas), and the areas with more scarce data (usually these are more rural locations). The first type of areas can include, for example, the metropolitan areas of Liège and Charleroi (as in Verhetsel *et al*., 2010) or a bigger number of *arrondissements* or municipalities.

The use of local residential location choice models is stipulated by significant differences among the areas. For example, Verhetsel *et al*. (2010) demonstrate that 'the city regions' of Liège and Charleroi have very different commuting patterns: 22.8% of commuters in Charleroi belong to the 'train users' cluster, while only 6.6% of the Liège commuters are found there. Shucksmith *et al*., (2009) explore urban-rural differences in quality of life across the European Union analysing the European Quality of Life Survey. They found that twelve richest countries of the EU (including Belgium) show little evidence of significant urban-rural differences in household income and deprivation, in accommodation and even in commuting time, but the differences in unemployment and education indicators are higher (urban areas are characterised by both higher education level and higher unemployment).

The proposed multi-scale approach has the following advantages: it takes into account local housing markets; differentiates urban and rural peculiarities; focuses on local spatial interactions; considers local demographic tendencies in simulated years instead of using only the overall regional control totals for population; mirrors local socio-economic realities, first and foremost residential location choice preferences. The regional "umbrella" should provide regional interactions, such as relocation to another area within the region.

5. Conclusion

The paper describes the experience of the existing land use simulation frameworks, coming to more details on residential location choice models of UrbanSim and ILUTE, which are compared with the Belgian project MOBLOC.

As an attempt to find a trade-off between regional and local scales in simulation, our study proposes the concept of an alternative approach to modelling residential location choice at regional level as an "umbrella" covering local models. With this, residential relocation and location choice take place at both local and regional levels. As a result, additional information is obtained about residential relocation between the zones of the region.

The advantages of the proposed approach and its potential applicability in Wallonia are discussed. The proposed regional "umbrella" approach is more flexible than the traditional one, though it needs more detailed data on demographic predictions and residential location preferences.

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