Transportation Research Part A 46 (2012) 1030–1053

Contents lists available at SciVerse ScienceDirect

Transportation Research Part A

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

Towards integrated land use and transportation: A dynamic disequilibrium based microsimulation framework for built space markets

Bilal Farooq [a,*], Eric J. Miller [b,1]

[a] Transport and Mobility Laboratory, Ecole Polytechnique Fédérale de Lausanne, GC A3 339, Station 18, CH-1015, Lausanne, Vaud, Switzerland
[b] Department of Civil Engineering, Cities Centre, University of Toronto, 455 Spadina Avenue, Toronto, Ontario, Canada M5S 2G8

ARTICLE INFO

Article history:
Received 1 October 2010
Received in revised form 27 February 2012
Accepted 18 April 2012

Keywords:
Microsimulation
Dynamic
Disequilibrium
Markets
Built-Space

ABSTRACT

Investigating the factors and processes that influence the spatiotemporal distribution of built space and population in an urban area, plays an extremely important role in our greater understanding of the urban travel behaviour. Existing location of activity centres, especially home and work, strongly influences the short-term individual-level decisions such as mode of transportation, and long-term household-level decisions such as change in job and residential location. Conditions in the built space market also affect households' and firms' location and relocation decisions, and hence influence the general travel patterns in an urban area. In this context, this paper addresses a very important, but at the same time, not very widely investigated dimension that plays a key role in the evolution of built space and population distribution: *Market*. A disequilibrium based microsimulation modelling framework is developed for the built space markets. This framework is then used to operationalize the Greater Toronto and Hamilton Area's owner-occupied housing market within Integrated Land Use Transportation and Environment (ILUTE) modelling system. Simulation results captured heterogeneity in the transaction prices, due to type of dwellings and different market conditions, in a very disaggregate fashion. The proposed methodology is validated by running the simulation from 1986 to 2006 and comparing the results with the historic data.

1. Introduction

A built space[2] market encapsulates the interaction of two different types of agents (seller and buyers) in the exchange of services, quasi-unique goods, and monetary transactions. The effect of interaction in the markets on the agents is the change in their utility and profit levels. Sellers are interested in selling/leasing/renting their services and goods, so as to achieve a gain in their profits. Buyers/renters are interested in buying/leasing/renting a space so as to achieve a gain in their total utility. The behaviour of a seller in the market is usually modelled using a profit function, while utility function represents the behaviour of buyer in the market. Modelling built space markets is very important in the context of understanding the evolution of urban systems in general and built space in particular, as they drive the pattern of population and space distribution in an urban area and represents the economic health of the region.

* Corresponding author. Tel.: +41 21 693 93 27; fax: +41 21 693 80 60.
E-mail addresses: bilal.farooq@epfl.ch (B. Farooq), miller@ecf.utoronto.ca (E.J. Miller).
[1] Tel.: +1 416 978 4076; fax: +1 416 978 7162.

[2] *Built space* is a generic term, used throughout this paper, to represent various types of spaces in an urban area that have a physical structure and associated monetary value; can be identified as individual quasi-unique units (based on their attributes and location); and provide opportunities for various activities. These spaces include: dwelling units, office spaces, retail spaces, industrial spaces, etc.

0965-8564/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tra.2012.04.005

Based on the price determination mechanism, built space markets in an urban area can be divided into two categories: *Price-taker* and *price-formation market*. In a price-taker market, a seller lists its built space at a certain asking price. The buyer is assumed to be a price-taker, that is, it accepts the asking price as is and determines the gain in its utility at that price. Based on the utility gains from various built space choices available to it, the buyer chooses an option. In terms of microsimulation modelling of such a market, the price-taker market clearing problem thus becomes a matching problem in which the modeller is interested in finding out "*who gets what*". The price determination and choice set formation models are exogenous to the clearing process. The agents are assumed to have limited information about the market and are individually profit/utility maximizers. At a given exogenously determined price surface for the built space stock and choice-sets of the buyer agents, the sequence of clearing in the market, guides the matching process. The most common example of a price-taker market is the rental housing market. Rent levels for the listed dwellings in the markets are fixed and are heavily regulated by the government (at least in the case of the Greater Toronto and Hamilton Area). The owners list their dwellings at a list price which they usually determine based on the quality of the space, location, and most importantly, the previous rent level. Each year, there is a steady rise in the rent of occupied dwellings which is based on the maximum rent increase allowed by the government. In rental housing markets, there is less dynamics in terms of the rent levels. In terms of market size, Giroux-Cook (2010) reported that there were 40,000–60,000 households active each year in the rental market in the GTA, between 1990 and 2006.

In a price-formation market, a seller lists its built space at a certain asking price, but, unlike the price-taker market, this price does not necessarily remain fixed during the clearing process. Each buyer generates its choice set based on factors including the asking price, minimum quality requirements from a built space, location, and various other needs. Buyers in the market bid for the built space so that they can outbid each other and at the same time achieve a maximum gain in their utility levels. Sellers, on the other hand, try to maximize their profit by accepting the highest possible bid. If the buyer cannot find a unit on which it can bid, so as to achieve a gain in its total utility, it may decide to leave the market. Similarly, if the seller does not get a good bid for its space, it may either leave the market or lower the asking price to generate more interest from the active buyers in the market. Thus, the resulting transaction price is a function of market interaction between the buyers and sellers and market conditions. In terms of microsimulation modelling of such market, the price-formation market clearing problem is a more difficult matching problem in which the modeller is interested in finding out "*who gets what at what price*". Given the current market conditions, the asking price captures the perception of a seller about the value that he can achieve from the built space he owns. Asking price is only a reference point for the final transaction price. Transaction price on the other hand, is an outcome of the market and is expected to be within certain range of the asking price. The buyers and sellers in price-formation markets are utility and profit maximizers, respectively. They are assumed to have limited information about the market and are non-cooperative agents. The most common example of price-formation market in the urban systems modelling context is the owner-occupied housing market. Builders and households list their new and existing dwellings in the market at certain asking prices. Based on their knowledge of the market, households that are looking for a dwelling in the market, choose a certain set of dwellings according to their needs and expectations from the dwellings listed in the market. Households bid on the dwellings, based on the maximum utility they can gain from the dwellings. This may result in the household with the highest bid becoming the new owner of the dwelling. At any time both buyers and sellers can leave the market if their expectations are not met. It should be noted that builders selling the stock of newly built dwellings may behave more rigidly and be better informed about the whole market than that of a household reselling its dwelling.

While the two types of housing markets discussed above are usually modelled separately due to the differences in the price mechanism, there is a strong two way interaction going on between both markets. At any time, these two markets are operating in parallel and households switch between the two as they learn more about each market. In some cases, if the rental market is more active than owner occupied-market, a household that was initially interested in selling the second dwelling may decide to rent it.[3] Thus, in any microsimulation modelling framework of built space evolution, one should carefully incorporate the two-way interactions between the two markets. In terms of a solution for the clearing of these two markets, the urban economics and integrated land use and transportation modelling literature is dominated by the approaches that impose some degree of strong market equilibrium assumption, so as to generate a unique price surface for the market (Anas, 1982, 1992, 1994, 1995, 1998; Putman, 1983; Echenique et al., 1990; Martinez, 1992, 1996a, 1996b; Anas and Arnott, 1993, 1994; de la Barra, 1995). While these approaches are easily operationalizable and exhibit well defined and well investigated properties, we think that the equilibrium assumption is an oversimplification of the market characteristics and behaviour of the agents in the market. In actual markets, agents have limited information about the market; they are individually utility/profit maximizers; they are non-cooperative among each others in the market; and their decisions are conditioned upon the sequence of decisions taken by them and other agents in past.

Based on the above observations, in a microsimulation clearing of housing market, potentially there could be infinite price surfaces, with each surface representing the sequence in which the market is cleared. The sequence itself is stochastic, depending on the previous and starting state of the market (as a system) and at any point, during the clearing, phenomena like who-gets-active-when and who-leaves-when. Moreover, there will always be households left in the active market that

[3] Such a situation may arise when a household who is looking to change its current dwelling, finds a new dwelling in the market, buys it, but has not yet been able to sell the current dwelling.