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Transit-oriented development in an urban rail transportation corridor

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ABSTRACT

Transit-oriented development (TOD) has been recognized as an important avenue for creating a green transportation system. This paper addresses TOD investment issue in terms of the location, number and size of the TOD zones along a rail line. An urban system equilibrium problem with TOD investment is first formulated. Two social welfare maximization models, which take into account different investment regimes for TOD projects (i.e., public and private), are then proposed for optimizing TOD investment schemes along a rail line and train service frequency on that line. In the public regime model, the government is responsible for the investment cost of TOD projects, which is borne by the private property developers in the private regime model. The proposed models explicitly consider the interactions among the government, property developers and households in the urban system, together with the effects of the TOD investment on households' residential location choices and housing market. The population thresholds for investing in a TOD project under the public and private regimes are also identified. The findings show that the TOD investment can cause population agglomeration at the TOD zones and a compact city; households and the society can benefit from the TOD investment; and the private TOD investment regime outperforms the public regime in terms of total social welfare of urban system.

1. Introduction

In response to rapid growth in the number of motorized vehicles and thus in traffic congestion, transit-oriented development (TOD) has been suggested as an effective tool for mitigating auto-related problems (e.g., traffic congestion and environmental issues) and controlling excessive urban sprawl (Cervero et al., 2004; Cervero and Day, 2008; Papa and Bertolini, 2015). TOD refers to medium- and high-density housing along with complementary public uses, jobs, retail, and services in mixed-use development around transit stations (Calthorpe, 1993). The TOD investment projects, as an important avenue for creating a green transportation system, have received considerable attention from the relevant authorities of many countries or regions in the world, such as United States, South Korea, and Hong Kong (Lund, 2006; Cervero and Day, 2008; Loo et al., 2010; Sung and Oh, 2011). Recently, the Chinese government has been developing the TOD projects in some densely populated cities, such as Guangzhou, Shenzhen, and Wuhan.

The TOD schemes can attract households to reside nearby transit stations by providing them with amenities for convenience, enjoyment, or comfort, and thus improve the land-use efficiency and the value of properties nearby transit stations

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Table 1
Contributions to the land use and transportation models.

Citation	Household's residential location choice	Housing market	Transit service optimization	TOD design in terms of location, number and size	TOD investment regime (public or private)
Eliasson and Mattsson (2000)	√	×	×	×	×
Chang and Mackett (2006)	√	×	×	×	×
Martínez and Henríquez (2007)	√	√	×	×	×
Li et al. (2012b)	√	√	√	×	×
Li et al. (2012c)	×	×	√	×	×
Li et al. (2013)	√	√	×	×	×
Ma and Lo (2013)	√	√	√	×	×
Li et al. (2015)	√	√	×	×	×
Ng and Lo (2015)	√	√	×	×	×
Wang and Lo (2016)	×	×	√	×	×
This paper	√	√	√	√	√

Note: "√" means that the associated item is considered, whereas "×" means that the associated item is not considered.

(Kay et al., 2014). The pedestrian-friendly environment inside TOD zones encourages residents to commute by public transit modes, which can effectively alleviate the auto-related problems (Cervero, 2007; Loo et al., 2010). However, the development of TOD neighborhoods around transit stations may be costly due to investment in the public amenities inside the TOD zones (e.g., pedestrian lane design, school, hospital, shopping centers and sports facilities) (for more details, see Nelson and Niles, 1999; Lee et al., 2016). This leads to a tradeoff between cost and benefit generated by the TOD investment projects.

In the TOD projects, the location, number and size of the TOD zones along a rail transit line play an important role in the cost and benefit analyses of the TOD investment. As a matter of fact, different locations, numbers or sizes of TOD zones on a rail transit line imply different residential distributions along that rail line and thus different passenger demands. They also imply different housing supplies and land development costs for the TOD facilities due to differential land values along the rail line and thus different costs and benefits of the TOD investment projects. Therefore, there is indeed a need to determine the optimal location, number and size of the TOD zones on a rail transit line such that the TOD investment projects are economic viable and cost-effective from an input-output perspective. The present study addresses the TOD investment issues for strategic planning purposes.

In the literature, there are some studies involving TOD design or investment issues (see e.g., Cervero, 1994; Bernick and Cervero, 1997; Cervero and Kockelman, 1997). However, these previous related studies mainly focused on the strategies and principles/rules for TOD design. For example, Cervero and Kockelman (1997) summarized the TOD strategies and design principles as high-density, mixed land use and pedestrian-friendly development around transit stations. Lund (2006) conducted a survey to find out the motivations that people move into the TOD zones and their travel mode choices. Cervero (2007) addressed the effects of TOD investment on the transit ridership of residents inside the TOD zones by using a statistical analysis method. Loo et al. (2010) revealed the important factors of affecting the transit ridership inside a TOD zone through a comparison of the case studies of New York and Hong Kong. Kay et al. (2014) carried out a hedonic regression analysis to examine the effects of the TOD investment and the amenities provided by the mixed land development on residential properties nearby the transit stations. However, these existing relevant studies usually adopted empirical and/or statistical approaches to address the TOD investment related issues, and few studies adopted an analytical modeling method. An exception is Lin and Gau (2006), which developed a multi-objective model to determine the optimal investment intensity (or the ratio of floor space to site space) inside a given TOD zone. However, their study only focused on a specific TOD station on a rail line, and did not concern the optimization problems of the location, number and size of the TOD zones along a rail line. The present study aims to fill the gap by developing an analytical model for investigating the TOD investment issues along a rail corridor.

In the literature, the interactions between urban land use and transportation system have been widely studied. For the convenience of readers, we have provided in Table 1 some principal contributions to the land use and transportation research, in terms of household's residential location choice, housing market, transit service frequency/fare optimization, and the TOD investment. Table 1 shows that the previous related studies have mainly focused on urban land use (in light of residential location choice and housing market) and/or transit service optimization issues. In particular, the studies of Li et al. (2012b), Ma and Lo (2013) and Li et al. (2015) incorporated the effects of rail line investment on the value of properties, households' residential location choices and housing market along the rail line. However, these relevant studies were not concerned with the TOD design problems in terms of the location, number, and size of TOD zones, together with the interactions among the TOD investment, households' residential location choices, and housing market. Some empirical studies (see e.g., Lund, 2006; Hess and Almeida, 2007; Duncan, 2011; Dröes and Rietveld, 2015) have shown that the TOD schemes can affect households' residential location choices and passenger demand distribution along the rail line, which in turn affect the decisions on the TOD investment and the train service frequency along the rail line. It is, therefore, important to consider such interactions among the TOD investment, households' residential location choices and train service frequency in the TOD design problems.

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