# Investigating land-use and transport interaction with an agent-based model

Charles Raux*

Tai-Yu Ma

Rémi Lemoy

LET (Transport Economics Laboratory), CNRS and University of Lyon, 14 avenue Berthelot F-69363 Lyon Cedex 07, France

* Email: charles.raux@let.ish-lyon.cnrs.fr

## Introduction

The earth population is now predominantly urban, and urban areas are expanding fast (Seto et al. (2011)). Empirical evidence shows that various urban development patterns significantly influence carbon dioxide emissions (Glaeser and Kahn (2010)). Low density brings about increasing vehicle usage while both low density and increased vehicle usage bring about increasing fuel consumption (Brownstone and Golob (2009)). Compact urban development would be the natural answer to these issues but the debate regarding welfare, distributive and environmental aspects is fierce between opponents and promoters of compact cities (see e.g. Gordon and Richardson (1997); Ewing (1997)). The issue of spatial and social structure and operation of cities has never been so acute, and there is an obvious need to better understand city spatial development (Anas et al. (1998)).

A good starting point is the well-known urban economics framework: the Alonso-Muth-Mills (AMM) model integrates Alonso (1964) monocentric model of land market followed by Muth (1969) and Mills (1967, 1972) models, which include housing in the residential location model. The AMM model was developed to study the location choices of economic agents in an urban space, with agents competing for housing. Agents have a budget constraint (given by their income) and a transport cost to commute for work. Agents usually represent single workers, but they can also be used to describe households, which can be made more complex in further versions of the model.

This analytical framework has proved its robustness in describing the higher densities, land and housing rents in cities centers (Spivey (2008); Mills (2000)), despite the limitations of the model as shown in the summary by Brueckner (1987). These limitations are, among others, the city is mono-centric, urban residents all earn the same income and the commuting cost function is exogenous.

Polycentrism (or multiple centers) is a reality, as shown by empirical evidence (Giuliano and Small (1991)). However, introducing polycentrism in the AMM model proves difficult from the point of view of analytical tractability. A well shared conclusion of the literature is that numerical simulations are needed.

## Methodology

These difficulties have brought us around another modeling tool i.e. agent-based models. Agent-based models in urban economics are still in the infancy. Basically, agent-based models include three main components, i.e. agents, an environment and rules of behavior. The agents have internal states, some fixed and others that can change, like their preferences, and follow rules of behavior. The environment is defined as a two-dimensional space supporting resources and can include a communication network. Rules of behavior determine the interactions between agents, between agents and the environment and within the environment. In our model these rules are grounded in the urban microeconomic framework.

The agent-based simulation framework is used to define microeconomic interactions between agents (households) and shown to reproduce the results of the AMM model (Lemoy et al, 2010). The simulated model is dynamic: starting from a random initial state, interactions between agents on an urban housing market lead progressively the whole system to an equilibrium state.

Three kinds of outcomes are provided: economic with the utility of the agents; social by comparing the variation of utility of “poor” and “rich” agents and social segregation within the city; and environmental through the commuting distances travelled by the agents, given the current vehicle technology, and the size of the houses.

## Findings

The model is made more complex by adding various ingredients. The first ingredient is heterogeneity through income groups: an illustration is given with two income groups. The second ingredient is multiple centers, shown here with two job centers at various distances from each other.

The simplest way to study a polycentric city consists in defining two employment centers, separated by a distance *d*. Agents work at the center which is the closest to their housing, and as a consequence, can change jobs as they move. This last feature seems unrealistic but helps to concentrate on the effect of polycentrism per se. Figure 1 shows the evolution of different variables characterizing the outcomes of this polycentric model, such as agents' utility *Umean*, the total commuting distance of agents *Dtot*, the total rent *Rtot*, the mean price *Pmean* and the total surface of the city *Stot*, compared with the reference monocentric configuration given by the case $d = 0$.

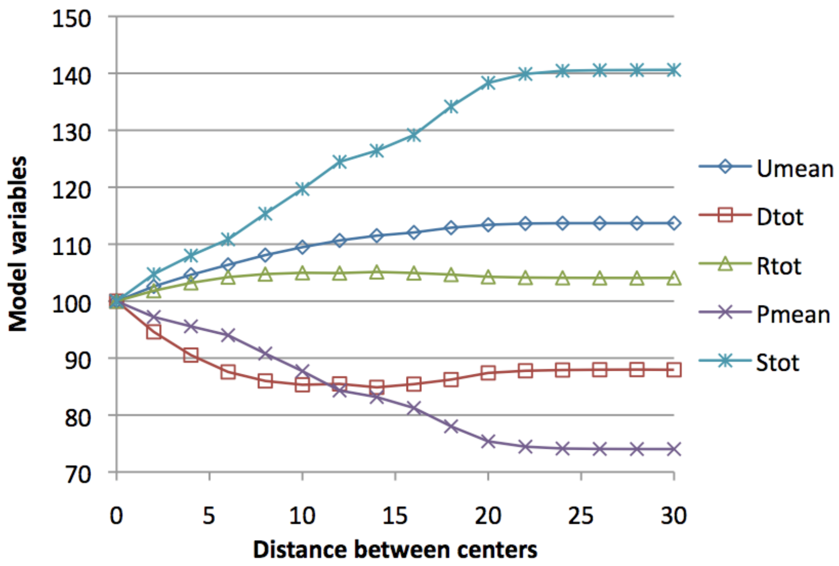


**Figure 1**

The economic outcome of the introduction of two centers is shown to be positive, as agents' utility increases when the distance between centers increases. However, pollution linked to commuting distances decreases first when centers are taken away from each other but then increases again. At the same time, the decreasing competition for land results in increasing housing surfaces and thus city size.

Then a more realistic ingredient is introduced, that is two-worker households whose partners may work in different job centers. Various distances between job centers and various mix in two-worker households are simulated. Regarding welfare it is shown that polycentrism is desirable, as long as centers are not moved too far apart from each other. The environmental outcome is also positive for small values of this distance but this positive effect is mitigated by the fact that housing surfaces increase, which may increase emissions of greenhouse gases.

These general results are obtained on an abstract city. Ongoing developments aiming at calibrating the microeconomic mechanisms against Lyon's data will be also presented at the time of the conference.

## References


Alonso, W., 1964. Location and land use. Harvard University Press.

Anas, A., Arnott, R., Small, K.A., 1998. Urban spatial structure. Journal of Economic Literature 36, 1426.

Brownstone, D., Golob, T.F., 2009. The impact of residential density on vehicle usage and energy consumption. Journal of Urban Economics 65, 91–98.

Brueckner, J.K., 1987. The structure of urban equilibria: A unified treatment of the Muth-Mills model, in: Mills, E.S. (Ed.), Urban Economics. Elsevier, North Holland. volume 2 of Handbook of Regional and Urban Economics. chapter 20, pp. 821–845.

Ewing, R., 1997. Is Los-Angeles-style sprawl desirable? Journal of the American Planning Association 63, 107–126.

Giuliano, G., Small, K.A., 1991. Subcenters in the Los Angeles region. Regional Science and Urban Economics 21 (1991) 163-182.

Glaeser, E.L., Kahn, M.E., 2010. The greenness of cities: Carbon dioxide emissions and urban development. Journal of Urban Economics 67, 404–418.

Gordon, P., Richardson, H.W., 1997. Are Compact Cities a Desirable Planning Goal? Journal of the American Planning Association 63, 95–106.

Lemoy, R., Raux, C., Jensen, P., 2010. An agent-based model of residential patterns and social structure in urban areas. Cybergeo: European Journal of Geography .

Mills, E.S., 1967. An aggregative model of resource allocation in a metropolitan area. American Economic Review 57, 197–210.

Mills, E.S., 1972. Urban economics. Scott, Foresman, Glenview, Illinois.

Mills, E.S., 2000. A thematic history of urban economic analysis. Brookings-Wharton Papers on Urban Affairs , 1–52.

Muth, R.F., 1969. Cities and Housing. University of Chicago Press.

Seto, K.C., Fragkias, M., Güneralp, B., Reilly, M.K., 2011. A meta-analysis of global urban land expansion. PLoS ONE 6, e23777.

Spivey, C., 2008. The Mills-Muth model of urban spatial structure: Surviving the test of time? Urban Studies 45, 295.