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Land use and transit ridership connections: Implications for state-level planning agencies

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ABSTRACT

In this article we attempt to establish the connections between transit ridership and land use and socio-economic variables, and project future ridership under different scenarios. We subdivided the state of Maryland, USA into 1151 Statewide Modeling Zones and developed a set of variables for the base year (2000). We estimated multiple models of transit ridership – using ordinary least squares and spatial error modeling approaches – for the entire state. We also test for the determinants of ridership within urban, suburban and rural typologies. We find that land use type, transit accessibility, income, and density are strongly significant and robust predictors of transit ridership for the statewide and urban areas datasets. We also find that the determinants and their coefficients vary across urban, suburban and rural areas. Next we used a suite of econometric, land use and other models to generate two sets of future transit ridership scenarios under conditions of – (a) business as usual and (b) high energy price – for a 30-year horizon. We analyze these scenarios to demonstrate the value of our approach for state-level decision-making.

Introduction

Planning for land use and transit in the United States often happens independent of one another. While land use planning is primarily done at the local level, the scale of transit planning depends on factors such as, the spatial extent of served areas, type and number of operating modes, and financing structure of the agency (Cervero and Landis, 1997; Badoe and Miller, 2000; Kitamura et al., 1997). This disconnect is evident in cases where, say, zoning restricts high-density development near transit stations. A number of studies implicate this lack of coordination to be in part responsible for the American auto-oriented landscapes and many underused transit systems (Volinski and Page, 2006; Shaheen et al., 2009).

Despite the potential to influence local decisions, larger scale planning agencies, such as state departments of transportation, have historically made few systematic efforts in harnessing the interdependencies between land use and transit. Consequently, the literature on frameworks of such coordination under existing governance structures remains underdeveloped (Garrett and Taylor, 2003).

Transit has been argued to be a catalyst to refocus developments in dense, mixed-use, and mixed-income communities (Badoe and Miller, 2000; Boarnet and Crane, 2001; Cervero, 1996; Cervero and Landis, 1997; Kitamura et al., 1997). According to these studies, proliferation of such communities can be associated with lower consumption of natural resources, residential and transportation energy savings, reduction in government expenditures in infrastructure and service provisions, and better resiliency to uncertainties in future energy prices. At the same time, higher densities and accessibility to transit is associated with better transit services and making higher ridership more viable (Tong and Wong, 1997; Messenger and Ewing, 1996; Moudon et al., 1997; Levine and Inam, 2004; Levine et al., 2005; Boarnet and Greenwald, 2000). Accordingly, researchers and practitioners have attempted to identify factors that encourage and sustain higher densities and transit use, such as design principles for new subdivisions, accessibility to stations and regional urban form, all factors influenced by local land use policy (Ewing and Cervero, 2001; Krizek, 2003; Miller et al., 1999; Heath et al., 2006). Advocates have promoted the incorporation of these ideas in urban plans and ordinances, and in transit siting decisions.

Many of these principles have been adopted at certain scales or in a piecemeal fashion. For example, land use change models consider transit services in determining development potential and attractiveness of land (Deal, 2001; Landis, 1994, 1995; Landis and Zhang, 1998; Waddell, 2002; Deal and Schunk, 2004), which could

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then be taken into account when planning for, say, transit-oriented developments or municipal zoning change (Cervero, 1994; Cervero et al., 1993; Taylor et al., 2004). Similarly, land use characteristics are routinely included in travel demand models that are sometimes used by transit planners.[1]

While the above approaches serve specific short-term, operational purposes, they have several planning limitations. Designed to further local objectives or resolve narrowly defined local concerns, most analytical approaches take factors that are beyond a local agency's control as givens. For example, land use patterns are often considered as exogenous inputs in a travel demand model (Boarnet and Crane, 2001; Boarnet and Sarmiento, 1998; Kockelman, 1997). By failing to consider the implications of variations in these factors more carefully, such approaches forego potentially richer analysis. Further, analyses that are limited to local scales fail to consider regional implications of local decisions and, by extension, their interaction with broader uncertainties. Land use patterns and transit provisions often have spatial, financial and other spillovers and it is the responsibility of larger scale agencies to balance negative regional externalities. For example, multiple transit agencies in a state may be looking to fund expansions of their own systems for a variety of reasons. Each may advocate in its own interest for state support. They might even compete for funds with yet other agencies, e.g. a municipality looking to support high-density land use development. However, a state agency with influence over both land use and transit ought to evaluate the overall outcome on its broader jurisdiction. The higher-level agency can harness possible interdependencies in making its own decisions by looking for trade-offs without regard to local interests and biases. Such analysis, however, needs a suitable analytical framework.

In this article, we develop such a framework. Using transit ridership as the key measure, we test how different outcomes in different futures may present a state agency with specific choices regarding planning. We chose the state of Maryland in the United States as our study area. Using a number of criteria, we subdivide the state into 1151 statewide modeling zones (SMZs) and, for each SMZ for the base year (2000), estimate a range of variables, including developed land under different uses, population and employment densities, developed land densities by industry category, auto-ownership, household income density, workers per household, free-flow and congested speeds of the existing transportation infrastructure, current transport capacities, and accessibility to different transport modes. Using the statewide SMZ dataset, we estimated ordinary least square and spatial error regression models for the base year data. We also model the relationships on subsets of SMZs representing urban, suburban and rural typologies. We find that characteristics of land use, transit accessibility, income, and density are strongly significant and robust predictors of transit ridership for the statewide and urban areas datasets.

We then used a suite of econometric and land use models to generate two sets of development outcomes for a planning horizon year (2030) – one under 'business as usual' conditions and the other under 'high-energy prices'. We use these conditions and our key ridership model to generate two distinct sets of scenarios for future transit ridership. The scenarios are constructed to separate the choices over which the decision-makers can exercise some control, from uncertainties or regional forces that are beyond their control. Drawing upon their differences, we discuss how such analysis can inform decision-making.

We proceed as follows. In the next section, we establish the connections between transit ridership and land use through a review of modeling practices to derive and frame the key planning questions. In the following section, we discuss the datasets, the rationale behind the choice of our study area, and the modeling framework for our empirical analysis; and in the next two sections, we present findings of this analysis and apply our model to develop scenarios for the horizon year and discuss implication for state level decisions, respectively. We offer concluding remarks in the final section followed by caveats and future scope of research.

Existing research on transit ridership modeling and decision making

Ridership is a commonly used measure to capture the effect of clustered development, diversity, density, transit supply, system efficiency, and surrounding land uses on transit use. Studies abound that attempt to model ridership on a variety of factors (Kockelman, 1997; Boarnet and Crane, 2001; Du and Mulley, 2007; Lin and Gau, 2006). However, for specific considerations on how ridership varies with land use and what that means for state level choices, we organize the available literature in the following streams: (1) land use considerations in transit models; (2) the lessons from, and limitation of such models in large-scale decision making; and (3) ongoing practices in large-scale decision-making.

Ridership estimation models are frequently studied in public transit and have been reviewed multiple times (see, for example, Kain and Liu, 1999; Abdel-Aty, 2001; Wang and Skinner, 1984; Horowitz, 1984; Taylor et al., 2004; Ben-Akiva and Morikawa, 2002). Not surprisingly, these studies are framed for transit agency related questions and purposes. Taylor et al. (2009) group ridership determination factors into two categories from a transit agency perspective: external and internal. External factors include population, economic conditions, auto ownership levels, and urban density; all factors over which agency managers have no control. Internal factors, in contrast, allow transit agency managers to exercise some control. They include the amount of service the agency provides, the reliability of service, service amenities, and fare. Taylor et al. (2009) show that understanding the influence of these factors is important to transportation system investments, pricing, timing, and deployment of transit services.

Studies about the influence of external factors on ridership have employed a variety of methodological approaches, including case studies, interviews, surveys, statistical analyses of characteristics of a transit district or region, and cross-sectional statistical analyses. These studies find that transit ridership varies depending upon a number of factors, such as (i) regional geography (e.g. total population, population density, total employment, employment density, geographic land area, and regional location) (Ong and Blumenberg, 1998; Kuby et al., 2004; Hsiao et al., 1997; Wu and Murray, 2005; Zhao et al., 1997; Polzin et al., 2002; Peng and Dueker, 1995), (ii) metropolitan economy (e.g. median household income, income distribution) (Ingram, 1998; Cohn and Canada, 1999; Frisken, 1991; Thompson and Brown, 2006; Fujii and Hartshorni, 1995; Yoh et al., 2003; Hirsch et al., 2000; Kyte et al., 1988; Cervero et al., 1993), (iii) population characteristics (e.g. percent of captive and choice riders, or household with zero cars) (Cohn and Canada, 1999; Polzin et al., 2000; Ewing, 2008; Davies, 1976), and (iv) auto/highway system characteristics (specifically non-transit/non-single occupancy vehicle trips, including commuting via carpools) (Cervero, 2007; Lisco, 1968; Holtzclaw et al., 1994; Taylor and Fink, 2002; Gómez-Ibánez and Fauth, 1980). They also

[1] The most common of these is the Four-step Travel Demand Model (TDM). Used for decades to determine both highway and transit demand, developing reliable TDMs can be expensive and time-consuming and require extensive computational effort. Modeling transit ridership component is particularly complex, as it requires creating a virtual transit network, conducting ridership surveys, and incorporating routes, stops, headways, and fare-matrix returns. As a result, only the transit planning agencies that have considerable resources use these practices.