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Research Paper

Exploring synergies between transit investment and dense redevelopment: A scenario analysis in a rapidly urbanizing landscape

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ABSTRACT

Like many urban areas around the world, Durham and Orange counties in North Carolina, USA are experiencing population growth and sprawl that is putting stress on the transportation system. Light rail and denser transit-oriented development are being considered as possible solutions. However, local agencies and stakeholders are concerned the light rail may worsen housing affordability and have questioned whether investment in both light rail and dense redevelopment are necessary to achieve community goals. We developed an integrated system dynamics model to quantitatively explore the outcomes of these land use and transportation options across multiple societal dimensions. The model incorporates feedbacks among the land, transportation, economic, equity, and energy sectors. This paper uses the results of four model scenarios, run between 2000 and 2040, to address two main questions: (1) what role does redevelopment play in capturing the socioeconomic benefits of transit infrastructure investment? And (2) how do redevelopment and light-rail transit interact to affect housing and transportation affordability? We find that transit investment and dense redevelopment combine synergistically to better achieve the goals of the light-rail line, including economic development, mobility, and compact growth. However, housing affordability does worsen in the combined scenario, as transportation-cost savings are not sufficient to offset the rise in housing costs. We emphasize that model users may input their own assumptions to explore the dynamics of alternative scenarios. We demonstrate how spatially-aggregated systems models can complement traditional land use and transportation models in the regional planning process.

1. Introduction

The Triangle region of North Carolina, USA is a rapidly growing area currently facing a common challenge among cities around the world: a sprawling pattern of growth, leading to a growing separation between people's homes and their workplaces, putting added stress on the transportation system.

To address this issue, a light-rail transit system has been proposed to connect the town of Chapel Hill and city of Durham along a heavily-used commuting corridor (Fig. 1). In conjunction with this proposal, planners are considering rezoning for denser redevelopment around the proposed transit stations in order to concentrate growth and limit sprawl (Triangle Transit, 2012). The stated goals of the light-rail project include promoting economic development, improving mobility, and increasing compact, mixed-use development (Triangle Transit, 2012). However, local agencies and stakeholders are concerned that the light-rail line and associated economic and land development may worsen housing affordability and displace transit-dependent populations (Triangle Transit and TJCOG, 2013).

Local and regional planning organizations have jointly developed detailed land-use allocation and transportation demand models to forecast the impact of alternative transportation and land use scenarios (TJCOG, 2014; TRM Service Bureau and TRM Team, 2012). These are essential for long-range planning. However, because the existing models rely on static land-use, economic, and demographic projections, they do not address feedbacks and synergies caused by complementary policy options, and were not designed to address affordability and environmental impacts.

The Durham-Orange Light Rail Project System Dynamics (D-O LRP SD) model can both help fill this gap locally and demonstrates how spatially aggregated SD models generally can complement current land use and transportation-planning models. It identifies the mutually

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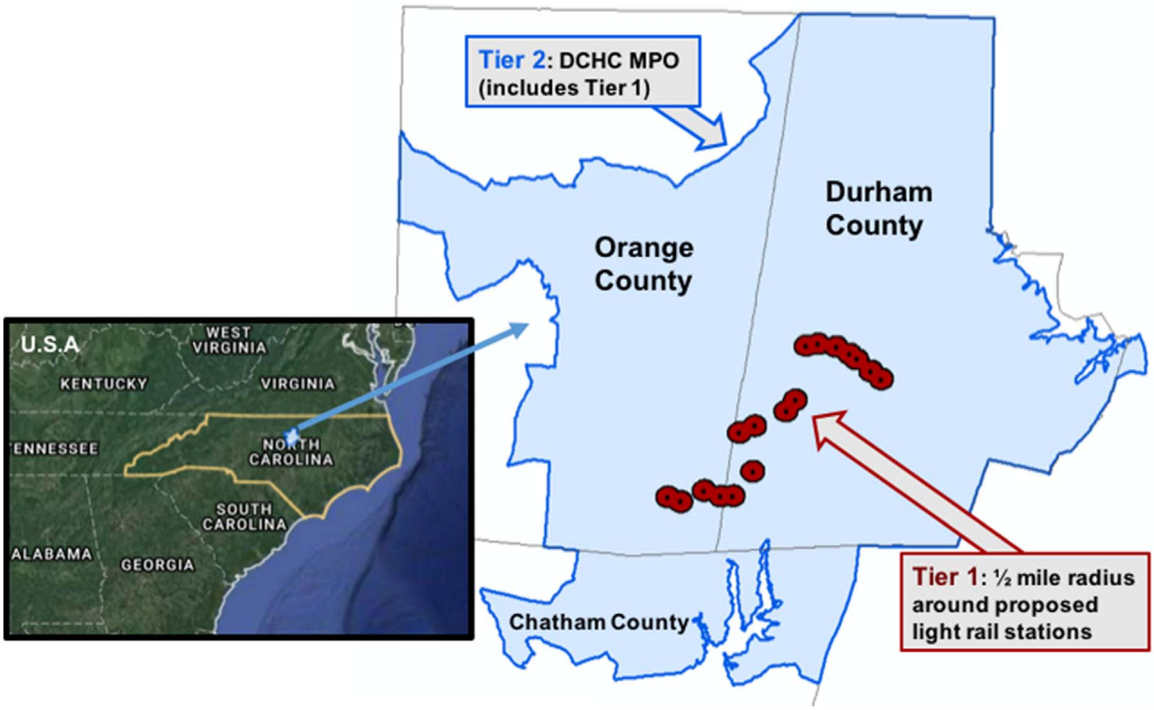

Fig. 1. Map of study area.

reinforcing relationships between compact development and transit investments and their social, economic, and environmental benefits and tradeoffs, and provides a prototype for how similar models could be constructed to suit other cases around the world. In this paper, we use results from four scenarios in the D-O LRP SD model to address two main questions: (1) what role does redevelopment play in capturing the socioeconomic benefits of transit-infrastructure investment? and (2) how do redevelopment and light-rail transit interact to affect housing and transportation affordability?

2. Literature review

Scenarios have been used to explore alternative futures in the land-use planning literature since the 1960s (Doxiades, 1966; Wallace-McHarg Associates, 1964). Though computer modeling has enabled scenarios to become more detailed, complex, and validated, the functions remain the same. Rather than forecast the future, scenario sets serve as a bridge between modelers and stakeholders and stretch users' thinking and perspectives, integrating knowledge to facilitate comprehension of a 'bigger picture' (Xiang & Clarke, 2003). More than just the outputs of computer models, scenario sets are curated from among the thousands possible, and interpreted to provide vivid narratives (Schoemaker, 1995; Xiang & Clarke, 2003). In this way, good scenario sets help to overcome cognitive biases and serve as a platform for consensus-building (Godet, 2000; Schoemaker, 1995; Xiang & Clarke, 2003).

In the 1990s, urban scenario planning began to use models that merged land use and transportation (Bartholomew & Ewing, 2009). Initially, these were treated using separate models, where the outputs of a land use model were used as inputs into a transportation-demand model (Aljoufie, Zuidgeest, Brussel, van Vliet, & van Maarseveen, 2013). However, that approach was limited in its ability to capture the dynamics of land use and transportation systems; relationships were traditionally unidirectional, and therefore did not allow transportation changes to affect land use, and their sequential processing did not allow for internal feedbacks (Haghani, Lee, & Byun, 2003). Increasingly, integrated models that allow bidirectional impacts are being developed, creating a class of tools called land use and transport interaction (LUTI) models (Waddell, 2011; Wegener, 2004).

A review of the literature shows there is growing interest in expanding LUTI models to address their implications for urban sustainability, as indicated by Geurs and Van Wee (2004). They reviewed LUTI models that incorporate sustainability indicators to some degree.

However, this approach has challenges. Because LUTI models require more data from a diversity of fields, it is challenging to quantify several social, economic, and environmental indicators with confidence. Conventional econometric and optimization models excel at simulating spatial and temporal development patterns on the basis of historical data (Santé, García, Miranda, & Crecente, 2010), and are less focused on how socioeconomic factors drive local land use and development (Han, Hayashi, Cao, & Imura, 2009). Geurs and Van Wee, 2004 (2004) concluded that contemporary LUTI models did not address macro-economic impacts of land use and transportation, nor many social or health effects. Finally, conventional models are not designed to address delays among urban activities, as optimization approaches primarily provide information on the optimal state of the system, rather than on transitions. This means that the models assume that urban systems are in a state of equilibrium, which is rarely the case (Haghani et al., 2003; Vina-Arias, 2013).

System Dynamics (SD) models complement traditional LUTI models by providing a simpler framework to capture the dynamic properties of systems through the explicit representation of feedback loops. By focusing on causal relations and simulating "what if" scenarios, they can more easily incorporate a variety of sustainability indicators (Sterman, 2000), and are therefore useful for evaluating responses to policy scenarios on transit investment and development (Han et al., 2009). In addition, their relative simplicity and low data-intensity make it easier to examine demographics, land use, transportation, water, and energy use in an integrated fashion (Rickwood et al., 2007). On the other hand, SD models are not spatially explicit and lack the detail that other models can provide. Therefore, the core contribution of SD models is the provision of a more comprehensive view of the urban system by integrating processes at different time scales (Abbas & Bell, 1994).

One of the first applications of SD was as a method to simulate