Journal of Transport Geography 52 (2016) 61–72

Contents lists available at ScienceDirect

Journal of Transport Geography

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

A latent class method for classifying and evaluating the performance of station area transit-oriented development in the Toronto region

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ARTICLE INFO

Article history:
Received 6 May 2015
Received in revised form 20 February 2016
Accepted 26 February 2016
Available online xxxx

Keywords:
Transit-oriented development (TOD)
TOD typology
Transportation and land use planning
Latent class analysis
Model-based clustering

ABSTRACT

Transit oriented development (TOD), which is generally understood as the provision of higher-density, mixed-use, amenity-rich, and walkable development around rapid transit stations, has been championed as one of the most effective solutions for maximizing the potential return on investment for existing and future rapid transit infrastructure projects. But it is clear that not all implementations of TOD are the same in every station catchment area across a transit network. This heterogeneity in station area contexts presents significant complexity for planners and policymakers interested in understanding existing TOD conditions, an area's TOD potential, and the relevant policy and planning interventions required to achieve planning goals. It also creates complications for researchers interested in associating station contexts with various TOD outcomes.

In response, the present paper develops a model-based latent class method for distilling measures of station area TOD inputs into a set of more homogeneous station types. Its application to 372 existing and planned rapid transit stations in the Toronto region reveals a typology of 10 distinct TOD contexts across a number of present and future transit lines. The end result is an empirical tool for policy evaluation and prescription that can be used to benchmark and compare performance of TOD inputs around existing and planned transit stations and offers a foundation for further research into the relationship between TOD inputs and outcomes. Furthermore, the use of latent class analysis improves on the previous literature in this area by offering model results that are easily interpretable and extendable to other applications.

1. Introduction

Much has been written about transit-oriented development (TOD) over the previous two decades. While there is no standardized definition of TOD, the concept generally refers to dense, mixed-use, and pedestrian friendly development oriented to rapid transit. When done correctly, with development *oriented* to transit and not merely transit *adjacent* (Renne, 2009a), the potential benefits of coordinated transportation and land use planning through TOD are abundant.

Higher levels of population and employment densities create a larger market for transit ridership, both inbound and outbound, which can increase farebox returns and help balance flows on the transit network. Mixing of land uses increases the potential for interaction between origins and destinations and reduces the distance between them, and pedestrian-friendly urban design, or the provision of more 'complete' streets, facilitates walking among these different land uses and to and from the transit station.

Built environment factors associated with implementations of TOD have been shown to come together to promote high levels of internal trip capture rates, greater transit ridership, and reductions in household vehicle kilometres/miles travelled (VKT/VMT) compared to single-use suburban developments (Ewing et al., 2011). More complete streets can also increase cycling for short- to medium-distance trips (Pucher et al., 2011). Furthermore, the benefits of TOD are self-reinforcing. A network of TODs can help to create more opportunities at origins and destinations linked by transit, potentially reducing the need for the private automobile. TOD factors can promote more active and healthy lifestyles and reduce transportation-related greenhouse gas emissions.

For individuals these benefits can be appealing for improving quality of life. This could include potentially lower household transportation costs or an avoidance of road congestion-induced stress (Gottholmseder et al., 2009; Stutzer and Frey, 2008). TOD can also allow individuals to express lifestyle preferences, with the concept viewed as particularly attractive to the young and empty-nesters (Cervero, 2004; Dittmar et al., 2004), population cohorts Foot (1998) refers to as the 'echo boomers' and 'baby boomers.' The benefits of transit accessibility and transit-oriented land use planning can also be priced into the urban land market (Bartholomew and Ewing,

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http://dx.doi.org/10.1016/j.jtrangeo.2016.02.012
0966-6923/

2011), resulting in higher property values for owners and potential profits for developers.

For planners and policymakers in regions, municipalities, transit agencies, or metropolitan planning organizations, which will be the primary focus of this paper, the promotion of TOD around transit stations is quite simply a great way to maximize the return on investment for present and future rapid transit infrastructure projects. TOD can help to achieve a host of social, economic, and environmental goals associated with factors such as intensification, revitalization, transport and land use sustainability, and equitable mobility. Furthermore, positive changes in land values from transit and TOD can be tapped to finance the transit infrastructure itself as part of a land value capture program.

Nevertheless, there is likely to be great diversity in implementations of TOD in a rapid transit network across a city or region. This creates complexity for positive assessments of existing TOD conditions, as well as in normative evaluations of a station area's TOD potential. Here, while the concept of TOD is seemingly general in its prescriptions for policy and planning, implementations of TOD should be sensitive to existing conditions and customized to achieve particular policy and planning visions for specific areas. Likewise, for researchers, changes in travel behaviour, land values, or other outcomes associated with TOD are not likely to be distributed evenly across a set of heterogeneous transit station contexts in a transit system.

How can the complexity of station-area contexts be reduced to achieve a better understanding of their diversity and associated outcomes? One emerging tool that has helped to understand this diversity is the production of station and TOD typologies, wherein characteristics of heterogeneous station areas are quantified and input into clustering models to distill such characteristics into more homogeneous station types. From there, planners and policymakers can use this information to evaluate the performance of existing conditions against TOD expectations, and derive context-sensitive policies to promote TOD and achieve broader planning goals.

The present research continues this tradition by creating a prescriptive performance measurement tool for planners and policymakers and applying it to the Toronto region. However, the paper improves upon previous research by proposing a probabilistic method for measuring and classifying station area TOD. Using a sample of 372 stations along present and planned rapid transit lines in the Toronto region, we first distill station area TOD into several quantifiable measures. Second, instead of the more traditional heuristic or exploratory methods used previously, we utilize model-based latent class clustering methods to arrive at an empirical estimation of the number station types and their individual characteristics.

For planning and policy applications, the result is a method that can be used first as a performance measurement tool for planners and policymakers to assess TOD around existing rapid transit stations. Second, the tool can also be used to analyze present TOD conditions around future stations, thereby offering benchmarks against which changes to land use and transportation policy and planning can be developed to fully capitalize on these investments. Furthermore, for research and practice, the method can be adopted to better capture the TOD context of transit station areas and associate them with other observed patterns or changes.

Note that performance here is used to refer to the degree to which existing conditions align with the potential of the TOD concept, specifically the performance of TOD *inputs*. We also offer an analysis of TOD *outcomes* associated with travel behaviour and socio-and economic and demographic indicators. However, because the present paper is focused on detailing a method for constructing TOD typologies this analysis is necessarily high-level. More detailed evaluation of other TOD outcomes is an avenue for future research but beyond the scope of the present paper.

The paper proceeds by first offering brief background information on the case of transit and TOD planning in the Toronto region and a review of previous TOD typology approaches in the literature. Next, we present a methodology for quantifying TOD and producing TOD typologies through the use of latent class analysis and discuss the merits of the method compared to other clustering approaches. Finally, we explore model results, define station clusters, and examine performance outcomes across station types. The paper concludes with a reflection on contributions and limitations and a discussion of the wider applications of the method outside of Ontario.

2. Background

2.1. Present and future rapid transit infrastructure projects in the Toronto region

The study area selected for the present research is that of the Toronto region, which consists of the City of Toronto and several surrounding municipalities. This region is an ideal case for developing a TOD typology as there are several existing rapid transit lines and a large number of new projects in various stages of construction and planning. We focus here on 18 separate projects (Fig. 1): 56 km of existing Heavy Rail Transit (HRT) across 3 Toronto Transit Commission (TTC) lines with another 40 km over 4 lines under construction and in planning, 360 km of existing Commuter Rail Transit (CRT) over 7 GO commuter lines with a 2.5 km extension presently under construction, 120 km of Light Rail Transit (LRT) over 9 lines and extensions under construction and in planning, and 43 km of Bus Rapid Transit (BRT) across 2 lines scheduled to open in segments over time. Given the historically fluid nature of transit planning in the region, other projects could be considered. But due to issues of data availability or service characteristics for specific lines in planning we limit our study to this sample. Across the selected lines are 372 individual rapid transit stations, which creates a significant amount of complexity in understanding existing and potential TOD contexts within their catchment areas. Our TOD typology seeks to reduce this complexity by identifying comparable station classes.

2.2. Previous TOD typology approaches

The recent literature demonstrates emerging interest in developing typologies of rapid transit stations as tools for informing policy prescription and evaluation. There are two related approaches to conceptualizing and estimating transit station typologies. The first is normative in nature, cognizant of the complexities involved in TOD implementation. The second is concerned with a positive classification of stations according to their TOD characteristics.

2.2.1. Normative TOD typologies

A primary consideration in much of the TOD literature is that while the concept itself is general in its prescriptions, the scale of TOD and its expected outcomes should be customized to different contexts. This notion was crudely recognized in Calthorpe's pioneering work where he argued for ‘urban’ and ‘neighbourhood’ scale TOD implementations. Recognizing that there can be no ‘one-size-fits-all’ approach to TOD, and that the intricacies of urban areas required a more sophisticated approach than that outlined by Calthorpe (1993), Dittmar and Poticha (2004) later produced a TOD-centric typology consisting of 6 hypothetical TOD contexts: urban downtown, urban neighbourhood, suburban centre, suburban neighbourhood, neighbourhood transit zone, and commuter town centre. This typology is normative in the sense that it outlines the general characteristics of what different TOD contexts should look like in terms of factors such as densities, housing types, and transit service.

However, realizing the promise of such a normative typology of potential TOD depends first on a positive assessment of existing TOD conditions if planners and policymakers are to derive context-sensitive solutions. Many cities have undertaken a broad assessment of existing station area characteristics to produce their own ideal or potential TOD typologies, and in some cases the resulting typology is