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On joint railway and housing development: Housing-led versus railway-led schemes

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ABSTRACT

This paper develops a time-dependent framework to analyze the revenues and costs of housing and railway developments over time in a Transit Oriented Development, explicitly capturing the housing and railway development phasing. A bi-level mathematical program is formulated, in which the upper level optimizes the housing supply and railway development over time based on the perspective of a joint housing and railway developer, versus that of consumers and that of government. At the lower level, a nested logit framework is formulated to model the combined bid-rent process, residents' location and travel choices in each period. Under certain assumptions, this study derives analytically the lead-lag relationships between housing development and railway development, based on the initial housing and transport conditions, as well as the stakeholders' perspectives. The development strategies are generally different among the stakeholders, whilst possible win-win situations, in terms of developer profitability and consumer surplus, are identified under certain low housing density conditions, leading to a social optimum. This study also conducts sensitivity analyses to extend the results to multiple time periods and heterogeneous income classes, revealing that, for profitability, the joint developer may introduce housing development phasing that segregates residents of different income classes.

1. Introduction

To provide sustainable transport services in a developing region, Transit Oriented Development (TOD) has been recognized as a financially favorable strategy to exploit the synergy between railway services and property developments nearby the railway stations. Nearby housing developments create new transport demands for the railway services. On the other hand, the housing rents or values of the TOD benefit from the increased accessibility introduced by the railway services (Cervero, 2007; Cervero and Murakami, 2009; Loo et al., 2010). A typical TOD involves massive investment and often takes a long time to plan, construct and operate. It is, therefore, important to study joint transport and housing supply over time to ensure that different stakeholders' perspectives are properly addressed. In the literature, most studies focused on the land use pattern or supply in a TOD for a single period. For example, Olaru et al. (2011) evaluated TOD characteristics, such as housing attributes, proximity of transport, using empirical analysis in Australia. Multi-objective programming models for TOD planning were applied to Taipei (Lin and Gau, 2006; Lin and Li, 2008). These studies incorporated relatively simple relations to describe the mechanism involved in housing supply, residential demand and transport usage. More recently, Peng et al. (2017) addressed the problem of determining the optimal location, number and sizes of TOD zones, and headway in

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a linear corridor using an amenity function. Yet, the above studies neglected the time-dependent nature of the TOD problem and hence the possible lead-lag effects between housing and railway developments. In this study, we incorporate the time dimension of TOD planning, considering the transport and housing supply strategies for different time periods, while analytically capturing their interactions over time.

TOD strategies can be broadly characterized by two approaches: railway-led and housing-led schemes. Railway-led development refers to the case that the railway is built first before substantial housing development. By constructing the railway first, typically invested by the railway sector, subsidized by the government, railway-led development increases the accessibility of the area, which in turn increases its land value and attracts property developers to develop housing. Housing-led development, on the other hand, takes the opposite direction. Housing is firstly developed to accommodate the initial population moving into the area. The railway operator then considers the financial viability of the new railway according to the potential demand and economic environment before committing to its construction. These two schemes exhibit different interactions between transport and housing supply over time. It is crucial to determine the timing and extent of the housing and railway developments in order to properly balance the benefits of residents having access to convenient and affordable transport services and the financial viability of the railway development. The lead-lag phenomenon between housing and railway developments was studied in Levinson (2008), which considered this "chicken and egg" problem between railway and land developments using empirical data in London over 13 decades. That study summarized the lead-lag phenomenon, namely, whether transport led housing or vice versa, based on different degrees of development in the area. In this paper, based on the combined bid-rent model developed, we derive analytical answers to understand the lead-lag phenomenon: basically, what conditions would lead to railway-led developments, or what to housing-led developments? The analytical results provide specific conditions to differentiate these two cases, which will be helpful to plan for future TODs.

The interaction between transport and land use has been studied for decades, for example: the bid-rent theory (Alonso, 1964), the hedonic price theory (Rosen, 1974), as well as the random utility theory (McFadden, 1978) and its extensions (Boyce and Mattsson, 1999; Eliasson and Mattsson, 2000). Subsequently, the stochastic bid-rent theory was developed to incorporate taste variations on the bid-rent function (Ellickson, 1981; Martínez, 1992; Martínez and Henríquez, 2007; Ma and Lo, 2012). More recently, the stochastic bid-rent theory and residents' discrete choices are integrated to capture the bidder choices as well as the auction process simultaneously (Chang and Mackett, 2006; Ma and Lo, 2012). This paper adopts the combined bid-rent and residents' location choices model developed in Ma and Lo (2012). Previous studies capturing the interaction between transport and land use, with different objectives, can be classified based on the static or the time-dependent framework. For the static framework, examples include road network improvement (Li et al., 2013), railway services improvement (Li et al., 2012), housing supply and network pricing (Ying, 2015), housing development (Ho and Wong, 2007; Ng and Lo, 2015) and joint railway and housing development (Ma and Lo, 2013). The static framework describes the long-term land use and transport interaction without considering the interim effects from the present to the eventual state, during which the economic environment and population may change. The time-dependent framework (e.g., Lo and Szeto, 2004, 2009; Szeto and Lo, 2006), on the other hand, is developed to analyze the development scheme over the planning horizon, with the costs and benefits, as well as the development phasing explicitly captured over time. There is a limited number of studies investigating the interaction between transport and land use using the time-dependent framework, such as for road network improvement (Ma and Lo, 2012) and road capacity improvement and tolls (Szeto et al., 2010). On the other hand, studies on the co-development and co-evolution between transportation network and land use have been developed using empirical analysis (Levinson and Chen, 2005; Levinson, 2008) and simulation approach (Levinson et al., 2007). Anas and Liu (2007) proposed a computational dynamic general equilibrium model of metropolitan transportation and land use. Yet, there is a need for theoretical analytical models to capture the governing conditions for TOD strategies.

With the time-dependent framework developed, the effects of additional housing supply, railway investment and railway improvement in each time period on the overall system performance can be explicitly analyzed. When additional housing is invested at a location in a particular period, it induces three effects on the rental or housing revenue. (1) The rent per unit will drop due to the supply effect, if everything else remains unchanged. (2) The revenue, on the other hand, will change as the number of housing units increases. (3) Additional housing supply will induce more residents to move in the region, which in turn will influence the rent via the presence of more people bidding for housing there. These three effects will influence the resultant rent, and thus the revenue and consumer surplus in that time period and onward. On the other hand, as the railway services are improved in a particular period, the fare revenue may increase, albeit it may not be sufficient to cover the massive railway improvement cost. But the improvement in rail services can attract more residents to move in the region who are willing to bid for higher rents, which indirectly helps to recover the railway investment cost.

This study aims to investigate the optimal transport and housing supply over time, subject to population growth in a time-dependent framework. Specifically, the lower level problem is formulated to encapsulate the combined bid-rent and resident location choices. At the upper level, stakeholders' benefits are maximized subject to population changes over time, with housing supply and railway services to be provided over time as the decision variables. The railway and housing developers, residents seeking housing, and the government are the main stakeholders in this study. Developers aim at maximizing their profits and residents maximizing their consumer surplus. The government considers social welfare, including the combined benefits for all: developer profit and residents' aggregated consumer surplus. This study considers the case of a joint partnership who develops both railway and housing, hence possibly allowing for cross-subsidization between housing and railway developments. The housing supply provided over the planning horizon is targeted to be able to cater to the population growth as predicted by population census. The railway service is targeted to be of quality, for example, to be within a