A VALUE PLANNING FRAMEWORK FOR PREDICTING AND RECAPTURING THE VALUE OF RAPID TRANSIT INFRASTRUCTURE

A VALUE PLANNING FRAMEWORK FOR PREDICTING AND RECAPTURING THE VALUE OF RAPID TRANSIT INFRASTRUCTURE

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ABSTRACT

Land value capture (LVC) has been used to capitalize on the symbiotic relationship between rapid transit and its potential land value uplift (LVU) benefits for more than a century. For the public sector in particular, the rationale to engage in LVC to recapture the ‘unearned increment’ is strong. While interest in LVC has wavered over this time, planners and policymakers in Ontario and around the world are increasingly looking to value capture as a potential solution for raising more revenue to fund the construction and operation of rapid transit projects.

However, significant theoretical, conceptual, and practical gaps remain in our knowledge of LVU and LVC that prevent the wider adoption of value capture as a strategy. First, a fundamental flaw in applications of LVC is that the value increment caused by rapid transit must to some degree be known *a priori* to set benchmark levels and ensure LVC tools capture the actual changes in land values caused by the project. Yet despite a rich history of research into the LVU benefits of rapid transit in cities around the world, a method for arriving at more empirical predictions of future LVU beyond simple approximation remains elusive.

This leads to a second issue. Previous research into the LVU effects of rapid transit has produced a body of work that exhibits significant heterogeneity in results. Such diversity in research outcomes is due to a singular focus on expectations of LVU from rapid transit accessibility, which has led previous research to ignore the potential for additional land value impacts from sorting into different bundles of transit-oriented development (TOD) based on individual preferences. As such, the results of previous

studies consider the value placed on a bundle of transit and TOD characteristics. This context-dependency makes them unsuitable for extensions to estimate the potential for LVC in future transit corridors.

To overcome these issues, the present dissertation develops a value planning framework for rapid transit. This is accomplished through five objectives. First, Chapter 2 establishes a theoretical framework for understanding the LVU effects of rapid transit accessibility and TOD. Second, Chapter 3 develops a typology of station area TOD to reduce the complexity of station area heterogeneity and control for such contextual factors in further research. Third, Chapter 4 applies the TOD typology to unbundle the LVU effects of existing rapid transit in the City of Toronto. Fourth, Chapter 5 develops the value planning framework to better conceptualize the drivers of LVU benefits and capturable revenues, the policy interventions to maximize them, and the beginnings of a model to utilize unbundled estimates of LVU in other study areas to derive context-sensitive predictions of LVU in future transit station areas. Finally, Chapter 6 conducts a theoretical application of the value planning framework to the case of a light rail transit line in Hamilton, Ontario, to demonstrate a rationale for engaging in value planning to promote value capture.

In accomplishing these objectives, the present dissertation makes a number of contributions to research and practice. However, it also raises a number of questions for future research. Nevertheless, this work presents a significant first step towards realizing research on rapid transit's LVU effects that is more theoretically comprehensive and practical for better informing LVC planning and policy around the world.

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LIST OF ABBREVIATIONS

AMM	Alonso-Muth-Mills Model
ARN	Assessment Roll Number
BIC	Bayesian Information Criterion
BRT	Bus Rapid Transit
CBD	Central Business District
CCD	Census Collection District
CRT	Commuter Rail Transit
CTOD	Center for Transit-Oriented Development
DA	Dissemination Area
GGH	Greater Golden Horseshoe
GIS	Geographic Information System
GTFS	General Transit Feed Specification
GTHA	Greater Toronto and Hamilton Area
HRT	Heavy Rail Transit
LRT	Light Rail Transit
LVC	Land Value Capture
LVU	Land Value Uplift
MPAC	Municipal Property Assessment Corporation
MTO	Ministry of Transportation of Ontario
PPP	Public-Private Partnership
SAD	Special Assessment District

TIF	Tax Increment Financing
TJD	Transit Joint Development
TOD	Transit-Oriented Development
TTC	Toronto Transit Commission
VKT/VMT	Vehicle Kilometres/Miles Travelled

PREFACE

The present dissertation is a compendium of five substantive chapters either accepted, submitted, or in preparation for publication in peer-reviewed journals. For this reason, there is some element of repetition among chapters, particularly as it relates to overlap in common methodologies. While all chapters are co-authored with the primary supervisor, sole responsibility for the content of each chapter rests with the dissertation author.

These substantive chapters are as follows:

Chapter 2:

Higgins, C. D., & Kanaroglou, P. S. (2015a). 40 Years of Modelling Rapid Transit's Land Value Uplift in North America: Diverse Methods, Differentiated Outcomes, Debatable Assumptions, and Future Directions. *Submitted to Transport Reviews.*

Chapter 3:

Higgins, C. D., & Kanaroglou, P. S. (2015b). A Latent Class Method for Classifying and Evaluating the Performance of Station Area Transit-Oriented Development in the Toronto Region. *Submitted to the Journal of Transport Geography*.

Chapter 4:

Higgins, C. D., & Kanaroglou, P. S. (2015c). Unbundling the Hedonic Price Effects of Rapid Transit and Transit-Oriented Development in Toronto. *In Preparation*, *Journal TBD*.

Chapter 5:

Higgins, C. D., & Kanaroglou, P. S. (2015d). Value Planning for Rapid Transit: Towards a Method for Predicting and Maximizing Land Value Uplift and Capture in Station Areas. *In Preparation*, *Journal TBD*.

Chapter 6:

Higgins, C. D., & Kanaroglou, P. S. (2015e). Rapid Transit Value Planning in Practice: Potential Value Uplift and Capture from Light Rail Transit in Hamilton, Ontario. *In Preparation*, *Journal TBD*.

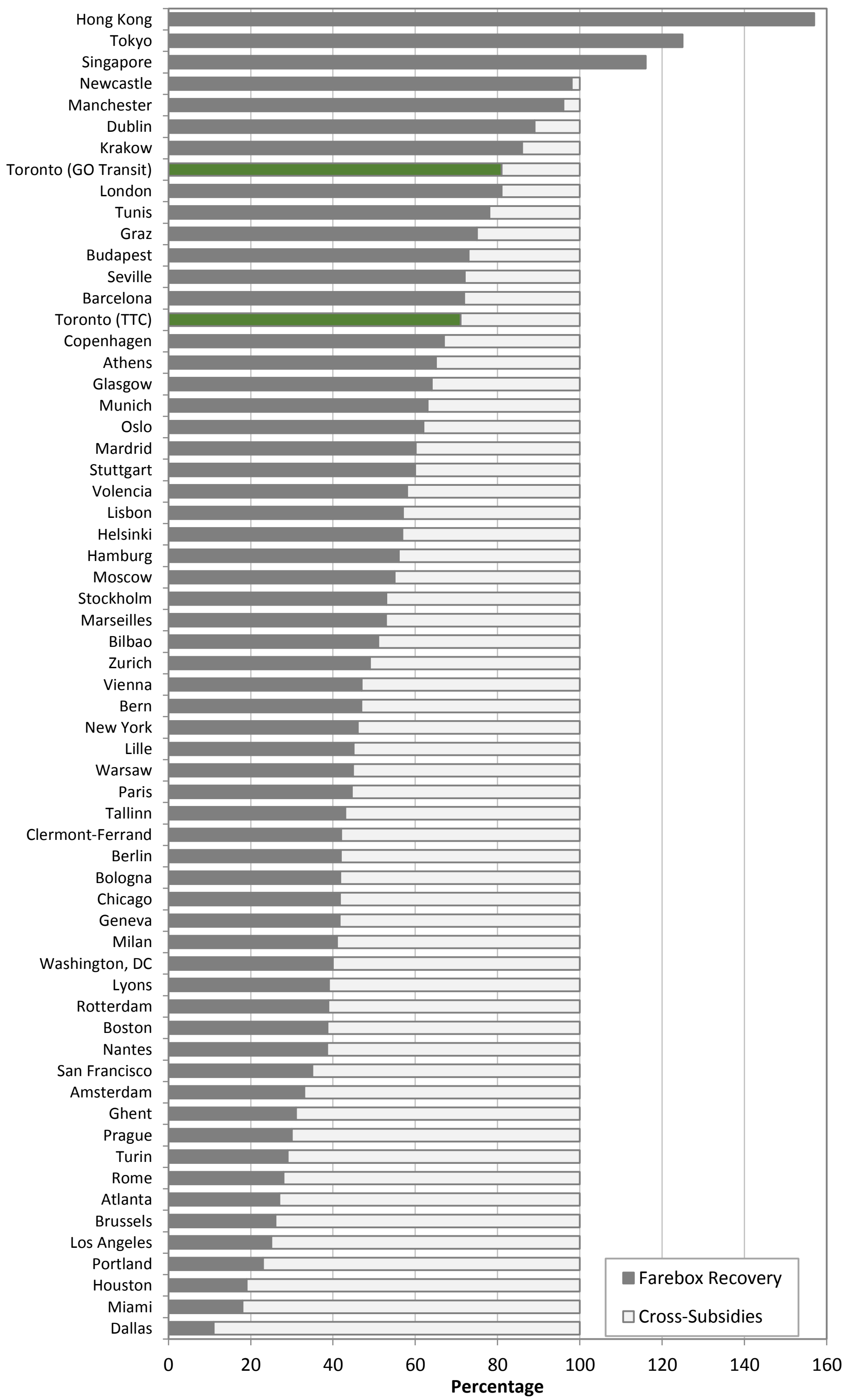
CHAPTER 1

INTRODUCTION

Governments and their public transit providers seem to be in perpetual need of greater funds to finance the construction and operation of rapid transit infrastructure. For example, excluding Hong Kong, Tokyo, and Singapore, public transit services in 58 cities across North America and the European Union recover on average only 50 percent of their operating costs through direct returns such as fares and advertising (Figure 1-1). While some transit systems recover much more than that, many others, particularly those in North America, require operational subsidies of 60 percent or more of total costs.

Still, in an effort to manage the land use and transportation challenges associated with rising levels of population growth and urbanization, planners and policymakers around the world are increasingly turning to rapid transit to ease congestion, reduce harmful pollution, enhance economic competitiveness, and improve quality of life. But in an age of fiscal restraint, especially in Europe and North America, governments at all levels are actively searching for more innovative ways to finance the construction and operation of rapid transit infrastructure beyond broad increases in property taxes, and one method that is attracting considerable attention is the promotion of Land Value Capture (LVC). LVC works from the notion that the benefits of rapid transit, such as improvements in travel time and accessibility, can generate significant increases in property values for nearby parcels of land and can have a transformative impact on adjacent land use patterns.

Figure 1-1. Transit Revenue Recovery and Subsidization



Source: Adapted from Murakami (2012) to include GO Transit and the Toronto Transit Commission

In the past, the economic value associated with such public investments has largely accrued to private individuals located around the infrastructure, resulting in a 'windfall' for private homeowners (Hagman & Misczynski, 1978), or what John Stuart Mill refers to as an 'unearned increment'. This unearned increment provides a rationale for LVC wherein the public sector uses the power of taxation to recoup some of its costs using LVC tools such as Tax-Increment Financing (TIF), Special Assessment Districts (SADs), development charges, and joint real estate development.

1.1 LAND VALUE CAPTURE IN THE PROVINCE OF ONTARIO

In the context of rapid transit planning in the Province of Ontario, there is a remarkable, albeit brief history of experience with understanding the relationship between rapid transit and LVU, and the use of this value uplift to help finance projects. An overview of this experience is provided in Appendix B. At present, policy and planning actors including the City of Toronto, the Ministry of Transportation of Ontario (MTO), and Metrolinx, the provincial agency responsible for transit across the Greater Toronto and Hamilton Area (GTHA), have shown a renewed interest in LVC as a potential tool to help fund several large investments in rapid transit around the region. Metrolinx in particular estimates that development charges alone around new transit stations can generate $100 million annually and is considering the potential of additional value capture tools.

Of course, Toronto's urban market may be unaffected by changes in transportation costs attributable to new rapid transit infrastructure, with such projects thus not offering any value to capture. The opposite may also be true and a strong case can be made that

LVC constitutes an untapped resource in the contemporary search for creative ways to finance the region's transit projects, particularly when bundled within a value planning approach that explicitly seeks to maximize capturable revenues. The present thesis will test this hypothesis. However, beyond examining present LVU, it will argue that several theoretical, conceptual, and practical issues continue to prevent a better understanding of the drivers of LVU and extensions of research findings to enable better predictions of LVC in Ontario and around the world.

1.2 RESEARCH PROBLEMS

1.2.1 The Unknown Value Increment

A fundamental conceptual issue affecting the implementation of LVC strategies is that for any LVC tools to be set at levels that are socially equitable and economically efficient, the value increment that results from transit must be known *a priori* by planners and policymakers. This is because timing is key: LVC tools like tax-increment financing seek to capture aggregate increases in land value that accrue as a result of the infrastructure project, thereby requiring a baseline estimate of present conditions against which the value increment is ascertained. But previous research has demonstrated LVU effects occurring as soon as the details of a rapid transit project become public knowledge and begin to spur a wave of speculation for property around future transit stations. Ideally this means a potential LVC strategy must be in place before a project is publicly approved, otherwise base level land values cannot be established, the total value increment that results from the project is unknown, and LVC revenues are potentially lost.

With this in mind, the question is then *how much will land values increase as a result of a new rapid transit project?* On its face such a question appears fairly innocuous, but it belies considerable complexity. In search of an answer, it is common for planners and policymakers to suggest that rapid transit *will* produce some level of LVU, and estimate the value increment based on previous research of experiences in other cities. As Chapter 2 will show, a wealth of studies have been conducted to draw on, and many support this notion of some LVU occurring. However, many other studies have found that rapid transit can have neutral, or even negative effects on property values.

This leads to the critical flaw in current approaches: although it is grounded in statistical inference from previous research, drawing conclusions about potential LVU from other cities is problematic as the results of previous studies are heavily influenced by implicit and unobserved contextual factors. This includes effects associated with different cities, transit lines, station areas, the structure of local economies, the time at which the study occurred, and a host of other considerations. As such, simply applying average results from a study of Washington DC’s MetroRail from the 1980s and 1990s to estimate the potential for value capture from an extension of a heavy rail transit (HRT) line in Toronto in 2022 would produce unreliable and potentially erroneous results that run counter to evidence-based policymaking.

Still, obtaining more reliable estimates of LVU to inform LVC also requires overcoming a second issue, namely the simultaneous LVU effects of rapid transit accessibility and transit-oriented development (TOD).

1.2.2 The Simultaneous LVU Effects of Transit and TOD

Previous expectations of the effects of rapid transit on land values are generally derived from the theoretical guidance of the Alonso-Muth-Mills (AMM) model of the urban spatial structure (Alonso, 1964; Mills, 1972; Muth, 1969). While Chapter 2 will explore the AMM model in greater detail, a basic hypothesis within the model is that changes in accessibility at a particular location should reduce transportation costs and be met with increases in land value that result in higher density development.

The framework of the model provides a convenient foundation on which expectations of LVU from rapid transit can be based. Because a new station should increase accessibility, the decrease in transportation cost offered by the project should cause land values around the station to increase and new high-density development to occur. But as mentioned, previous studies of rapid transit's LVU effects have shown a diversity of results. As Chapter 2 shows, this can be due to a lack of an accessibility benefit produced by rapid transit relative to other modal options, something that is likely to be particularly relevant in automobile-oriented cities.

But a second explanation is that beyond changes in accessibility, LVU can also accrue from integrated transportation and land use planning that prioritizes the implementation of higher-density, mixed-use, amenity-rich, and pedestrian-friendly TOD. Since the 1990s, the promotion of TOD has become a fundamental element in rapid transit planning in the United States and Canada (Higgins et al., 2014). Crucially, like planning interventions that alter transportation costs through improvements in accessibility from rapid transit, associated TOD planning and policy can also result in

LVU by offering individuals an opportunity to express a desire or higher willingness to pay for different housing and lifestyle options, a notion supported by previous research (Bartholomew & Ewing, 2011).

Thus taken together, increases in accessibility and TOD planning can result in a bundle of goods that produce simultaneous and potentially self-reinforcing LVU effects. Furthermore, this bundle of goods is likely to be different across the stations that make up a rapid transit network, creating different submarkets of transit and TOD. With this in mind, how can these simultaneous effects be unbundled, and similarly, what are the implications of this bundling for predictions of LVU around future transit stations?

In response to these methodological deficiencies, the present dissertation formulates, establishes, and applies a more empirically sound value planning framework for predicting the value increment associated with new and future transit infrastructure. Such a framework presents an innovation in planning and policy, as unlike previous research focused on specific cities and contexts, it can be widely applied to any city interested in exploring alternative ways of raising revenue for investments in transit infrastructure.

1.3 RESEARCH OBJECTIVES

In response to the issues above, this thesis develops a rapid transit value planning framework that can be used to not only better predict potential LVU from future rapid transit projects, but maximize project benefits and capturable revenues. Because the research problem and its solution are both practical and timely given the present and planned rapid transit projects underway in the Province of Ontario, this research was conducted in accordance with the needs of stakeholders at the MTO. As such, the focus of the value planning framework will be based on experiences with and plans for rapid transit within the context of the GTHA.

The production of the framework will be accomplished through five main objectives, each of which make up a substantive chapter of this dissertation:

Objective 1: Establish a Theoretical Framework for Understanding the LVU Effects of Rapid Transit and Transit-Oriented Development

To begin, Objective 1 is to establish a theoretical framework for understanding the simultaneous LVU effects of rapid transit and TOD. This is accomplished through a comprehensive critical analysis of previous approaches used to estimate the LVU effects of rapid transit accessibility and TOD in Chapter 2. This chapter reviews more than 100 studies that have occurred in North America, finding that a focus on the theoretical guidance of the AMM model has been insufficient for developing expectations of LVU associated with integrated transportation and land use planning. Furthermore, this lack of complete theoretical guidance may be responsible for the great diversity seen in previous research outcomes. In response, Chapter 2 argues for an augmentation of this focus on accessibility benefits with the incorporation of LVU effects associated with Tiebout's (1956) model of individual sorting into different station area submarkets informed by various bundles of transit accessibility and TOD characteristics.

Objective 2: Develop a Typology of Station Area Rapid Transit and Transit-Oriented Development

With theoretical expectations in place, Chapter 3 proposes a methodology for better understanding a transit station area's accessibility and TOD characteristics. Using latent class model-based clustering techniques, Chapter 3 performs a spatial analysis on 5 measures of TOD inputs and uses them to produce a typology of 10 distinct station types along present and future rapid transit infrastructure projects in the GTHA. Validating each station type against several performance outcomes reveals that TOD inputs are indeed associated with measures such as transit and alternative mode use, household vehicle kilometres travelled, and demographic trends.

On its own, this suggests that the typology captures different spatial TOD submarkets in transit station areas around the region. However, it also provides a foundation for incorporating such heterogeneous station contexts into further research on the LVU effects of existing rapid transit projects and land use planning initiatives and potential value uplift in future station areas, topics explored by Objectives 3 and 4 respectively.

Objective 3: Unbundle the LVU Effects of Transit and TOD in Toronto

The potential of any LVC tool to generate revenue in the GTHA must be assessed in accordance with the impacts of existing transit facilities in similar contexts. Though three prior studies of Toronto exist (Bajic, 1983; Dewees, 1976; Haider & Miller, 2000), the data from the most recent of these occurred several decades prior, making their conclusions severely out of date. Furthermore, like much of the research in this area, these studies considered the simultaneous and self-reinforcing LVU effects of rapid transit accessibility and TOD as a single research outcome.

To remedy this, Chapter 4 conducts a new study of the land value increases associated with rapid transit and TOD in the GTHA region. This research works from the theoretical expectations established in Objective 1 to unbundle the simultaneous LVU effects of rapid transit accessibility and station-area TOD. In line with expectations, results suggest heterogeneity in LVU across different station types and the existence of station area transit accessibility and TOD submarket effects.

Objective 4: Develop a Value Planning Framework for Rapid Transit

The research started from a question of how to better predict LVU associated with future investments in rapid transit infrastructure. Chapter 5 combines the research outcomes of the three previous objectives into the development of a rapid transit value planning framework. In Chapter 4, rapid transit and TOD were found to produce LVU effects that varied according to station area context. But with the LVU effects of rapid transit accessibility and TOD distilled into different packages associated with particular station context types through the TOD typology from Chapter 3, Chapter 5 proposes a value planning framework that enables more empirical and context-sensitive estimations of LVU in future transit station areas.

However, a lack of applicable previous research in this area restricts the full development of the framework. As such, the paper is a call for further study and proposes directions to ensure future research proceeds in a way that permits greater extensions to planning and policy for LVC.

Objective 5: Theoretical Application of the Value Planning Framework

The final objective of the present thesis is to offer a hypothetical application of the information learned in completing Objective 4 to derive estimations of total aggregate LVU associated with future projects to demonstrate a base rationale for engaging in LVC. Furthermore, recognizing the changes in the value increment that can result from policy and planning interventions that promote high levels of relative transit accessibility and transit-oriented land use planning, the research seeks to establish value planning as an ethos for guiding planning and policy to ensure future projects achieve a maximum return on investment.

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CHAPTER 2

40 YEARS OF MODELLING RAPID TRANSIT'S LAND VALUE UPLIFT IN NORTH AMERICA: DIVERSE METHODS, DIFFERENTIATED OUTCOMES, DEBATABLE ASSUMPTIONS, AND FUTURE DIRECTIONS

ABSTRACT

Identifying and measuring the land value uplift (LVU) impacts of rapid transit is important for a number of reasons, including gauging the effects of rapid transit on land use and validating benefits assumptions made during planning. The existence and magnitude of LVU also creates a rationale for land value capture. But despite a general consensus among planners and policymakers that rapid transit does confer positive LVU benefits, our critical review of more than 60 studies completed in North America over the past 40 years finds significant heterogeneity in study results, leaving many significant questions that pertain to these broad rationales unanswered. Beyond methodological, temporal, modal, and geographic differences, we argue that a fundamental source of variability is the incomplete theoretical guidance afforded by a singular focus on accessibility in expectations of LVU, which results in debatable assumptions, a lack of comparability, and potentially misleading conclusions.

LVU from rapid transit is a product of a bundle of goods: regional accessibility to people and jobs and local accessibility to transit-oriented development, neither of which are likely to be valued the same by different segments of the population. To better identify and estimate the benefits of this bundle, we suggest the adoption of better measures of accessibility and the complimentary theoretical guidance of Tiebout's focus on sorting and self-selection to control for confounding influences in the urban land market and better identify the existence and sources of LVU. Still, true comparability in study results remains limited by the theoretical assumptions informing hedonic prices. Nevertheless, these solutions can help to minimize heterogeneity and ensure future research in this area proceeds in a manner that is more comparable, generalizable, and theoretically sound.

2.1 INTRODUCTION

The study of rapid transit's impacts on land values, referred to here as the process of land value uplift (LVU), is important for a number of reasons. Primary among them is a desire to identify and measure the nature of the symbiotic relationship between transportation and land use. Changes in land values act as a proxy for a number of important facets of the urban market. If transportation entails a cost in terms of money, time, or stress and individuals seek to minimize these costs, an increase in accessibility attributable to a transit line should increase land values around transit stations. Likewise, transit projects are often justified in part by their potentially transformative impact on land use with the goal of promoting a concentration of mixed-use transit-oriented development (TOD) in station areas. Locations that command a rent premium should thus attract more intensive development and redevelopment resulting in greater concentrations of population and employment and an increase in transit ridership.

Measuring such impacts is of paramount importance for planners and policymakers. Estimates of LVU can contribute to evidence-driven policy by validating economic development justifications, demonstrating value for money, and providing a sound rationale for continued public investment in transit infrastructure. Outputs from models have even been used as a defense in legal proceedings brought against planners of transit projects by homeowners arguing that their property values would decrease as a result of a new project (Weinberger, 2001).

A second and related rationale for the study of rapid transit's land value impacts concerns the potential to capitalize on the LVU generated by a project through the process of land value capture (LVC). In as much as rapid transit confers positive externalities and these externalities are priced into the private land market, there is a rationale for the public sector to recapture some of these LVU benefits, termed the ‘unearned increment’, to fund the project through public-private partnerships for Transit Joint Development or localized policy tools such as Tax-Increment Financing and Special Assessment Districts. In an age of widespread fiscal restraint, these and other alternative sources of capital for financing rapid transit that involve contributions from a range of public and private stakeholders have become increasingly attractive (Zhao & Levinson, 2012).

But if value capture tools are to be designed and applied in an economically efficient and socially equitable manner they must be set at levels that reflect the actual value increment associated with the transit project and the geographical distribution of such LVU benefits over space. Furthermore, because many studies have detected LVU as soon as station locations are announced, planners and policymakers interested in fully maximizing their return on investment through LVC must arrive at estimates of anticipated future LVU and initiate their value capture programs long before researchers have an opportunity to validate planning assumptions.

A problem obviously arises in that if planners and policymakers do not know *a priori* the magnitude of the value uplift to be expected, they cannot design their value capture tools to achieve such objectives. Consider the following questions:

- Should the values of commercial properties increase by 10% around a new light rail transit (LRT) station? Or is it only 7%?

- How much can actually be attributed to the transit line itself alongside other transportation and land use planning initiatives?
- Do such LVU impacts change in magnitude over time?
- Does this amount decrease over a distance of 800 meters? Or is the impact area limited to only 500 meters?
- What if we built bus rapid transit (BRT) instead?
- To answer such questions it seems practical to turn to previous studies of rapid transit's value uplift as a way to help shape uplift projections, but does the literature offer any consensus on such issues?
- How accurate are estimates?
- Finally, are the modelling approaches employed appropriate for drawing causal inferences?

Clearly there are important rationales for engaging in research that seeks to quantify the LVU impacts of rapid transit. To date, the past 40 years have seen more than 60 studies and 130 separate analyses completed that consider the impact of rapid transit on property values in North America alone (Table 2-1). But in the span of four decades, what have we *really* learned from this body of work? Are we any closer to being able to generalize findings and resolve the broader questions associated with the rationales outlined above in a manner that is readily interpretable and empirically satisfactory?

The purpose of the present expository paper is to survey, review, and critically reflect on the state of practice in research on rapid transit's land value uplift impacts. The paper does not engage in a meta-analysis, as we argue that missing information renders such an analysis unfeasible. Instead, we offer a comprehensive account of the LVU literature in North America and in doing so reveal significant heterogeneity in research outcomes. Next, we analyze this body of work in an attempt to account for the sources of heterogeneity and argue that aside from obvious differences in context, research in this area fundamentally suffers from incomplete theoretical guidance that results in debatable assumptions, a lack of comparability, and potentially misleading conclusions. Finally, we offer directions for addressing these issues by proposing solutions that can place future research in this area on a more common and empirically comprehensive theoretical footing.

Table 2-1. Studies of Rapid Transit's Land Value Uplift in North America

A: Hedonic Multiple Regression

Author	Location	System/Line	System Open-ing	Study Period	Observ-ations	Transit Type	Property Type	Dependent Var.	Study Design	Func. Form	Study Extent	Access Method	Spatial Method	Outcome
(Boyce et al., 1972)	Philadelphia, PA Camden, NJ	Philadelphia Lindenwold High Speed Line	1969	1965-1971	24,082	CRT		A	A	A	A	C		+$149 to +$200/dollar of travel time savings
(Lee, 1973)	San Francisco, CA	BART	1972	1961[a], 1971[b]	156[a], 143[b]	HRT	Single	A	B	B	A	A		*ns*
(Dewees, 1976)	Toronto, ON	Bloor-Danforth Subway	1966-1968	1961; 1971	690; 1,174	HRT	Single	A	B	A	C	C		+$4,380/mile (0-⅓ mile)
(Smith, 1978)	Chicago, IL	CTA El	1892	1971	300	HRT	Single	A	A	A	B	A		+$600/mile
(Damm et al., 1980)	Washington, DC	Metrorail	1976	1969-1976	286	HRT	Single	A	A	B	B	A		+11%/mile
					771	HRT	Multi	A	A	B	B	A		+19%/mile
					353	HRT	Comm.	A	A	C	B	A		+68%/mile
(Skaburskis, 1982)	San Francisco, CA	North Oakland BART	1972	1968-1975	602	HRT	Single	A	A	E	A	A		-7% at 500 ft.; -3% at 1,000 ft.; -1% at 1,500 ft.
(Bajic, 1983)	Toronto, ON	Spadina Subway	1978	1971; 1978	2,000	HRT	Single	A	B	C	C	C		+$2,237 near rail
(Ferguson et al., 1988)	Vancouver, BC	Expo Line	1986	1971-1983	6,218	LRT	Single	A	B	A	A	A		*ns*
					6,451	LRT	Single	A	A	A	A	A		+$4.90/ft.
(Nelson & McClesky, 1990)	Atlanta, GA	MARTA Blue Line	1979	1986	286	HRT	Single	A	A	C	B	A		+0.7%/100 ft.

(Voith, 1991)	Philadelphia, PA[a]; Camden, NJ[b]	SETPA[a] PATCO[b]		1980	571[a]; 107[b]	CRT	Aggr.	B	A	A	B	E		+6.4%[a+b]; +3.8%[a]; +10%[b] for tracts with rail access
(Grass, 1992)	Washington, DC	Metrorail	1976	1980	6,004	HRT	Single	A	A	B	B	B		+46% (0-¼ mile)
(Nelson, 1992)	Atlanta, GA	MARTA Blue Line	1979	1986	286	HRT	Single	A	A	A	B	A		+6%/100 ft. (south) -2%/100 ft. (north)
(Al-Mosaind et al. 1993)	Portland, OR	Eastside MAX	1986	1988	235	LRT	Single	A	A	A	B	B		+$4,324 or 10% (0-500m)
					90	LRT	Single	A	A	A	A	A		*ns*
(Gatzlaff & Smith, 1993)	Miami, FL	Metrorail	1984	1971-1990	912	HRT	Single	A	C	B	A	D		*ns*
(Voith, 1993)	Philadelphia, PA	SEPTA Regional Rail		1970-1988	59,000	CRT	Single	A	B	A	B	E		+4% to +15% for rail access by year
(Armstrong, 1994)	Boston, MA	Fitchburg Line		1990	451	CRT	Single	A	A	B	A	E	D	+6.7% for rail access
(McDonald & Osuji, 1995)	Chicago, IL	Midway Line	1993	1980; 1990	79	HRT	Aggr.	B	B	B	A	B		+15.4% *ns* (0-½ mile)
(Landis et al., 1995)	Alameda County, CA	BART	1972-1974	1990	1,132	HRT	Single	A	A	A	B	A		+$2.29/meter
				1988-1994	1,430	HRT	Comm.	A	A	B	B	B		*inconclusive*
	Contra Costa County, CA	BART	1972-1974	1990	1,229	HRT	Single	A	A	A	B	A		+$1.96/meter
				1988-1994	836	HRT	Comm.	A	A	B	B	B		*inconclusive*
	San Mateo County, CA	Caltrain	1980	1990	233	CRT	Single	A	A	A	B	A		*ns*
	Sacramento, CA	RT Blue/ Gold Line	1987	1990	1,131	LRT	Single	A	A	A	B	A		*ns*
	San Diego, CA	Trolley Blue Line	1981	1990	1,228	LRT	Single	A	A	A	B	A		+$2.72/meter
				1988-1994	2,968	LRT	Comm.	A	A	B	B	B		*inconclusive*

	Santa Clara, CA	VTA LRT	1987	1990	232	LRT	Single	A	A	A	B	A		*ns*
(Landis & Loutzenheiser, 1995)	San Francisco, CA	BART	1972	1993	96	HRT	Comm.	C	A	A	B	B		*ns*
	Oakland, CA		1972	1993	56	HRT	Comm.	C	A	A	B	B		*ns*
	Walnut Creek, CA		1972	1993	60	HRT	Comm.	C	A	A	B	B		*ns*
(Benjamin & Sirmans, 1996)	Washington, DC	Metrorail	1976-1991	1992	250	HRT	Multi	C	A	B	A	A		+2.42%/0.1 mile
(Cervero, 1996)	San Francisco, CA	BART	1972	1994	60	HRT	Multi	C	A	A	A	B		*ns* (0-¼ mile)
(Lewis-Workman & Brod, 1997)	San Fancisco, CA	Pleasant Hill BART	1973	1984-1996	263	HRT	Single	A	A	A	A	A		+$15.78/ft.
	New York, NY	Queens MTA	1936	1978-1996	1,738	HRT	Single	B	A	A	A	A		+$23.49/ft.
	Portland, OR	Eastside MAX	1986	1995	4,170	LRT	Single	B	A	A	A	A		-$1.41/ft.
(Bollinger et al., 1998)	Atlanta, GA	MARTA	1979	1990-1996	>1,565	HRT	Comm.	C	A	A	B	B		- effect (0-¼ mile)
(Chen et al., 1998)	Portland, OR	Eastside MAX	1986	1992-1994	302	LRT	Single	A	A	B	A	A		+$32.20/meter, local nuisance effect
(Nelson, 1999)	Atlanta, GA	Midtown	1981	1980-1994	30	HRT	Comm.	A	A	A	A	A		*ns*
(Haider & Miller, 2000)	Toronto, ON	TTC Subway	1954-1980	1995	26,910	HRT	Single	A	A	B	B	B	A	+1.7% (0-1.5km)
(Bowes & Ihlanfeldt, 2001)	Atlanta, GA	MARTA	1979	1991-1994	22,388	HRT	Single	A	A	B	B	B		-20%(0-¼ mile) +Crime (near CBD) +Retail (suburbs)
(Knaap et al., 2001)	Portland, OR	Westside MAX	1998	1992-1996	1,537	LRT	Vacant	A	A	C	B	B		+36% post station announcement (0-½ mile)
(Weinberger, 2001)	Santa Clara, CA	VTA LRT	1987	1984-2000	3,701	LRT	Comm.	C	A	B	B	B		+9% (0-¼ mile) +7% (¼–½ mile)
(Cervero &	Santa Clara, CA	a: VTA LRT	1987[a]	1988-	1,197	LRT	Comm.	B	A	A	B	B		+23% (0-¼ mile)

Duncan, 2002a)		b: Caltrain c: ACE	1980[b] 1998[c]	1999		CRT	Comm.	B	A	A	B	B		+120%[b], *ns*[c] (0-¼ mile)
(Cervero & Duncan, 2002b)	Santa Clara, CA	a: VTA LRT b: Caltrain	1987[a] 1980[b]	1999	7,098	LRT	Multi	B	A	A	B	B		+$9/ft² (0-¼ mile)[a]
						CRT	Single Multi	B	A	A	B	B		+$4/ft² (0-¼ mile)[b]
(Cervero & Duncan, 2002c)	Los Angeles, CA	Red Line	1993	2000	40,966	HRT	Single	A	A	A	B	B		*ns*
					3,803	HRT	Multi	A	A	A	B	B		*ns*
					13,462	HRT	Condo	A	A	A	B	B		-16.8% (0-½ mile)
				1999-2001	1,241	HRT	Comm.	A	A	A	B	B		-20.6% (0-¼ mile)
		a: Blue Line, b: Green Line	1990[a]; 1995[b]	2000	40,966	LRT	Single	A	A	A	B	B		*ns*
					3,803	LRT	Multi	A	A	A	B	B		*ns*
					13,462	LRT	Condo	A	A	A	B	B		*ns*
				1999-2001	1,241	LRT	Comm.	A	A	A	B	B		*ns*
		a: Antelope b: Riverside c: San Bernadino d: Ventura	1992[acd] 1993[b]	2000	40,966	CRT	Single	A	A	A	B	B		*ns*
					3,803	CRT	Multi	A	A	A	B	B		*ns*
					13,462	CRT	Condo	A	A	A	B	B		+12.6%[a], *ns*[bcd] (0-½ mile)
				1999-2001	1,241	CRT	Comm.	A	A	A	B	B		-29.8%[b], *ns*[acd] (0-¼ mile)
		a: Ventura b: Wilshire	2000	2000	40,966	BRT	Single	A	A	A	B	B		*ns*[a], -15.2%[b] (0-¼ mile)
					3,803	BRT	Multi	A	A	A	B	B		*ns*
					13,462	BRT	Condo	A	A	A	B	B		*ns*[a], -8.4%[b] (0-½ mile)
				1999-2001	1,241	BRT	Comm.	A	A	A	B	B		*ns*[a], +13.3%[b] (0-¼ mile)
(Cervero, 2004)	San Diego, CA	a: South Line b: East Line c: Mission	1981	2000	14,756	LRT	Single	A	A	A	B	B		*ns*[a], -1.5%[b], -4.2%[c] (0- ½ mile)
					1,495	LRT	Multi	A	A	A	B	B		+17%[b], *ns*[acd] (0-½ mile)

		Valley Line d: Downtown			9,672	LRT	Condo	A	A	A	B	B		+6%[b], *ns*[acd] (0-½ mile)
				1999-2001	372	LRT	Comm.	A	A	A	B	B		+72%[c], *ns*[abd] (0-½ mile)
		a: Coaster b: Downtown	1996	2000	14,756	CRT	Single	A	A	A	B	B		+17%[a] (0-½ mile)
					1,495	CRT	Multi	A	A	A	B	B		*ns*
					9,672	CRT	Condo	A	A	A	B	B		+46%[a] (0-½ mile)
				1999-2001	372	CRT	Comm.	A	A	A	B	B		-10%[a] (0-½ mile) +91%[b] (0-¼ mile)
(Garrett, 2004)	St. Louis, MO	Metrolink		1998-2001	1,516	LRT	Single	A	A	B	A	A	D	+$14.4/foot (0-¼ mile)
(McMillen & McDonald, 2004)	Chicago, IL	Midway Line	1993	1983-1999	17,034	HRT	Single	A	B	B	A	A		+4.2% to +19.4%/mile at different times and stations
(Ryan, 2005)	San Diego, CA	Trolley	1981	1986-1995	1,020	LRT	Comm.	C	A	C	B	A		-/*ns* effect (office) +/-/*ns* effect (industrial)
(Armstrong & Rodriguez, 2006)	East Massachusetts	MBTA		1992-1993	1,860	CRT	Single	A	A	A	B	C	A	+10% for rail access +10% (0-½ mile)
(Hess & Almeida, 2007)	Buffalo, NY	Metro Rail	1985	2002	7,357	LRT	Single Multi	B	A	A	A	A		+$1/ft. (global) -$26 to +$27/foot (different stations)
(Duncan, 2008)	San Diego, CA	Trolley[a], Caltrain[b]	1981[a], 1995[b]	1997-2001	4,970	LRT CRT	Single	A	A	A	A	B	D	+6% (0-¼ mile)
					4,166	LRT CRT	Condo	A	A	A	A	B	D	+17% (0-¼ mile)
(Perk & Catalá, 2009)	Pittsburgh, PA	East Busway	1983	2007	6,654	BRT	Single	B	A	A	A	A		Positive, non-linear: +$9,745 (at 100 ft. vs. 1,000 ft.)
(Atkinson-Palombo, 2010)	Phoenix, AZ	METRO LRT	2008	1995-1999[a]; 2001-	10,571	LRT	Single	A	B	B	B	B	D	Mixed Use: +6%[a], +6%[b] Residential: -12% (TOD zoning)[b]

				2007[b]	5,285	LRT	Condo	A	B	B	B	B		Mixed Use: +28%[a], +16% & +37% (TOD zoning)[b] Residential: -13%[a], +3% & -11% (TOD zoning)[b]
(Goetz et al., 2010)	Minneapolis, MN	METRO Blue Line	2004	1997-2007	3,514	LRT	Single	A	B	A	A	A	A	- effect post 2004 (West), *ns* (East)
					2,041	LRT	Multi	A	B	A	A	A	A	+$350/m (West), reduction in disamenity (East)
(Dubé et al., 2011)	Quebec City, QC	Métrobus	1992	1986-2004	11,285	BRT	Single	A	C	B	B	B	D	Central corridor: +7% (50-150 meters), +3% (150-300 meters) Extended corridor: *ns*
(Duncan, 2011)	San Diego, CA	Trolley	1981	1997-2001	3,374	LRT	Condo	A	A	D	A	A		Walk-up: +15.3%[a], +6.4%[b], -7.6%[c] Park-n-ride: +11.6%[a], +2.8%[b], -11.2%[c] (pedestrian environment a: good; b: average; c: poor)
(Chatman et al., 2012)	New Jersey	River Line	2004	1989-2007	31,470	LRT	Single	A	C	B	B	B		Slightly negative to neutral: -15% to -8% during construction, +12% to +14% after operation (0-3 miles)
(Golub et al., 2012)	Phoenix, AZ	METRO LRT	2008	1988-2010	88,308	LRT	Single	A	B	C	A	A		+87%/ft^2 at operation (at 200 feet vs. 2 miles) *ns* TOD Zoning
					25,652	LRT	Multi Condo	A	B	C	A	A		+9%/ft^2 at operation (at 200 feet vs. 2 miles) *ns* TOD Zoning
					5,521	LRT	Comm.	A	B	C	A	A		+63% /ft^2 at operation (at 200 feet vs. 2 miles) *ns* TOD Zoning

					1,788	LRT	Vacant	A	B	C	A	A		+83%/ft^2 at operation (at 200 feet vs. 2 miles) +5% TOD zoning
(Hewitt & Hewitt, 2012)	Ottawa, ON	O-Train	2001	2006-2009	3,735	LRT	Single Semi	A	A	A	A	A	C	-$12 to -$39/meter (close to stations)
(Yan et al., 2012)	Charlotte, NC	Lynx Blue Line	2007	1997-2008	6,381	LRT	Single	A	B	C	A	A	D	Prices decrease closer to stations, but disamenity shrinks after line begins operation
(Dubé et al., 2013)	Montréal, QC	South Shore CRT	2000-2003	1992-2009	23,978	CRT	Single	A	C	B	B	B		Walking distance: +9% (0-500m), +7% (500m-1km), +3% (1-1.5km) Driving time: +12% to -1% depending on travel time to station and distance from CBD
(Kim & Lahr, 2013)	New Jersey	Hudson-Bergen LRT	2000	1991-2009	13,599	LRT	Single	A	C	B	B	A		Greater appreciation in 2 suburban station areas (+12% to +16.5%, 0-400 meters) Appreciation decays 1%/15 meters
(Ko & Cao, 2013)	Minneapolis, MN	METRO Blue Line	2004	2000-2008	1,054	LRT	Comm. Indust.	A	A	A	B	A		*ns*
					529			A	A	A	A	A		Post opening: -$6,000/meter (0.004%) at 400 meters -$4,000/meter (0.003%) at 800 meters
(Pan, 2013)	Houston, TX	METRORail Red Line	2004	1983-2007	529,734	LRT	Single	A	A	C	B	B		-19% (0-¼ mile), *ns* (¼-3 miles)
(Perk et al., 2013)	Boston, MA	Silver Line BRT	2002	2000-2001[a]; 2007, 2009[b]	437[a]; 895[b]	BRT	Condo	A	B	A	A	A		a: -3%/ft^2 at station vs. 960 feet b: +7.6%/ft^2 at station vs. 867 feet

(Petheram et al., 2013)	Salt Lake City, UT	TRAX LRT	1999	1,301	LRT	Multi	B	A	B	A	B		+\$7/ft^2 (0-¼ mile), +\$4/ft^2 (¼-½ mile), +\$5/ft^2 (½-¾ mile), +\$4/ft^2 (¾-1 mile), +\$4/ft^2 (1-1¼ mile), *ns* (1¼-1½ mile)

ns = Not Significant at 95% confidence level
Transit Type: HRT: Heavy Rail Transit; CRT: Commuter Rail Transit; LRT: Light Rail Transit; BRT: Bus Rapid Transit
Property Type: Single: Single Detached; Semi: Semi-Detached; Multi: Multi-Family; Comm: Commercial; Indust: Industrial; Aggr: Aggregate Zone
Dependent Variable: A: Sale; B: Assessment; C: Rental
Study Design: A: Cross-Section / Pooled; B: Longitudinal / Repeat Cross Section; C: Panel / Repeat Sales / Difference-in-Differences
Functional Form: A: Linear; B: Log-Linear; C: Log-Log; D: Mixed; E: Linear-Log
Study Extent: A: Corridor; B: Expansive; C: Treatment-Control
Accessibility: A: Proximity Distance (Continuous – change in dependent variable as distance to the station *decreases*); B: Proximity Bands (Fixed Effects – change in dependent variable within distance band); C: Travel Time; D: Before-After; E: Station Presence in Aggregate
Spatial Methods: A: Spatial Lag Model; B: Spatial Error Model; C: Geographically Weighted Regression; D: Spatial Dependence Tested but Not Found

B: Matched Pairs and Repeat Sales Methods

Author	Location		System Open.	Study Period	Treatment: Control Ratio	Transit Type	Property Type	Dependent Var.	Study Design	Access Method	Outcome
(Davis, 1970)	San Francisco, CA	BART	1973	1967		[illegible]	[illegible]	A	B	A	+2% to 14% (new suburban area)
(Dornbush, 1975)	San Francisco, CA	BART	1973	1974		HRT	Single	A	A	B	-4% (0-400ft.), +2% (400-1,500ft.)
(Falcke, 1978)	San Francisco, CA	BART	1973	1973-1976		HRT	Single	A	B	A	+$1.35/ft^2/ft. (0-1,000 ft.)
						HRT	Multi	C	B	A	*ns*
						HRT	Office	C	B	A	Oakland CBD: +10% (0-500ft.), +4% (500-1,000ft.), *ns* (>1,000ft.) San Francisco: *ns* Walnut Creek: +6% (0-200ft.), *ns* (>200ft.)
						HRT	Retail	A	B	A	Urban: +1% (0-500ft.), *ns* (>500ft.) Suburban: +8% (0-1,000ft.), *ns* (>1,000ft.)
(Dyett et al., 1979)	San Francisco, CA	BART	1973	1974-1975		HRT	Single	A	A	B	+17% (0-500ft.), +5% (500-1,000ft.), +3% (1,000-1,500ft.), +2% (1,500-2,000ft.), +1% (2,000-2,500ft.)
(Rybeck, 1981)	Washington, DC	Metrorail	1976	1977-1980		HRT	Multi	A	A	B	+$16.90 to $18.60 (0-¼ mile)
						HRT	Comm.	C	A	B	Washington CBD: +9% (0-300ft.) Silver Spring: +14% (0-300ft.)
(Alterkawi, 1991)	a: Washington, DC; b: Atlanta, GA	Metrorail[a]; MARTA[b]	1976[a]; 1979[b]	1975-1990		HRT	Single	B	B	A	+0.8 to +2.03[a], +1.58[b] (price/distance elasticity)

(Bernick & Carroll, 1991)	San Francisco, CA	BART	1973	1973-1985		HRT	Multi	C	A	B	+5% (0-¼ mile)
(VNI Rainbow, 1992)	San Diego, CA	Trolley	1981	1982-1990		LRT	Single	A	A	B	+2% (0-200ft.)
						LRT	Multi	C	A	B	0 to +5% (0-200ft.)
						LRT	Office	C	A	B	*ns*
						LRT	Retail	C	A	B	+167% (0-200ft.)
(Cervero & Landis, 1993)	Washington, DC[a]; Atlanta, GA[b]	Metrorail; MARTA	1976[a]; 1979[b]	1978-1989		HRT	Comm.	C	A	B	+12.3% to 19.6%[a] +11% to 15.1%[b] (0-300ft.)
(Fejarang, 1993)	Los Angeles, CA	a: Red Line b: Purple Line	1993; 1996	1980-1990	75:77	HRT	Comm.	A	A	B	$\$102/\text{ft}^2$ near rail, $\$71/\text{ft}^2$ away from rail
(Bernick et al., 1994; Cervero, 1996)	San Francisco, CA	BART Stations: a: Concord/ PH/WH b: Albany/ EC/Richm. c: UC/Freemt	1973	1994	4:20[a]; 1:3b; 2:6c	HRT	Multi	C	A	B	One-bed/bath: +10%[a], +2%[b], +9%[c] Two-bed/bath: +16%[a], -2%[b], +15%[c] (0- ¼ mile)
(Weinstein & Clower, 1999)	Dallas, TX	DART LRT	1996	1994-1998	700:160	LRT	Single	B	A	B	-5.1% global, -49% to +49% by station (0-¼ mile)
						LRT	Aggr.	B	A	B	-35% global, -81% to +8.95% by station (0-¼ mile)
						LRT	Office	B	A	B	+23% global, -43% to +67% by station (0-¼ mile)
						LRT	Retail	B	A	B	+4.6% global, -50% to +76% by station (0-¼ mile)
						LRT	Indust.	B	A	B	+3.8% global, -36% to +25% by station
(Clower & Weinstein, 2002)	Dallas, TX	DART LRT	1996	1997-2001	3,027:3,486	LRT	Single	B	A	B	+18.2% (0-¼ mile)
					410:208	LRT	Aggr.	B	A	B	-16.7% (0-¼ mile)
					428:1,189	LRT	Multi	B	A	B	+7.2% (0-¼ mile)
					47:121	LRT	Office	B	A	B	+13.2% (0-¼ mile)
					111:155	LRT	Retail	B	A	B	-2.1% (0-¼ mile)
					104:158	LRT	Indust.	B	A	B	-8.5% (0-¼ mile)

(Kahn, 2007)	14 Cities in US	a: Walk-and-Ride station; b: Park-and-Ride station	1970-2000	1970-2000	6,215:559[a], 816[b]	HRT LRT	Aggr.				Global: +3%[a], *ns*[b] (low income) Cities: + effect[a] (6 cities), - effect[b] (2 cities)
(Kittrell, 2012)	a: Phoenix, AZ b: Tempe, AZ c: Mesa, AZ	METRO LRT	2008	1990-1997, 1998-2008	259:33	LRT	Vacant	A	A	B	a: +117% global, +250% to –12% by station b: +429% global, +1,639% to +28% by station c: -12% Control: +281% to +86%

ns = Not Significant at 95% confidence level
Transit Type: HRT: Heavy Rail Transit; CRT: Commuter Rail Transit; LRT: Light Rail Transit; BRT: Bus Rapid Transit
Property Type: Single: Single Detached; Semi: Semi-Detached; Multi: Multi-Family; Comm: Commercial; Indust: Industrial; Aggr: Aggregate Zone
Dependent Variable: A: Sale; B: Assessment; C: Rental
Study Design: A: Matched Pairs / Quasi Experimental; B: Repeat Sales Comparison
Access Method: A: Proximity Distance (Continuous – change in dependent variable as distance to the station *decreases*); B: Proximity Bands (Fixed Effects – change in dependent variable within distance band)

2.2 DIVERSE METHODS AND DIFFERENTIATED OUTCOMES

It is now generally accepted among planners and policymakers that the construction of a new rapid transit line will result in some amount of land value uplift. It has become so common that the estimation of such benefits frequently makes up an important part of the rapid transit planning process through benefits-cost analyses that outline the principal justifications for different rapid transit projects. However, based on the studies Table 2-1, it is not hard to conclude that research in this area defies easy synthesis, making such a narrative simplistic and potentially problematic.

It should first be noted that the present paper limits its analytical the scope to research that has occurred on rapid transit systems in North America in the previous 40 years. There are of course many more studies that have occurred around the world, as well as earlier than this time period (e.g. Spengler, 1930). However, the purpose of the paper is not to conduct a global literature review. Rather, the choice to focus on North America was done to make the paper manageable, but also to provide a relatively homogeneous sample of studies and to use this sample as a foundation on which the commentary can be based.

Our sample includes more than 60 studies within which there are 131 separate analyses of LVU. Table 2-2 provides a basic categorization of these analyses by transit mode and property type. A majority of studies examine the effects of HRT and LRT on single-detached housing, followed by commercial properties. In general, studies for CRT and BRT are under-represented, as are studies of other property types.

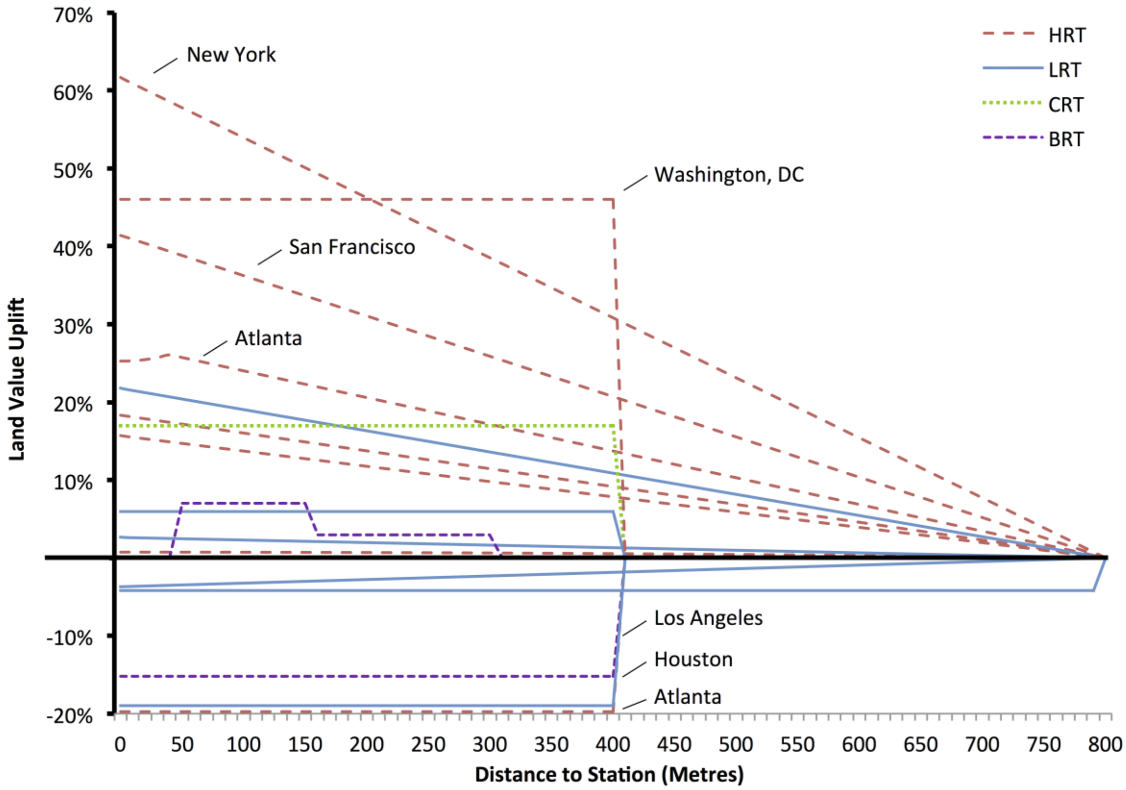
Table 2-2. Categorization of North American LVU Analyses

Mode	Single Detached	Multi-family	Condominium	Commercial	Office	Retail	Industrial	Vacant	Mixed	Aggregate	Total
HRT	23	8	1	12	1	1				1	47
LRT	22	7	5	7	3	3	2	3	3	2	57
CRT	8	2	2	3					1	1	17
BRT	3	1	2	1							7
Mixed	1		1							1	3
Total	57	18	11	23	4	4	2	3	4	5	131

From this body of work, our review in Table 2-1 reveals that many studies have indeed found significant positive relationships between rapid transit and land values. However, there is a dramatic range in findings, and several seemingly similar studies have drawn opposite conclusions, with some finding that transit has actually decreased land values. This can be seen visually in Figure 2-1, which considers a small sub-sample of studies that examined the LVU effects of different modes on only single-detached homes.

To offer a rough comparison we assume a constant starting value for land and plot the rate of LVU derived from model coefficients across transit modes and a distance of 800 metres from a station (½ mile). At about a 10-minute walk this is the distance at which such LVU effects are typically expected (Guerra et al., 2013). From this we can see dramatic variation in estimated LVU across modes and cities. Several heavy rail transit (HRT) systems exhibit very high rates of uplift, some with local disamenity effects close to a station. However, some HRT studies are insignificant, negligible, or even negative, and there are sometimes stark differences between studies in the same city. The same is true for LRT, BRT, and commuter rail transit (CRT), and the inconsistency in LVU outcomes is only magnified when considering all the analyses in Table 2-1 and Table 2-2.

Figure 2-1. Sample LVU Coefficients for Single-Detached Homes



Still, while Figure 2-1 is useful for illustrating differences, making direct comparisons between studies is problematic as a number of factors introduce heterogeneity and limit comparability in the previous literature. At a high level, differences can be attributed to variation in transit modes and their respective accessibility characteristics, property type, the time frame of study relative to the transit investment, and geography, which includes different countries, cities, neighborhoods, transit corridors, and station areas. Authors have also utilized a range of methodological approaches. Table 2-1 captures the two broad families of methods: hedonic multiple regression in Part A, and matched pairs or repeat sales comparisons in Part B. Methods also differ within each family. Among regression studies for example, Table 2-1 captures variation in sample size, which can range from a handful of records to several thousand, different types of dependent variable, such as using sales, rents, or assessments, cross-sectional or longitudinal study designs, model functional forms, the spatial extent of the study area, and the different types of key independent variables used to measure the LVU of rapid transit. Furthermore, a small number have incorporated either tests for or remedies to issues associated with spatial autocorrelation in multiple regression models, which if not accounted for can violate assumptions of independence of errors, inflate test statistics, and erode model validity.

Taken together, the simple explanation is that the context of a particular study is fundamental to its outcomes. Such heterogeneity in results has not stopped recent attempts to provide at least a rough qualitative outline of progress to date (e.g. Bartholomew & Ewing, 2011). Likewise, two meta-analyses have also been conducted that seek to statistically control for variations in such variables and draw out generalizations (Debrezion et al., 2007; Mohammad et al., 2013). But is the previous literature's heterogeneity in outcomes really only a product of the importance of geographic, temporal, or methodological context noted earlier? Or is something larger at play, something even meta-analyses cannot control for? We argue that aside from context, one of the fundamental reasons for such inconsistency in research outcomes is that the previous literature has suffered from incomplete theoretical guidance that contributes to omitted variables, limits consensus and comparability, and exposes previous studies to potentially misleading results.

2.3 DEBATABLE ASSUMPTIONS

2.3.1 Hedonic Pricing and Spatial Equilibrium

It is first useful to review what is meant by 'value' and the theoretical frameworks that surround its interpretation in the literature. The land value impacts of rapid transit are understood in terms of the values, prices, or the willingness to pay that individuals associate with the positive and negative properties of the infrastructure. In the context of the studies in Table 2-1, the unit of measurement is expressed as US or Canadian dollars at a particular period in time (no studies of LVU could be found for Mexico). One of the benefits of working in terms of such values is that they are intrinsically intuitive for scholars, practitioners, and the public alike. However, it is important to remember that any value must be interpreted in reference to a state of equilibrium. Broadly speaking, equilibrium occurs when the price of a good is such that the amount demanded matches that supplied and the market clears. When demand outstrips supply, prices rise and the market re-equilibrates. Similarly, falling demand or increasing supply causes prices to decrease and a new equilibrium to emerge.

While this presents a powerful model for understanding the pricing and consumption of many goods, it does not readily apply to a highly differentiated good such as housing that sells for a variety of prices. Of course, the price of a home varies because a home is really a composite package of seemingly endless combinations of attributes.

For example, it would be reasonable to expect that homes with more bedrooms or bathrooms tend to sell for more money. But just how much is an extra bedroom or bathroom actually worth? Rosen (1974) established the hedonic pricing method for estimating the implicit value of differentiated goods through the use of multiple regression analysis whereby the price of a product is regressed on the attributes of that product. In this sense, a hedonic price reveals the point of equilibrium between supply and demand for these attributes.

However, because a real estate market is inherently spatial, hedonic prices in such an application must be interpreted according to a state of equilibrium that occurs across space. To date this condition has been satisfied in the LVU literature through a focus on accessibility, which we explore below. The prices in matched pairs or repeat sales comparisons are also interpreted in relation to spatial equilibrium conditions.

Before proceeding, it should be noted that a number of issues with hedonic models have been identified since the method was proposed. According to Kim et al. (2003) they can be classified within four broad families: issues related to functional form, model identification, statistical efficiency, and benefit estimation, the latter of which includes issues of spatial dependence mentioned above. While all four families should be considered when estimating hedonic models, our focus here is on the final issue of the conceptualization and estimation of benefits as they relate to rapid transit.

2.3.2 Alonso and Accessibility

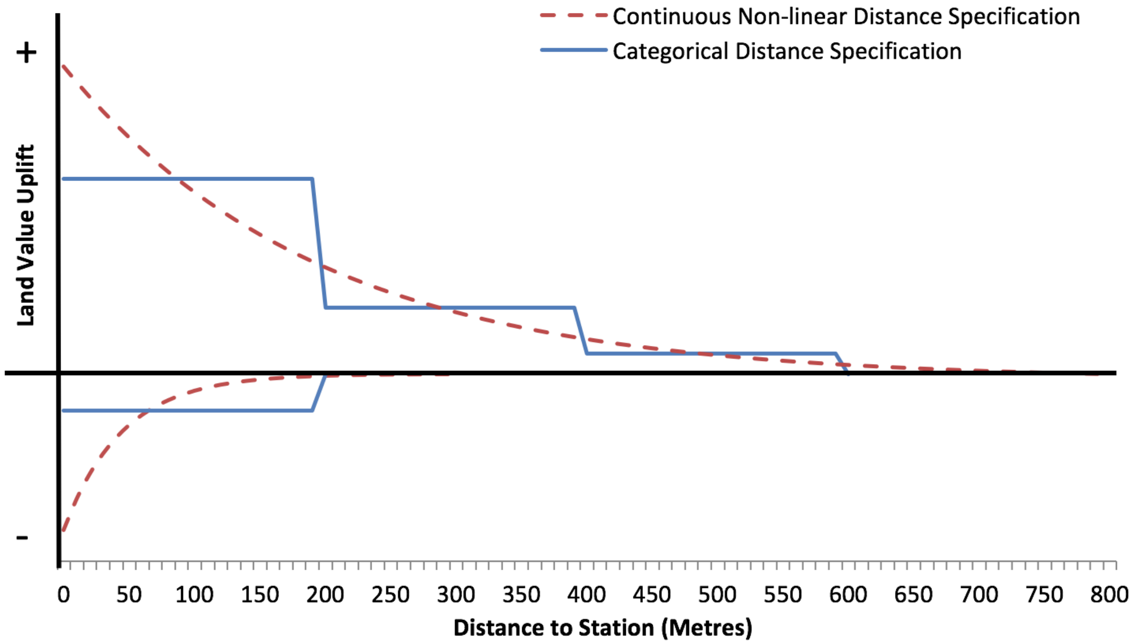
The theoretical basis of past studies seeking to understand how rapid transit affects land values has overwhelmingly been the spatial equilibrium framework developed by Alonso (1964), Muth (1969), and Mills (1972) referred to here as the Alonso-Muth-Mills (AMM) model. The model focuses on the location decisions of firms and households. Firms seek locations that maximize profitability by minimizing transportation costs, with retail firms for example theorized to locate in the central business district (CBD) due to its high levels of accessibility. Households on the other hand seek to maximize utility in a trade-off between two factors: transportation costs or locational accessibility and land rent or housing consumption. Readers interested in a more detailed explanation of the model are directed to Brueckner (1987).

The model is of course an abstraction of the factors that affect the location of people and firms. But through its focus on changes in bid-rent attributed to changes in transportation cost, the AMM model provides a convenient foundation on which to study effects of rapid transit on accessibility and land values. By offering an increase in accessibility and a decrease in transportation costs, the opening of new rapid transit infrastructure should create a locational advantage for land close to rapid transit stations, causing people and firms to outbid one another for access, which should be reflected in a localized bid-rent surface that peaks at transit stations.

It is either the existence or temporal changes in the bid-rent surface that the researchers in Table 2-1 have sought to capture to identify the LVU impacts of a rapid transit project. The vast majority of studies have operationalized accessibility through measures of proximity to rapid transit access points (Figure 2-2). For example, those utilizing hedonic multiple regression on a cross-section of sales of single-detached homes typically employ either continuous linear or non-linear measures of distance to the nearest station in an attempt to capture the marginal change in land values associated with changes in distance or walking time. Others utilize a set of categorical or dummy variables corresponding to a parcel's location within various circular rings of distance around a station.

Some studies have also noted the presence of negative externalities such as noise, vibration, pollution, or crime associated with being too close to a station or a transit right-of-way. In the former, aside from studies that find an overall negative land value gradient, simultaneous specifications of distance to the station and distance squared account for amenities and disamenities of immediate proximity to stations (e.g. Chatman et al., 2012; Chen et al., 1998; Goetz et al., 2010; Nelson, 1992; Nelson and McClesky, 1990) and the balance of the positive and negative effects of proximity are used to determine LVU. The distance band used by many other studies can also detect any disamenities associated with immediate proximity. Both of these scenarios are depicted in Figure 2-2 below. In the latter case, similar methods have been used to isolate any disamenities that accrue from being too close to a transit right-of-way, a location that may also exhibit depressed price effects from negative externalities but without a corresponding increase in accessibility. Studies such as Armstrong and Rodriguez (2006), Ferguson et al. (1988), Goetz et al. (2010) and Landis et al. (1995) have found this to be the case.

Figure 2-2. Positive and Negative LVU Effects by Distance Specification



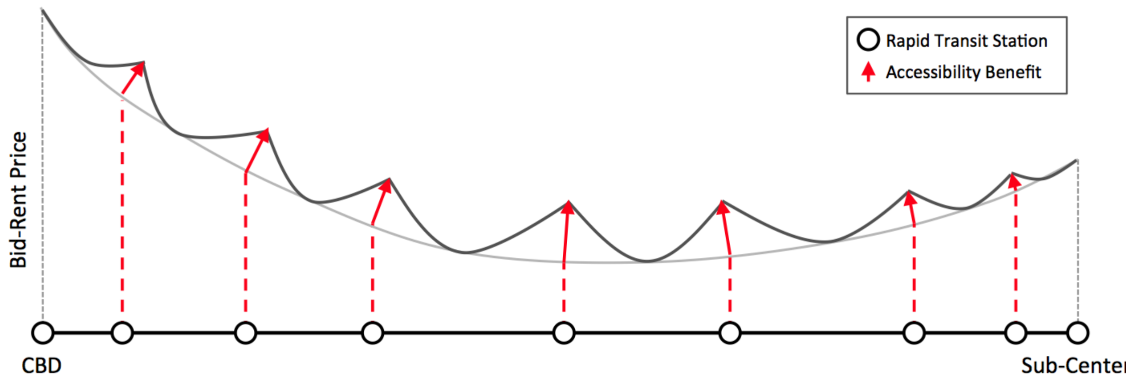
The overall magnitude of LVU depends on the magnitude of positive and negative externalities. For positive, this consists of changes in both local and regional accessibility. Regional accessibility refers to the reduction in transportation costs associated with travel between regional origins and destinations. Generally speaking, the AMM model in its original monocentric form hypothesizes a peaking of land values in the CBD due to its high levels of regional accessibility. The increasing costs of travel to the CBD as distance increases leads to a decline in values into more suburban areas. Extending the model to a more realistic depiction of polycentric cities naturally means a rise in accessibility around regional sub-centres.

In this sense, a new rapid transit line that connects the CBD and a regional sub-centre such as that depicted in Figure 2-3 results in an increase in accessibility and land values around stations. For homes, the magnitude of this change is less for central locations where accessibility is already high, and greater for more suburban areas where the aggregate change in accessibility and reduction in transportation costs for travel to regional centres due to the new line is potentially greatest. Figure 2-3. Regional Rapid Transit Accessibility Benefits and Bid-Rent Prices focuses on home users, and this theoretical relationship stands to be different depending on alternative economic actors. For example, a new transit line may make land in the CBD significantly more valuable for firms due to greater access to the regional market.

In line with the AMM model, regional accessibility should in theory be a considerable driver of LVU. However, local accessibility also matters. This refers to neighbourhood accessibility to local services which, among other things, can be tempered by the existence and type of local businesses or amenities in an area and design of the street network connecting them to homes. This is a topic we return to later, but together both local and regional accessibility determine the overall scale of LVU captured through measures of proximity.

Note that land value changes associated with accessibility accrue to land, not structures. This makes examining price changes for unimproved or vacant land the most ideal modelling scenario, though a lack of such parcels compared to other types makes such analyses impractical. Indeed, Table 2-2 shows only 3 such analyses within our sample. In response, researchers using other property types complete the hedonic model by including attributes of the structure and other locational factors to control for the price of these characteristics. According to theory, the resulting specification isolates the effects of transit proximity on land and the nature of the bid-rent surface as it relates to levels of accessibility for different locations at spatial equilibrium.

Figure 2-3. Regional Rapid Transit Accessibility Benefits and Bid-Rent Prices



However, although it has been widely applied, this approach is problematic. While measures of proximity can capture changes in bid-rent gradients, such measures merely act as proxies for a host of underlying factors that influence the distribution of land values across space. In the previous literature, the focus on the AMM model's theoretical guidance has meant that any significant proximity effects are interpreted as accessibility benefits. In some cases this may be true – accessibility is being reflected in a bid-rent gradient around a transit station. But in other cases, the focus on regional accessibility as a driver of LVU appears tenuous. In measuring just proximity, researchers are capturing only the very surface of a complex and substantial relationship, only part of which may be attributable to accessibility. These issues are explored further below.

2.3.3 Accessibility Revisited

Despite its simplicity, the AMM model enables some relatively powerful predictions to be made regarding the power of rapid transit to affect land values and shape land use. However, there are two interrelated reasons to re-evaluate the focus on accessibility as the foundation of modelling value uplift: first, unaccounted variation that can be attributed to the poor theoretical guidance offered by the AMM model when considering the limits of rapid transit accessibility and second, the omitted LVU effects of simultaneous transit-oriented land use planning.

2.3.3.1 Relative Accessibility and Unaccounted Variation

The first significant factor confounding previous findings is the practicality of expectations of LVU derived from the AMM model when considering the potential limits to a rapid transit line's *relative* regional accessibility benefits in many contexts. If a rapid transit project in and of itself is to have a large impact on land values and land use, the AMM model makes it clear that it must offer an increase in accessibility and reduction in transportation costs. However, accessibility in the abstract is not valued. A transit line must connect important regional origins and destinations that individuals value access to, and offer a tangible reduction in the costs of travel between them. But generally speaking, a transit facility by nature offers service to a localized corridor and likely constitutes only a small subset of all regional transportation infrastructure. This is particularly problematic in very decentralized regions where even a large transit network can only reach a small subset of all important origins and destinations.

Furthermore, even for those locations that it does serve, transit may still not offer a competitive option relative to other modes. Locations throughout an urban area may already be well-served in terms of transportation accessibility, such as through convenient access to a highway system that offers low travel times with little congestion or through cycling, pedestrian and existing transit options in dense and mixed-use central locations. In these examples, even if it offers exemplary service, the addition of a new transit line may not realize much of a benefit in accessibility or locational advantage compared to present options and therefore should not be expected to greatly impact land values. In this sense, it can plausibly be argued that rapid transit as a mode cannot offer a measurable increment in accessibility and locational advantage given the near ubiquity of automobile-oriented accessibility in many urban areas, particularly for those with built forms that have developed around the car.

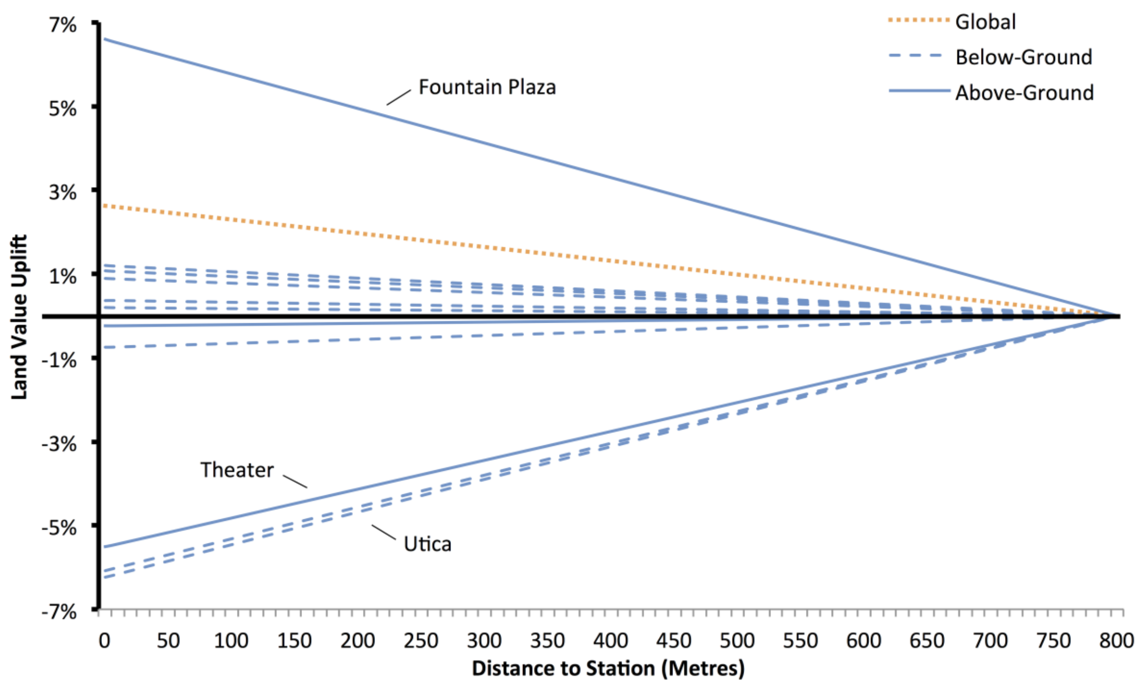
Of course, factors such as road congestion, fuel cost, parking supply, and road pricing can alter the attractiveness of the automobile relative to transit in such contexts. A good proxy for relative accessibility of transit is ridership, as if a system offers competitive travel times and travel costs between important regional origins and destinations compared to other modal options then it should be reflected in the number of individuals that choose to use the service. An example of this in practice can be seen in Landis et al.'s (1995) study of Sacramento's LRT where low relative accessibility offered by transit was attributed to the area's uncongested highway network, resulting in low ridership and insignificant land value effects in LRT station areas.

Given the limits of rapid transit's relative accessibility benefits in many automobile-oriented urban contexts, the focus on the AMM model's theoretical guidance can leave significant variation in LVU benefits unaccounted. Consider the results of some recent studies. Like Landis et al.'s (1995) research on Sacramento, a researcher working through the lens of the AMM model could reasonably expect minimal LVU effects to be associated with rapid transit considering its potentially low relative accessibility benefits in other auto-oriented cities. In the recent cases of LRT in Phoenix or San Jose for example, neither line reaches a large proportion of all regional destinations. In San Jose in particular, ridership per kilometer of track remains comparatively low when viewed against other systems in North America. However, several studies have indeed found positive and statistically significant land value effects associated with this system (Cervero and Duncan, 2002a; 2002b; Weinberger, 2001). Such results appear to run counter to what would be expected. Can such LVU effects really be attributed to the transportation cost reductions induced by the transit line itself?

As a second example of counterintuitive findings and unaccounted variation, consider the case of a single rapid transit line. Based on an application of the AMM model, it would not be unreasonable to expect accessibility effects to be fairly consistent across neighboring stations, fluctuating along the line in concert with a particular station's distance from the CBD or other major activity centers as in Figure 2-3. Thus, the accessibility benefits should be reflected in relatively homogeneous LVU effects across stations. The vast majority of models are conducted under this assumption by considering a number of station areas simultaneously and returning 'global' or average LVU impact coefficients within the study area. However, some studies have gone deeper to explore LVU within individual station areas and found wildly different results.

In Dallas, Weinstein and Clower's (1999) comparisons of single detached homes within one-quarter mile of different stations ranged in value from +49% to -49%. In Phoenix, Kittrell (2012) found that prices of vacant land ranged from -12% to +1,639% at different METRO LRT stations. And in the case of Buffalo, Hess and Almeida (2007) found that across their sample of homes within one-half mile walk of *any* LRT station, prices increased by roughly $1 for every foot closer they were to a station. However, a separate model considering different stations individually found results ranged from +$27 to -$26 per foot. Even among four neighboring stations, the LVU impacts were determined to be -$26, +$5, -$23, and +$27 per foot closer to each respective station. The stark differences in these coefficients can be seen in Figure 2-4 below, which are plotted in the same manner as Figure 2-1. Is it really the case that accessibility varies quite substantially from one station to another along a single line? If it is not strictly *accessibility* driving LVU in these examples, then what other factors or relationships are affecting land values around transit stations? This leads to the second factor limiting the application of the AMM model to this area of study.

Figure 2-4. Rates of LVU along the Buffalo Metro Rail LRT



2.3.3.2 Rapid Transit and Land Use Planning

Building on the above, a second reason to re-evaluate the previous literature's focus on the AMM model is that viewing relationships only through the lens of accessibility often fails to account for other simultaneous factors associated with rapid transit planning, factors that can have a profound effect on the urban land market. Consider first an ideal application of the AMM model in this research area: to afford the researcher a high degree of certainty in associating changes in bid-rent curves with accessibility, all factors within an urban market are held constant other than a change in accessibility offered by the new rapid transit infrastructure. However, as Giuliano (2004) explains, cities do not exist in stasis and rapid transit projects rarely occur in isolation of other simultaneous land use and transportation planning initiatives. A focus strictly on accessibility fails to control for these factors and can contribute to variability among study outcomes and questions concerning model validity and causality.

Research on the power of transit to shape land use has long acknowledged the complementarities of transportation and land use planning, finding that transit alone has generally been insufficient for spurring development and redevelopment (Higgins et al., 2014). In the AMM model, changes in land value that accrue from increases in accessibility should result in more intensive uses of land to cover the cost premium, triggering land use change around stations. However, in examining the impacts of several transit systems in North America, Knight and Trygg (1977) found that little change had occurred in practice. This prompted the conclusion that the magnitude of transit's accessibility benefit, if any, is not sufficient for affecting land use change on its own in many contexts, and furthermore that such impacts are dependent on the presence of other complementary factors including a healthy and growing regional economy, positive physical and social characteristics in station areas, available land for development, and public policies that incentivize development.

Responding to the lessons learned from the last point specifically, transit planning has since become much more integrated with land use planning as part of a policy shift towards promoting transit-oriented development (TOD). In the United States, a pivotal turning point came in 1998 when six explicit land use planning criteria became part of the Federal Transit Administration's process for evaluating New Starts projects. In Canada the shift is similar, though comparable programs formalizing and incentivizing TOD at the federal level do not exist. Crucially, this shift to integrated transit and land use planning has a profound effect on the estimation of LVU models. Though there are many aspects of TOD, a growing body of evidence suggests that TOD-related factors can have a significant effect on land values in addition to, or even potentially irrespective of transit accessibility.

For example, consider zoning regulations. Land use development is not carried out in a purely free market as zoning regulates the type and character of development in a given area and can therefore dramatically alter the value of land. More restrictive zoning can reduce the value of land if the market would have allocated it to a different use, while less restrictive zoning can free a parcel from externalities and potentially increase its value (Dewees, 1976). A common element of TOD land use planning is incentivizing development through changes to zoning ordinances that permit higher-density development and the mixing of land uses, and it is not unreasonable to expect that such market interventions can affect patterns of LVU. If such bonuses are selectively applied to a defined area around a transit station, and in as much as the market values high-density development and the returns outweigh the costs of construction, they can create a locational advantage around a transit station that should be reflected in higher land values.

Beyond zoning there is a growing body of literature that has acknowledged additional price effects of aspects of land use planning and TOD outside of accessibility to the transit facility itself. Bartholomew and Ewing (2011) offer a review of recent literature in this area, noting that studies have found significant positive LVU spillover effects associated with TOD factors such as mixed use zoning, open and public spaces, amenity-rich neighbourhoods, and pedestrian-oriented street design. In this sense, TOD provides an element of neighbourhood accessibility to local amenities, and if not explicitly controlled for can obscure a transit project's regional accessibility effects. However, the value placed on these amenities may not be equal across all segments of the population, and we expand on solutions to accommodate this in future research below.

2.4 FUTURE DIRECTIONS

Taken together, the arguments presented above present a case for re-evaluating the theoretical foundations of research into rapid transit's LVU effects. In response, we propose two remedies that can help to ensure that future research in this area progress in a way that reduces the potential for heterogeneity across studies and leads to results that are more empirically valid.

2.4.1 Accessibility Redefined

First, one of the major problems in the previous literature is the way accessibility has been operationalized in hedonic and sales comparison models. Measures of proximity to a station can capture changes in bid-rent surfaces. But the problem arises in determining just what conditions these surfaces are associated with in the underlying urban system. When viewed through the AMM model these bid-rent gradients are interpreted as reflective of accessibility benefits. However, in her review of the LVU literature, Ryan (1999) argued that researchers need to better specify accessibility if their models are to actually capture the expected relationship between accessibility and land values.

Instead of merely using proximity as a proxy for accessibility, one solution is to utilize measures that actually reflect accessibility such as incorporating generalized transportation costs into cross-sectional models and changes in these costs in longitudinal models. This includes time and monetary factors associated with regional accessibility such as transit travel time and relative travel time compared to other modes in free-flow and congested travel, fare levels, and the availability and cost of parking. Such measures can be operationalized directly or integrated into aggregate regional accessibility metrics such as a measure of gravity between population and employment at regional origins and destinations.

Greater adoption of such measures in the future will help to better identify actual transport costs and levels of accessibility offered by the transit facility and help to isolate their LVU effects. However, such measures consider regional accessibility, and there is still a need to isolate regional from local accessibility. This leads to our second solution below.

2.4.2 Tiebout Sorting, Self-Selection, and Transit-Oriented Development

Above we have taken the position that first, the fragmentation in previous results is a product of a value placed on other local neighbourhood characteristics associated with the rapid transit project in tandem with, or beyond just the regional accessibility afforded by the transit infrastructure itself, and second, that the past literature's overwhelming focus on the AMM model has resulted in studies that either omit these characteristics from LVU models or misconstrue their LVU effects. From this, a strong argument can be made that in addition to, or even in the absence of a regional accessibility benefit, individuals, households, and firms have been shown to value locations based on a number of other factors such as building type, neighborhood amenities, or the lifestyle choices available in a particular location, and many of these factors that are influenced by transit-oriented land use planning.

From this, the second way in which the literature in this area can be improved concerns better isolating the LVU effects of regional accessibility from these local factors. An immediate solution for modelling LVU is to incorporate more variables to control for local-scale drivers of LVU, which leaves generalized transport cost metrics or simple station proximity to reflect regional accessibility.

However, past research has argued that such local-scale factors associated with TOD are not valued equally across the population. For example, both Cervero et al. (2004) and Dittmar et al. (2004) noted a clear submarket of young individuals, retirees, and recent immigrants that are particularly important target markets for transit-oriented lifestyles. This leads to an issue of heterogeneous preferences, and incorporating measures of local transport costs and local amenities and the LVU effects associated with individual preferences for them into an assumption of spatial equilibrium requires the adoption of a wider theoretical perspective beyond the AMM model's focus on accessibility.

This leads to a second spatial equilibrium framework, that of Tiebout's (1956) theory of sorting, whereby individuals 'self-select' their location based on the best fit between their preferences and particular baskets of public goods and prices. Crucially, Tiebout's theory provides a basis for understanding how amenities shape locational decisions. For example, if a subset of individuals has a preference for higher-density, mixed-use, and walkable built environments, they may pay a premium to locate in such a neighborhood. If due to restrictive zoning or other reasons the supply of such neighborhood types is constrained, then it would also be reasonable to assume that if a transit-oriented secondary planning area permits such development then prices for this type of good will increase. This same relationship holds true for many of the other benefits of rapid transit such as a reduction in local air pollution that makes an area more desirable relative to others. Even transit accessibility itself can be understood as a local amenity that certain segments of the population may value more than others based on preferential factors beyond rational considerations of transportation costs.

Sorting based on preferences can be problematic for drawing inferences from hedonic models as it creates spatial sub-markets within a study area, and equilibrium prices based on such preferences cannot be assumed to reflect those of the wider city or region. As such, the failure to take such factors into account reduces the ability to draw generalizations from previous studies. Still, locational control variables and spatial statistical methods can implicitly take geographic submarkets into account, thereby enabling more precise estimation of other benefits on land values directly specified in the hedonic model.

However, the central issue here is the explicit recognition of drivers of spatial market segmentation as they relate to rapid transit and the estimation of their LVU effects. Simultaneous rapid transit and transit-oriented land use planning creates a bundle of locally-oriented and regionally-oriented goods, and particular bundles are not likely to be valued equally across all segments of the population. Hedonic models based on an expanded theory of accessibility and sorting recognize this and allow for the identification of the separate benefits of regional accessibility to jobs and local accessibility to TOD and a more precise estimation of their combined LVU benefits.

For example, research working from a foundation in proximity only may indeed find a statistically significant association between distance to a rapid transit station and higher land values. But how much of this bid-rent gradient can be attributed to the regional accessibility effects of the rapid transit line, and how much to other local factors? A measure of generalized transport cost may reveal that the relative accessibility impact of the rapid transit line is limited. However, the addition of other land use planning and built environment variables may account for previously omitted LVU impacts resulting from the value created by individuals self-selecting to locate in a mixed-use, pedestrian-oriented, and amenity-rich TOD near a transit station rather than the regional accessibility offered by the rapid transit station in and of itself. Such factors stand to be important drivers of LVU and can potentially explain why some station areas along a single transit line or lines in the same city see dramatic increases in price while others experience insignificant or negative price impacts.

2.4.2.1 Sorting and Accessibility

To clarify, Tiebout sorting and the AMM model should not be understood as exclusive. Rather they are complimentary. On a practical level, a mixture of the AMM model's focus on accessibility and Tiebout's amenities and sorting hypothesis is intuitive for explaining how rapid transit causes LVU. Accessibility to places of employment and other non-work destinations remains a very significant factor in location choice. Yet given the number of travel options between many locations, other preferential factors also necessarily come into play when individuals and households decide where to live and how much to pay. Both theoretical approaches reinforce the need to adopt a wider theoretical lens while still examining past and future LVU within a station area's local context.

While no studies have explicitly incorporated of Tiebout's theory, many have implicitly taken elements of sorting into account by utilizing spatial statistical models or controlling for the characteristics of census tracts, school districts, or locations in different counties. Other studies have examined sorting as it relates to spatial sub-markets and rapid transit specifically. Many studies in Table 2-1 have found differing price effects for different property and neighbourhood types. Duncan (2011) found greater LVU effects for condominiums than single-detached homes around stations in San Diego. Nelson (1992) controlled for different neighborhood types and found that LVU effects around several MARTA stations were positive in low-income areas south of the line and negative in higher-income areas north of the line. Kahn (2007) examined average price changes for census tracts with new rail rapid transit systems and found that for cities where prices appreciated, they did so only in areas with walk-and-ride stations, while park-and-ride stations were associated with a disamenity effect.

In terms of TOD, Kitrell (2012) argues that the extension of unlimited height zoning ordinances as part of transit-oriented and use planning contributed to spiking land prices around Phoenix LRT stations. Mathur and Ferrell (2009) indirectly examined the effects of transit-oriented amenities, finding that prices of single-family homes within 1/8 mile of a transit station did not gain in value until during and after the construction of a mixed-use TOD that replaced a park-and-ride lot. Duncan (2011) examines LVU by explicitly taking elements of TOD into account and found that higher densities, walkable environs, street network connectivity, and retail employment led to higher prices around San Diego Trolley stations. Finally, Atkinson-Palombo (2010) works from a similar assumption that certain individuals are more likely to self-select to locations that offer higher densities and greater amenities. This study in particular presents a promising approach that first identifies broad station-area types and constructs hedonic models that estimate the land value gradient in these more homogenous areas along the Phoenix LRT.

A final note considers extensions of Tiebout's theory to LVC. The rationale for value capture is based on the notion of extracting some or all of the value created through a public investment, value that would otherwise manifest itself in unearned gains or 'windfalls' for private individuals and firms. In this sense, the direct accessibility benefits that result from a public improvement lend themselves to a firm rationale for LVC. But an argument could be made that the LVU benefits that result from land use change or an increase in neighborhood amenities actually accrued through *private* investment, and thus there is no rationale for public value capture. However, in so much as such public actions such as changes in zoning undertaken through simultaneous transit and land use planning enabled any such private improvements, the rationale for LVC from this aspect of rapid transit's LVU effects arguably still exists.

2.4.3 The Limits of Hedonic Comparability

Although we have identified two remedies to help improve future research in this area, an important drawback concerning the interpretation of hedonic coefficients exists that, if not explicitly controlled for, will continue to produce unaccounted variability in higher-level generalizations and meta-analysis in the literature. Because a hedonic price is interpreted at the intersection of supply and demand in a state of equilibrium, they can only be understood as a snapshot of the value placed on a particular good at a particular interval in time. This means that the willingness to pay for accessibility or local amenities is tempered by a host of contextual factors from fares, gas prices, the characteristics of the transit service and levels of congestion to population and employment growth and the nature of the local real estate market. Quite simply, the outputs of a rapid transit LVU model will continue to be shaped by its inputs and as such the results of one study cannot be assumed to be applicable in another location at a different point in time. While meta-analyses can control for such factors, without information on them they contribute to omitted variable bias and impair the accuracy of broader estimates of LVU.

Furthermore, researchers will continue to be limited by what they can empirically observe. An incorporation of Tiebout's sorting into the theoretical guidance surrounding the estimation of hedonic multiple regression models can help to quantify the value or willingness to pay for locational amenities. However, this represents only the prices associated with *revealed* preferences. In a hedonic LVU model based on transacted real estate prices for example, without collecting information on the home buyers themselves through additional survey data collection, the interpretation of results will continue to be limited to understanding model coefficients as they relate to some unobservable preferential equilibrium. This is especially pertinent for temporal shifts in LVU. In the United States for example, per capita VMT has fallen for nine consecutive years while inner-city population growth and transit ridership have increased. If these shifts reflect changes in underlying preferences, they should be reflected in higher values placed on transit infrastructure.

2.4.4 Alternative Modelling Frameworks

To this point, the present paper has focused on the hedonic pricing method as a strategy for revealing the implicit value placed on transit accessibility and TOD in the urban land market. However, an alternative to hedonic models can be found in an application of random utility theory and discrete choice methods. Hedonic models assume individuals make continuous choices about characteristics of a home and location. In contrast, discrete choice models assume that individuals choose among a set of quasi-unique bundles of housing and locational goods (McFadden, 1978). A further integrated framework that considers both the bid-rent functions of the AMM model and discrete choices can be found in Martinez (1992). Both modelling frameworks are compatible with the arguments made above, and applying them to LVU research is an avenue that appears promising and should be investigated in the future.

2.5 CONCLUSIONS

The present paper began by describing two important rationales for understanding the LVU impacts of rapid transit. However, heterogeneity in the results of more than 60 studies and 130 analyses completed over the past 40 years in North America suggests that firm answers to many important questions surrounding these rationales will continue to remain elusive. As such, while the notion that rapid transit *will* increase land values is convenient for policy and planning purposes and indeed reflective of the results of many studies, it is nonetheless ignorant of the differentiated results found in the wider literature.

If answers to these questions are to be realized, future sources of heterogeneity must be identified and minimized. At a high level, differences in methods, geography, time, and transit technology naturally make findings across studies difficult to generalize. However, a more fundamental source of heterogeneity concerns the incomplete theoretical guidance informing these studies and the debatable assumptions that result. Working through the theoretical lens of the AMM model, the vast majority of previous work has sought to identify rapid transit's LVU effects by capturing the existence of, or changes in bid-rent prices attributed to rapid transit's regional accessibility benefits. But there are several important reasons to re-evaluate this focus on accessibility. Many findings have been inconsistent with the AMM model and there are limits to rapid transit's relative accessibility benefits in many contexts.

But more importantly, a focus on accessibility hinders the identification of additional factors affecting land values around rapid transit stations. More often than not such a relationship is operationalized on models through measures of proximity to nearby transit stations. But proximity is itself a proxy for many things. While they may capture a bid-rent gradient, measures of proximity reflect only the tip of a very complex iceberg. With a growing emphasis on incentivizing transit-oriented land use change, planning for rapid transit rarely occurs separate from land use planning. Yet studies that equate proximity with accessibility omit this important aspect of a rapid transit project's total LVU impacts and expose themselves to potentially misleading results. This is especially problematic when considering the extensions of research to benefits-cost analyses, legal challenges, and localized land value capture tools.

In response to these issues, we reflect on expanded theoretical guidance for future research along two dimensions. First, where possible, researchers should utilize measures that better reflect a rapid transit project's regional accessibility benefits. Second, an explicit adoption of Tiebout's sorting hypothesis provides an alternative theoretical basis around which expectations of rapid transit's LVU impacts can be formed, particularly as they relate to sorting and self-selection among individuals and firms around amenities. The spatial equilibrium frameworks of the AMM model and Tiebout sorting complement one another and enable the separate identification of the land value impacts of accessibility, transit-oriented development, and other external amenities.

Still, the equilibrium assumptions involved in the interpretation of hedonic prices and the heterogeneity introduced by unobservable preferences means that pure comparability across future studies through literature reviews and meta-analyses may never be achieved. Nevertheless, transit and TOD are a bundle of goods, and in an age of coordinated transit and land use planning they need to be unbundled to determine the land value impacts, or lack thereof, for each. The adoption of a wider lens beyond accessibility enables a more comprehensive and empirically valid account of these total land value impacts and provides a sound theoretical basis on which more directly comparable research can build. Only in doing so can researchers and practitioners begin to answer the broader questions surrounding rapid transit's land value impacts and the extensions of such findings for planning and policy.

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CHAPTER 3

A LATENT CLASS METHOD FOR CLASSIFYING AND EVALUATING THE PERFORMANCE OF STATION AREA TRANSIT-ORIENTED DEVELOPMENT IN THE TORONTO REGION

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 of 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 that distils 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 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.

3.1 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 & 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 et al., 2004; Dittmar et al., 2004), cohorts Foot (1998) refers to as the 'echo boomers' and 'baby boomers' respectively. The benefits of transit accessibility and transit-oriented land use planning can also be priced into the urban land market (Bartholomew & Ewing, 2011; Authors, forthcoming), 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 evenly distributed across a set of heterogeneous transit stations in a transit system.

How can the complexity of station-area contexts be reduced to achieve a better understanding of their contextual 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 distil 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 distil 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 evaluations of other TOD outcomes is an avenue for future research but beyond the scope of the present paper.

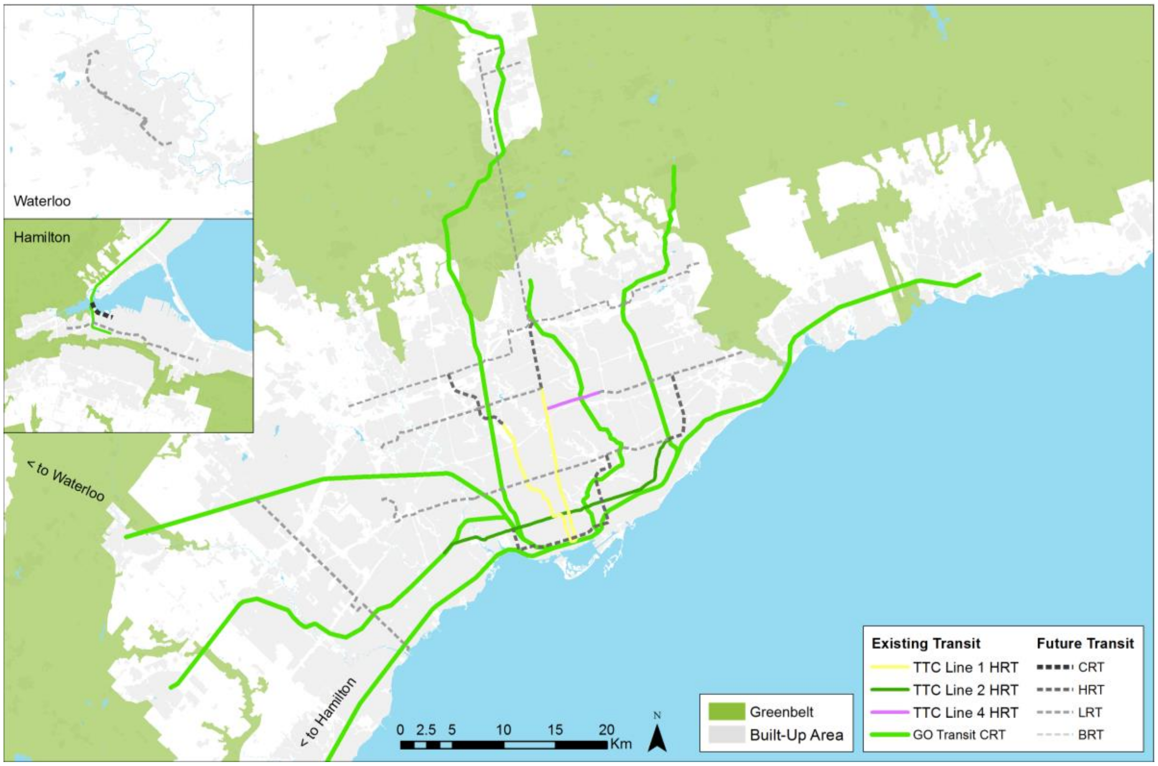
The paper proceeds by first offering brief background information on the case of transit and TOD planning in the Toronto region and a review of previous TOD typology approaches in the literature. Next, we present a methodology for quantifying TOD and producing TOD typologies through the use of latent 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.

3.2 BACKGROUND

3.2.1 Present and Future Rapid Transit Infrastructure Projects in the Toronto Region

There are several existing rapid transit lines and a number of new projects in various stages of construction and planning across the Toronto region. The present research focuses on 18 separate projects (Figure 3-1): 56km of existing Heavy Rail Transit (HRT) across 3 Toronto Transit Commission (TTC) lines with another 40km over 4 lines under construction and in planning, 360km of existing Commuter Rail Transit (CRT) over 7 GO commuter lines with a 2.5km extension presently under construction, 120km of (LRT) over 9 lines and extensions under construction and in planning, and 43km 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 transit stations, which create 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.

Figure 3-1. Present and Future Rapid Transit in the Toronto Region



3.2.2 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.

3.2.2.1 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 (1993) 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, 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 accompanied by appropriate policies required to help turn such visions into reality. For example, the City of Denver (2014) delineated 5 different station types (downtown, urban centre, general urban, urban, suburban) along the city's LRT and CRT lines around which context-sensitive planning policies can be put in place, such as higher zoning allowances for downtown stations and greater building setbacks for suburban stations. Still, the need for more rigorous positive assessments in planning and policy has driven two additional strands of research that seek to quantify TOD and TOD-related factors to arrive at more empirical classifications of station-area characteristics.

3.2.2.2 Positive TOD Typologies

There are generally two positive approaches to classifying TOD around stations seen in the previous literature. The first seeks to quantify and classify the performance of transit station areas according to several nodal or place-based measures. Node-place indices implicitly take TOD into account. In the TOD literature, nodal functions include acting as access points to transit and as an interface between modes in a regional transportation network while places are employment or neighbourhood centres featuring a host of mixed-uses, amenities, and pedestrian-friendly urban design. Dittmar and Poticha (2004) argue that to maximize the potential impact of TOD projects, they need to be cognizant of finding a balance between these functions.

Within this family of research, several authors have been engaged in analyzing the performance of European rail stations according to their position within a node-place index. Research in this area began with the work of Bertolini (1999), who produced a node-place index to classify a number of rail stations in the Netherlands according to their nodal accessibility (such as intensity and diversity of transport options) and place-based characteristics, such as the intensity and diversity of activities within 700 metres of a station. The classification produced four types of stations: two types that exhibited a balance between their node and place functions with the highest intensities said to be in ’stress’ due to the scale of competing demands, and the lowest as ‘dependent’ where low demand for accessibility means other interventions keep the station active. Among those out of balance, stations are said to be ‘unsustained’, where the magnitude of a station’s node or place functions outweigh the other.

Reusser et al. (2008) adopted and expanded on Bertolini’s model with additional node and place measures, and used it to classify more than 1,600 rail stations in Switzerland. Here, a hierarchical cluster analysis applied to 11 node and place indicators resulted in five types of stations: smallest, small, mid-sized in populated areas, mid-sized but unstaffed, and large- to very-large stations in major centres.

Zemp et al. (2011) extend the work of Bertolini and Reusser et al. to classify 1,700 railway stations in Switzerland. The authors perform a hierarchical cluster analysis on 10 standardized indicators resulting in a 7-cluster solution: central stations, large connectors, medium commuter feeders, small commuter feeders, tiny tourist stations, isolated tourism nodes, remote destinations. A principal components analysis was then performed to reduce these indicators to node-place and density-use indices to further describe the clusters.

Finally, Chorus and Bertolini (2011) apply the node-place model to 99 station areas in Tokyo, plotting the results in a similar manner to Reusser et al. The information is then used to determine the factors associated with real estate development dynamics. The authors conclude that proximity to the central business district by train and government policies are important factors influencing development around stations.

Outside of node and place models, other researchers have been actively engaged in a second positive approach to developing transit station typologies that explicitly seeks to classify particular existing TOD characteristics. In analyzing the land value uplift associated with transit-oriented zoning changes enacted in advance of Phoenix's first LRT line, Atkinson-Palombo (2010) first identified 5 distinct clusters of neighbourhood types according to their land use mix: amenity rich, residential-dominated mixed-use, amenity-rich with vacant land, amenity-dominated mixed-use, and residential. Running separate hedonic multiple regression analyses for each neighbourhood type revealed significant price premiums for single-detached homes and condominiums within amenity-dominated mixed-use neighbourhoods and an additional benefit for overlay zoning.

Later, Atkinson-Palombo and Kuby (2011) performed a second analysis of transit-oriented overlay zoning in Phoenix along the line's 27 stations. Twelve separate indicators covering transportation, social and demographic, and land use characteristics were collected for each station area, and a factor analysis reduced these to 5 composite measures. A hierarchical cluster analysis classified stations according to 5 station types: transportation nodes, high population rental neighbourhoods, areas of urban poverty, employment and amenity centres, and middle-income mixed use. Using the typology, the authors find an uneven distribution of overlay zoning across station-area types, with areas of urban poverty seeing the most overlay zoning and transportation nodes, which had the highest proportions of single-detached homes, as receiving the lowest amount, as well as other findings related to the value and type of TOD that occurred in different station contexts.

Finally, Kamruzzaman et al. (2014) used 6 TOD indicators (employment density, residential density, land use diversity, intersection density, cul-de-sac density, and public transit accessibility) to classify 1,734 census collection districts (CCDs) in Brisbane. A two-step cluster analysis resulted in four TOD types across Brisbane's CCDs: existing neighbourhood residential TOD, activity centre TOD, potential TOD, and non-TOD. Validation of the typologies against a travel survey revealed that those in TOD CCDs utilized transit and active modes more often compared to non-TOD districts.

3.2.2.3 What is Performance? TOD Inputs versus TOD Outcomes

It is interesting to note that aside from normative and positive approaches, there is another dichotomy between studies that concerns their use of measures of TOD inputs versus TOD outcomes. In expanding on the work of Bertolini (1999), Reusser et al. (2008) incorporate a measure of passenger frequencies into their node-place index and use it in the creation of a station typology. However, Zemp et al. (2011) counter this strategy by arguing that passenger frequencies are in fact a measure of TOD *outcomes* rather than a measure of station context, as it is result of the interplay between different contextual *inputs*.

This distinction between inputs and outcomes is important, and Zemp et al.'s argument is supported by Renne (2009b) who notes that there are a number of ways to measure the performance of TOD outcomes, including transit ridership, but also farebox returns, household automobile ownership and VKT, changes in property values, or economic development among others. To assess performance, Renne (2009b) argues that such indicators should be measured against different sets of comparators: TOD versus TOD station areas, TOD versus non-TOD station areas, and TOD station areas compared to regional averages.

Indeed, this approach to performance measurement is to some degree exemplified in the study by Austin et al. (2010) for the Center for Transit-Oriented Development (CTOD). The CTOD work consists of a matrix of 15 different station types classified by measuring use-mix in terms of a station area's orientation to population or employment, and a measure of household VMT derived from multi-dimensional regression analysis. This method was then applied to classify the performance of 3,760 stations across 29 regions in the United States. The end result was that a majority of stations were found to perform better than the national average in terms of exhibiting lower levels of household VMT. Additional metrics computed for different station types showed that higher density and lower VMT station areas exhibited lower household transportation costs, lower levels of automobile ownership, higher densities, and greater transit use than other station types. However, like Reusser et al., here the typology considers both TOD inputs (use-mix) and outcomes (VMT) simultaneously.

What does this mean in terms of conceptualizing inputs, outcomes, and performance in the present paper? We adhere to the dichotomy of TOD inputs and outcomes in conceptualizing variables. Performance is examined according to TOD outcomes, however only in an ancillary manner. Instead, because our focus is on classifying and evaluating TOD conditions around existing and future rapid transit station areas, our primary emphasis is on assessing the performance of TOD inputs against policy benchmarks. For future stations in particular, TOD outcomes cannot yet be ascribed to particular policy interventions, limiting our use of such measures to an additional descriptive approach. In the framework of Renne (2009b), we are thus primarily analyzing input performance between TOD and TOD station types, and TOD and non-TOD station types, but not against regional averages.

3.3 METHODOLOGY

3.3.1 Latent Class Model-Based Clustering

Clustering involves the classification of observations into similar groups in such a way that observations in the same group are more similar to each other than to observations in other groups. In the previous literature, authors such as Atkinson-Palombo and Kuby (2011), Reusser et al. (2008), and Zemp (2011) have used unsupervised cluster analysis to determine their station or station-area typologies through the use of agglomerative hierarchical clustering methods such as Ward's. Using a measure of 'distance' between observations, typically Euclidian distance or Euclidian distance squared, Ward's algorithm merges single observations into similar clusters that minimize within-cluster variance. The algorithm successively merges these clusters together across iterations until the data is agglomerated into a single cluster.

But the challenge involved in hierarchical clustering (as well as the k-means vector quantization clustering method) is deciding how many clusters to retain from the algorithm. Hierarchical methods offer little guidance to help make such a decision, and although the choice can be guided by theory, intuition, or convenience, it is ultimately an arbitrary one.

In contrast, latent class clustering, which is also referred to as finite mixture modeling, latent profile analysis, or model-based clustering, uses a probabilistic approach to cluster analysis. For an in-depth overview readers are directed to the work of Masyn (2013), but briefly latent class models assume the clustering structure within the population is unobserved, but represented by other manifest variables. Estimating this latent structure involves an assumption of an underlying set of probability distributions within the population. Using maximum likelihood for parameter estimation, the model maximizes a log-likelihood function and clusters cases according to posterior class membership probabilities. This process is similar to k-means clustering, but has the added advantage of producing statistics such as the Bayesian Information Criterion (BIC) on which more formal decisions about the number of clusters can be based.

Other advantages to latent class models include the ability to accommodate unscaled or unstandardized variables, which allows model outputs to be interpreted in their original units. In contrast, the scaling of variables is often an issue in hierarchical and k-means clustering models as unequal variance can result in some clusters dominated by variables with the most variation, a constraint that has led authors to standardize variables through z-score transformations. Latent class models can also accommodate nominal, ordinal, and continuous variables simultaneously and resulting model parameters can easily be extended to predict the classification of additional cases within an existing cluster solution.

The benefits of latent class models do come at the cost of being more computationally intensive than hierarchical or k-means models. Latent class models also rely on the fundamental assumption of local independence, wherein manifest variables are assumed to be independent from one another across clusters and that the latent variable is wholly responsible for explaining the cluster structure. Local dependence typically arises from collinear manifest variables in one or more clusters after latent class estimation, which essentially means the variables are capturing overlapping information. If such relationships are not taken into account, this can result in the locally-dependent variable pairs inflating their importance to determining the latent class structure compared to other locally-independent indicators.

This assumption has different implications for different study areas; in survey research local dependence can result from similarly-worded questions that capture similar information from respondents. In geographic research, local dependence can result from well-known issues that arise from dependencies in variables over space. Still, local dependence can be minimized through the use of quality indicator variables. Furthermore, the flexible structure of latent class models allows locally-dependent relationships to be directly modeled through the use of covariate relationships between manifest variables. In the present research, we utilize this ability to model spatially-dependent relationships among two TOD variables.

Outside of latent class methods, the two-step clustering method used by Kamruzzaman et al. (2014) also appears promising. The method estimates procedures similar to k-means and hierarchical clustering across its two stages, and also offers the ability to incorporate nominal and continuous variable types (but not ordinal) and select the number of clusters based on statistical inference. However, Bacher et al. (2004) found lower levels of performance for the two-step method as implemented in the statistical program SPSS compared to latent class methods implemented in the LatentGOLD software program. Using synthetic data, their comparison noted that the two-step method performs well using continuous variables, but results are mixed when incorporating multiple variable types. In contrast, latent class methods performed well across all tests, providing more accurate cluster solutions and less biased estimators.

Taken together, we argue that the properties discussed above make latent class cluster models a superior and powerful method for conducting research that is not only empirically rigorous but also easily interpretable and extendable to other situations. While a comparison of methods would be interesting, our use of a covariate model structure precludes the use of hierarchical, k-means, and Two-Step clustering methods. Still, further examinations of the differences between methods in geographic applications is an avenue for future research.

3.3.2 Model Variables

While previous authors have defined TOD outcomes, an important issue to overcome in classifying transit stations according to the performance of their TOD inputs is how to define these inputs and then operationalize them into measurable variables. Cervero et al. (2004) note that no strict definition of TOD exists. In general terms the concept is understood to loosely refer to related to high-density, mixed-use, and walkable development oriented to transit service. Other authors have attempted to offer a more precise account of TOD inputs. Dittmar and Poticha (2004) consider TOD as a combination of locational efficiency, a rich mix of choices, adding value, place making, and resolution of the tension between node and place.

But a more precise way to operationalize TOD inputs can be found in the literature that considers the effects of the built environment on travel behaviour. One such framework that incorporates Dittmar and Poticha's definition and is subsequently used to guide the present analysis is that of the 'D' variables first proposed by Cervero and Kockelman (1997) and expanded by Ewing and Cervero (2010). Briefly, they are density of activities such as population and employment, diversity of land uses, design of the urban fabric including pedestrian orientation, destination accessibility or regional accessibility, distance to transit, and demographics. In the travel behaviour literature, it is argued that each of these variables can influence transit and alternative mode use. TOD as a concept seeks to capitalize on this relationship by providing the inputs required to influence such travel outcomes, but the combination of TOD factors measured by the D variables can also affect the other potential outcomes noted by Renne (2009b).

Working from this base, we collect several types of data from a range of sources to construct our typology (Table 3-1). The three broad types of data used to measure TOD inputs are station-area land use, population, demographic and employment data, and metrics covering transit, pedestrian, and automobile accessibility. The particular variables that enter the model and their definitions are provided in Table 3-2. Each variable's relation to TOD is as follows.

Distance to Transit: the distance from a station, or how a station area is defined is a central consideration for transit research. Our analysis uses the work of Guerra et al. (2013) as a base and defines station areas according to their theoretical area and their functional area. The theoretical station area consists of a circular 800-metre buffer around stations and is used to capture the general context of particular stations. The functional station area considers the actual pedestrian shed within a 10-minute walk from the station along the road network with pedestrian pathways considered where available. These buffers capture how we assume stations are used.

Density: reflects the intensity of opportunities for interaction within a station area, which influences both its ability to generate and attract trips on the transit network, as well as promote internal trips within the station area itself. Density is measured as total population and employment per hectare. Station area employment counts are derived from a 2012 InfoCanada database, which is based on telephone-verified business lists. This data is imperfect, as investigations by the authors have found that employment totals for certain entities are inaccurate such as low employment numbers at regional universities. Still, this remains the best data for obtaining geographically-rich employment estimates in Canada, and such spatial disaggregation is crucial for the present analysis. Development mix is employed to control for each station's role as either a neighbourhood or employment centre.

Table 3-1. Station Area Typology Data Types and Sources

Data Type	Source
1. Land Use Coverage	
• Geographic Information System (GIS) Shapefile of Ontario's Parcel Fabric	Teranet Inc.
• Property Usage Codes linked to Assessment Roll Numbers (ARNs) for the Greater Golden Horseshoe	Municipal Property Assessment Corporation (MPAC)
2. Population, Demographic, and Employment Data	
• 2011 Dissemination Area GIS Shapefile	Statistics Canada
• 2011 Canadian Census of Population	Statistics Canada
• 2011 National Household Survey	Statistics Canada
• Business Location and Employment Counts for 2012	InfoCanada
3. Transit, Pedestrian, and Automobile Accessibility	
• Road Network GIS Shapefile	DMTI Spatial Inc.
• Transit Timetables and Geographic Network Information for existing GO and TTC	General Transit Feed Specification (GTFS) files for July 2014
• Station locations, route alignments, and travel times for future infrastructure	Relevant Business Case Analyses and planning documents

Diversity: to control for the diversity of land uses, which can increase the potential for interaction within and between station areas, we also control for land use mix. However, instead of incorporating a land use mix index such as a measure of entropy (which has previously been found problematic, c.f. Hess et al. (2001)) or the popular Simpson index of land use diversity, we calculate each station's proportion of particular major land uses and enter them into the model directly. This accounts for land use mix while also offering a more precise classification and immediately interpretable results. Commercial and institutional land uses, which account for traditional private commercial uses and public-sector uses such as university campuses and government buildings respectively, are combined as it was felt that both play a similar role in being net attractors of trips.

Table 3-2. Model Variables and Definitions

A. Base Measures for Station Typology Analysis

1. *Density:*
   Reflects density and the intensity of land use development in a station area. Calculated as total Population + Employment / Hectare within each station's theoretical buffer area.
2. *Development Mix:*
   A statistic ranging between 0 and 1 that reflects the balance between population and employment in a station area. Calculated as the ratio of Employment to Population + Employment.
3. *Street Connectivity:*
   Measures overall street connectivity and the quality of pedestrian access to the transit station. Calculated as the ratio of a station's 10-minute walk buffer on the local road network to its 800-m circular buffer. In this case all station buffers were permitted to overlap to give a measure of overall street connectivity in the neighbourhood.
4. *Interaction Potential:*
   Regional station accessibility and interaction potential, or measure of gravity considering population, employment, and travel time. For station areas oriented to population (Development Mix <.5), total interaction potential is calculated as:

$$POPEMPGRAV_{ij} = \ln\left(\sum_{\forall j \neq i} \frac{(Pop_i)(Emp_j)}{TT_{ij}^2}\right)$$

   Where:
   Pop_i = the total population in the labour force in station i
   Emp_j = the total employment in station j
   TT_{ij} = the travel time on transit between stations i and j squared
   The numerator is reversed for stations oriented to employment (Development Mix >.5)
5. *Land Use Mix:*
   The proportion of residential, commercial, institutional, mixed, and industrial land in each station area. Commercial and institutional lands are combined into a single category.

B. Additional Descriptive Performance Measures

1. *Transit Commute Mode Share:*
   Commute to work mode share for transit among those 15 years and older from the 2011 National Household Survey.
2. *Walking Commute Mode Share:*
   Commute to work mode share for walking among those 15 years and older from the 2011 National Household Survey.
3. *Cycling Commute Mode Share:*
   Commute to work mode share for cycling among those 15 years and older from the 2011 National Household Survey
4. *Household VKT:*
   Total vehicle kilometres travelled divided by the number of households in the zones that make up each station area from the 2011 Transportation Tomorrow Survey.
5. *Average Median Household Income:*
   Station area average of median household income values for each Dissemination Area (DA) from the 2011 National Household Survey, weighted by each DA's proportion inside the station area.

Continued…

6. *Bachelors Degree and Above:*
   Proportion of station area population aged 15 years and older with a Bachelor's degree or above
7. *Population 20-35 Years Old:*
   Proportion of the population that is between the ages of 20 to 25 in each DA from the 2011 Canadian Census.
8. *Population 50-65 Years Old:*
   Proportion of the population that is between the ages of 50 to 65 in each DA from the 2011 Canadian Census.

Design: because the start and end of every transit journey is made on foot, TOD champions pedestrian-oriented street design and high levels of street connectivity. To gauge street connectivity, authors such as Kamruzzaman et al. (2014) use the density of intersections and cul-de-sacs. In our analysis, we utilize the ratio between the area included in a theoretical 800-metre circular buffer and the area covered by a 10-minute walk on the road network, which also includes the manual addition of pedestrian paths where available. This method is similar to the 10-minute 'ped-shed' proposed by Porta and Renne (2005) and when considering other measures used in this research the approach is similar to that of Frank et al.'s (2005) 'walkability index'. Both the ped-shed and walkability index metrics were found to perform as well as, or better than WalkScore indicators by Manaugh and El-Geneidy (2011). The isochronic measure used here implicitly captures cul-de-sac and intersection density and we believe it provides an adequate proxy for station-area street connectivity. More qualitative data such as that used by Porta and Renne that considers overall street design in terms of pedestrian-friendliness was not available.

Destination Accessibility: to measure a station's overall accessibility within the transit network, we utilize a measure of interaction potential that considers station area population and employment within a 10-minute walk of the station, and travel time between stations. Travel times between existing stations are computed according to GTFS schedules in ArcGIS Network Analyst. For future stations, the end-to-end travel times for a line are drawn from planning documents and employed in Network Analyst to calculate trip times for line segments. Depending on a station area's development mix, interaction potential is calculated between people and the pool of jobs, or jobs and the pool of people. Of course, there is an element of disparity between present and future population and employment that may result from TOD planning around new stations. However, the variable as specified provides an assessment of existing conditions designed to offer a benchmark for potential policy interventions.

Additional measures were also considered but ultimately excluded from the analysis to improve model convergence, such as dummy variables representing different transit modes. Station parking stalls and existing transit service levels such as service frequencies were also considered but because this information was not available for future stations they were dropped in the interest of producing a typology that is broadly comparable across the region. Furthermore, we argue that variables in the model such as accessibility, land use, and densities adequately account for the functional differences between modes and contextual differences between park-and-ride or walk-and-ride stations.

Beyond the above, Table 3-2 also describes several supplementary measures we use to provide an assessment of TOD performance outcomes. One of these is the final 'D' variable *demographics*. Of all the 'D' variables, demographics present a complex factor to control for as it can be both an input to TOD and an outcome. Foot (1998) famously argued that demographics explain two-thirds of everything, and noted that young individuals have always maintained a preference for urban living, though locational preferences generally shift over a person's life due to changing priorities. Authors in the TOD literature such as Cervero et al. (2004) and Dittmar et al. (2004) have noted that locational preferences tied to different demographic groups are beneficial to the type of lifestyle choices offered by development oriented to transit, particularly for young professionals and empty-nesters.

However, such preferences lead to an issue of self-selection wherein these groups drive market demand for TOD, which can influence the extent to which TOD inputs are provided. The existence of such preferences affects all TOD outcomes to some extent. In the travel behaviour literature for example, are the 'D' variables affecting travel decisions, or are preferences for particular lifestyles driving travel behaviour, and to what degree? Such confounding factors can be problematic for research, though Ewing and Cervero (2010) note that many authors have attempted to control for such issues. But because our typology considers both existing and future rapid transit station areas where issues of self-selection are conceptually fuzzy, our primary focus is on TOD inputs with information on TOD outcomes provided for descriptive purposes only.

3.3.3 Model Estimation

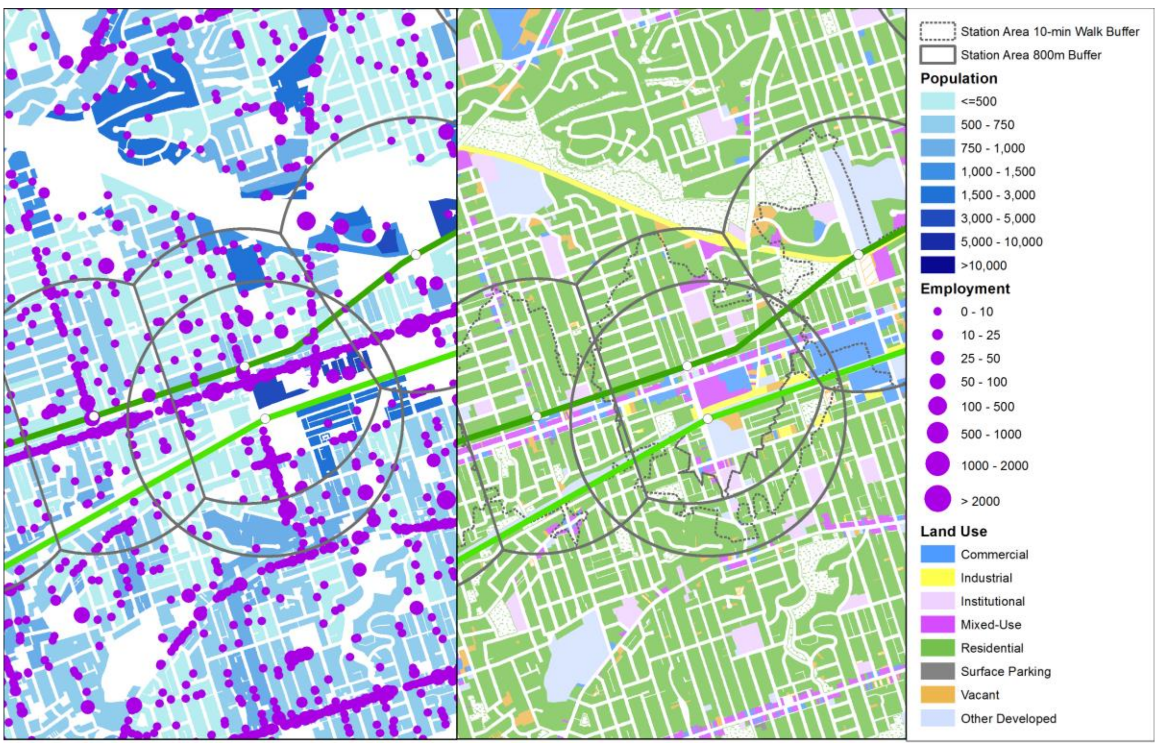
The typologies were estimated as follows. First, we created the theoretical 800 metre circular and 10-minute walk functional buffers around each station. Buffers surrounding adjacent stations were not permitted to overlap. The exception to this is between the GO

CRT rail network and all other networks. This was done because an analysis of travel patterns in the 2011 Transportation Tomorrow Survey, the Toronto region's household travel survey, reveals that the vast majority of users do not transfer between adjacent stations on the GO CRT and TTC HRT networks (88%) and between HRT and CRT (97%). Furthermore, because there is flat fare on the TTC network, those that do transfer from GO to TTC generally do not travel the very short distances on the TTC that would make this conceptualization of catchment areas problematic.

Next, using ArcGIS we quantified the 'D' variables for each station area. For point data such as InfoCanada's employment counts, this consisted of summing all employment within the station area. For information on land use and population derived from underlying census geographical areas, variables were created in two steps. First, to increase the accuracy of dissemination area (DA) aggregations from the 2011 Census and National Household Survey, we used land use data to remove any areas within a DA boundary that were not residential or mixed-use. While still an aggregation of underlying census variables, this provides a more accurate estimate of the underlying population characteristics within these areas. Second, we determine the proportion of each DA within the station area and then take the share of the variable weighted by this proportion. For example, if a DA contains 1,000 individuals and 60% of that DA is within the station area, we assign 600 of those individuals to the station area. This is repeated for all DAs in the station area and the results are summed.

Figure 3-2 provides a graphical demonstration of this process. Station catchment areas between the GO CRT network and local HRT service are permitted to overlap. The left panel shows the geographical boundaries of DAs after subtracting parcels that are not residential or mixed-use, colour-coded by the number of people residing within each. The figure also shows the distribution and size of employment locations within each station's 800-metre buffer along a selection of station on the TTC Line 2 Subway and the Danforth GO Station. The right panel shows the distribution of land uses in the same area and each station's 10-minute walk buffer.

Figure 3-2. Overview of Station Area Data and Methods of Analysis



We also determined the amount of population and employment within a 10-minute walk of each station and calculated travel times between each origin-destination pair. Note that these variables are based only on travel between stations on the region's rapid transit lines and excludes local bus service. Next, we combine this information into a database and use the resulting matrix of characteristics for all 372 stations as input into creating the variables defined in Table 3-2.

3.3.3.1 Local Independence

At this stage several authors of other node-and-place typologies have used factor or principal components analysis to reduce collinearity between variables and the number of variables entering the cluster model. An examination of correlations among our manifest variables in Table 3-3 does indicate the presence of strong and significant dependence (according to Pearson's r) among many TOD measures, though the relationships are intuitive. Density and Interaction Potential for example exhibit very strong correlations. Both variables capture different aspects of TOD, but should reflect a similar pattern over space as highly-dense stations located close to the CBD are also more likely to exhibit higher levels of accessibility to people and jobs at neighbouring stations. The opposite relationship should also be seen in more distant low-density suburban and exurban station areas throughout the region. Likewise, a station area's measure of Development Mix should also be partly reflective of its land use characteristics. As Table 3-3 shows, this is true for Residential, Commercial/Institutional, and Industrial land uses, where employment-oriented stations tend to exhibit higher proportions of employment-oriented development and lower residential development, with the opposite true in more population-oriented stations.

Table 3-3. Correlation Matrix of TOD Measures

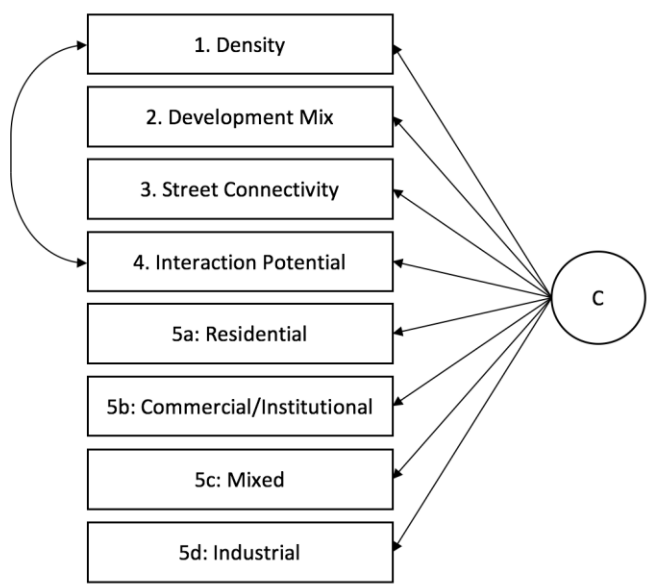
TOD Measure	1. Density	2. Development Mix	3. Street Connectivity	4. Interaction Potential	5a. Residential	5b. Commercial/ Institutional	5c. Mixed-Use	5d. Industrial
1. Density	1	0.016	0.559***	0.828***	0.211***	0.284***	0.586***	-0.217***
2. Development Mix	0.016	1	-0.125**	-0.005	-0.734***	0.495***	-0.052	0.581***
3. Street Connectivity	0.559***	-0.125**	1	0.672***	0.392***	0.186***	0.400***	-0.340***
4. Interaction Potential	0.828***	-0.005	0.672***	1	0.183***	0.226***	0.553***	-0.213***
5a. Residential	0.211***	-0.734***	0.392***	0.183***	1	-0.399***	0.068	-0.569***
5b. Commercial/ Institutional	0.284***	0.495***	0.186***	0.226***	-0.399***	1	0.131**	-0.072
5c. Mixed-Use	0.586***	-0.052	0.400***	0.553***	0.068	0.131**	1	-0.274***
5d. Industrial	-0.217***	0.581***	-0.340***	-0.213	-0.569***	-0.072	-0.274***	1

Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller

However, a reduction of bivariate correlations among manifest variables through factor or principal components analysis was not done in the present paper for three interrelated reasons. First, variables were selected for easy interpretability to benefit policy prescription and analysis and standardizing them into z-scores sacrifices this interpretability. Second, latent class methods do not require the standardization of variables entering the model. Finally, multicollinearity among latent class predictors in the sample is not deemed to be problematic for cluster model estimation, in fact some correlation amongst manifest variables across the sample should be expected as no correlation would imply there is no latent structure within the data to classify.

Nevertheless, the continued existence of relationships among manifest variables within a single latent class after model estimation is problematic as this is a violation of the assumption of local independence. As the following section will discuss in greater detail, post-estimation model diagnostics revealed that a strong locally-dependent relationship was still found to exist between a station area's Density and Interaction Potential. To overcome this violation, we specified a model structure that takes this covariate relationship into account (Figure 3-3). Here latent structures within the manifest variables are informed by the categorical variable C, and a covariate relationship is specified among Density and Interaction Potential. From this, station variables were input into the latent class model to derive a classification of different station types.

Figure 3-3. Latent Class Model Structure



3.4 RESULTS

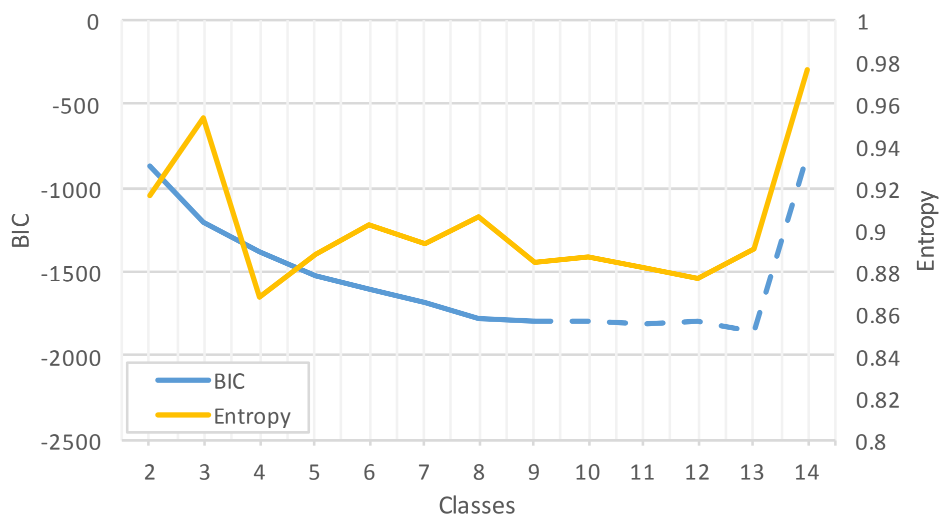
3.4.1 TOD Typology

Using MPLUS 7.2, the best fitting model according to the BIC was one with ten distinct station types. However, problems with model convergence were detected for three stations at the Lester B. Pearson International Airport due to a lack of measured population and land use attributes. The three stations featured nearly 100% of their land use as 'Other Developed', which was not one of the land use types that directly entered the model. This type of scenario creates problems for model-based clustering as the particular characteristics of these three stations creates outliers against which model standard errors cannot be reliably computed. As such, these three stations were qualitatively determined to constitute their own cluster and were subsequently dropped from the model. Re-running the statistical clustering analysis without the 'Airport' cluster revealed the best fitting model to converge at nine distinct station types, bringing the total derived through this hybrid quantitative/qualitative approach to ten.

As mentioned above, model diagnostics for the initial estimations using the reduced sample indicated that moderate residual covariance between Density and Interaction potential remained after the delineation of the latent classes, resulting in the adoption of the covariance structure depicted in Figure 3-3. Re-estimations of the model resulted in some stations shifting classes and improved overall model fit as measured by the BIC.

To demonstrate the class selection process we display the distribution of BIC and Entropy values across different class solutions in Figure 3-4. Here we estimated model solutions ranging from 2 to 14 clusters. The lowest stable BIC of -1,800.55 was achieved for a solution with 9 clusters, after which some smaller BIC values are achieved, but models do not converge due to the model attempting to extract more clusters than supported by the sample. The Entropy statistic provides a secondary indicator of classification quality or certainty, where values approaching 1 indicate clear delineation of latent classes in the model. All cluster solutions achieve values greater than 0.86, and with a value of 0.89, the 9-class solution indicates good separation of classes.

Figure 3-4. Latent Class Model Fit Statistics



Full model results are shown in two tables. Table 3-4 displays model output including data for the qualitative ‘Airport’ cluster. We use this information to derive the cluster names and definitions displayed in Table 3-5 and incorporate them to label the clusters in Table 3-4. A supplemental graphical overview of land use mixing in each station is also provided later in Table 3-6. In Table 3-4, model output is given in two forms. Model coefficients represent each cluster’s mean value for each measure of TOD and associated test of whether this value is statistically different from zero. Numbers in parentheses below model coefficients correspond to each station type's deviation in percentage terms from the sample mean. Again because latent class models do not require variable transformations model output is interpreted according to original variable units.

The right-hand column also displays latent class variances and sample means for each measure. To aid in model convergence, the default latent class modeling routine in MPLUS assumes variances are constant across classes and clusters cases accordingly. This may be an unrealistic assumption in different modeling scenarios. However, for the present application, constant variances ensures that the resulting typology is maximally homogeneous within each class while ensuring the greatest levels of heterogeneity across classes, thereby enabling a powerful classification of similar station types according to TOD input characteristics and contexts.

In general, the classification of 10 station types is organized from urban to suburban. More urban stations demonstrate higher densities, greater regional accessibility due to their central location, and higher walking connectivity attributable to grid-street network design. These values generally decrease as the typology progresses into more suburban areas. Other station characteristics help to define the role of each type, with some more oriented to employment and commercial and institutional land uses, while others feature high levels of mixed-uses or are primarily residential or industrial. Finally, the covariance between Interaction Potential and Density was found to be strong and statistically significant, supporting its explicit specification in the model. Results for specific station types will be discussed in greater detail below.

Table 3-4. Latent Class Cluster Model of TOD Inputs

TOD Measure (Average)	1. Urban Commercial Core	2. Urban Mixed-Use Core	3. Inner Urban Neighbourhood	4. Urban Neighbourhood	5. Suburban Neighbourhood	6. Outer Suburban Neighbourhood	7. Suburban Centre	8. Outer Suburban Commerce Park	9. Outer Suburban Industrial Park	10. Airport[1]	Class Variance (Average)
Accessibility											
Interaction Potential	19.57*** (26%)	19.55*** (25%)	17.61*** (12%)	16.48*** (5%)	14.94*** (-5%)	12.04*** (-23%)	15.53*** (-1%)	14.32*** (-10%)	14.20*** (-9%)	11.82 (-33%)	1.54*** (15.67)
Land Use											
Normalized Density	501*** (468%)	370*** (318%)	112*** (27%)	68*** (-23%)	41*** (-53%)	18*** (-80%)	50*** (-43%)	14*** (-84%)	25*** (-72%)	14 (-84%)	1.34*** (88)
Development Mix	0.83*** (112%)	0.49*** (27%)	0.34*** (-13%)	0.18*** (-54%)	0.28*** (-28%)	0.27*** (-32%)	0.66*** (70%)	0.84*** (117%)	0.95*** (145%)	1.00 (158%)	0.03*** (0.39)
Walk Connectivity	0.61*** (28%)	0.59*** (25%)	0.56*** (18%)	0.55*** (15%)	0.45*** (-5%)	0.25*** (-47)	0.45*** (-5%)	0.41*** (-15%)	0.34*** (-28%)	0.32 (-33%)	0.01*** (0.48)
Land Use Mix											
Residential	0.10*** (-75%)	0.29*** (-30%)	0.49*** (16%)	0.67*** (63%)	0.44*** (7%)	0.28*** (-32%)	0.18*** (-56%)	0.07*** (-83%)	0.04** (-91%)	0.00 -	0.01*** (0.41)
Commercial/ Institutional	0.57*** (216%)	0.30*** (63%)	0.19*** (5%)	0.12*** (-34%)	0.15*** (-16%)	0.11*** (-42%)	0.24*** (30%)	0.50*** (174%)	0.09*** (-53%)	0.06 (-67%)	0.01*** (0.18)
Mixed-Use	0.06*** (152%)	0.17*** (631%)	0.06*** (139%)	0.02*** (-3%)	0.01*** (-44%)	0.01*** (-62%)	0.01*** (-62%)	0.01 (-62%)	0.00* (-96%)	0.00 -	0.00*** (0.02)
Industrial	0.01*** (-88%)	0.02* (-86%)	0.04*** (-64%)	0.02*** (-80%)	0.06*** (-54%)	0.11*** (-1%)	0.33*** (186%)	0.08 (-33%)	0.65*** (474%)	0.07 (-36%)	0.01*** (0.11)
	n=11	*n*=8	*n*=43	*n*=92	*n*=115	*n*=22	*n*=47	*n*=13	*n*=18	*n*=3	*n*=372
Model Covariates											
Normalized Density with Interaction Potential				0.442***							

Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller; 1) qualitative assessment

Table 3-5. Station Type Definitions

Station Type	Definition
1. Urban Commercial Core	Stations are located in the downtown core of the City of Toronto and are served by high-capacity subway and commuter rail rapid transit. Primarily commercial and institutional land uses with some residential development and mixing of uses at very high population and employment densities. One other station of this type can be found in downtown Hamilton.
2. Urban Mixed-Use Core	Stations with very high population and employment densities and a high mixing of uses. Generally located just outside the urban commercial core in the City of Toronto and at key intensification hubs.
3. Inner Urban Neighbourhood	Stations with high-density residential, commercial, and mixed uses with high levels of accessibility to employment and jobs due to their location close to the urban core. A grid street pattern ensures good pedestrian accessibility.
4. Urban Neighbourhood	Rapid transit stations located in predominately residential neighbourhoods that feature higher densities and some commercial activity and land use mixing. Station areas are older and well-established, feature a grid street pattern, and have good access to population and employment.
5. Suburban Neighbourhood	Predominately residential areas with some commercial and institutional development but lower overall population and employment densities. Located farther from employment centres and increasing use of cul-de-sac street layout. Important trip origins along future rapid transit lines.
6. Outer Suburban Neighbourhood	Low-density residential suburban or exurban areas with some commercial and industrial development. Many stations are located along CRT corridors. Low pedestrian accessibility due to automobile-oriented urban design. Large proportions of vacant land provide opportunities for future intensification.
7. Suburban Centre	Station areas oriented to employment with high levels of commercial, industrial, and institutional land uses, but lower overall development intensity. Stations are important secondary destinations along present and future rapid transit lines.
8. Outer Suburban Commerce Park	Low-density and automobile-oriented suburban and exurban areas with high proportions of commercial, institutional, and industrial land uses, which may present opportunities for future intensification. They are however important trip attractors.
9. Outer Suburban Industrial Park	Predominately automobile-oriented suburban and exurban industrial areas that feature low overall development intensity and low levels of pedestrian accessibility. Stations are located along CRT corridors and future rapid transit lines.
10. Airport	LRT stations that service Lester B. Pearson International Airport and its surrounding environs. Stations feature low employment densities, but exist as important regional trip destinations.

3.4.2 Performance of TOD Inputs

The TOD typology provides a useful tool for delineating and describing regional transit station area types across the Toronto region in terms of their built environment and accessibility characteristics. At the most urban is the Urban Commercial Core station type. With a class average density of 501 people and jobs per hectare, density levels for the 11 stations within this station type are 468% greater than the sample average of 88. Station areas also feature very high levels of regional accessibility, street connectivity, employment, and commercial and institutional land uses, but low levels of residential and industrial development. Such features are characteristic of a location in the central business district and indeed this is where such stations are found.

Urban Mixed-Use Core stations feature the second-highest average densities, regional accessibility, and street connectivity, but are more balanced in development mix between population and employment. The proportion of mixed land uses, which are single parcels with more than one residential, commercial, and institutional land use code, among the 8 stations in the Urban Mixed-Use Core station type is 17%, which is 631% greater than the sample average. Overall station area land use mix is also controlled for in the individual proportions of different types of land use, with this station type also exhibiting approximately 30% of its land area as residential and commercial/institutional (this information is also shown graphically in Table 3-6).

Moving across neighbourhood types from inner urban to outer suburban, we see a general shift across all variables. More urban stations are higher in density and accessibility and feature greater walking connectivity as a result of their grid street pattern. Land uses feature greater levels of mixing in urban neighbourhoods, reflecting higher levels of interaction potential and greater possibility of local amenities within walking distance. In contrast, land uses become more homogeneous as the typology progresses to suburban neighbourhoods. The remaining four station types consider different bundles of development that are generally suburban in nature. They range from medium density commercial and industrial employment agglomerations in Suburban Centres to low-density commercial and industrial development at Outer Suburban Commerce Parks and Industrial Parks, as well as airport-related development at the three Airport stations. Suburban Centres are unique among these stations as they are higher in density and accessibility than the other suburban station types, reflecting their role as suburban sub-centres in the polycentric region.

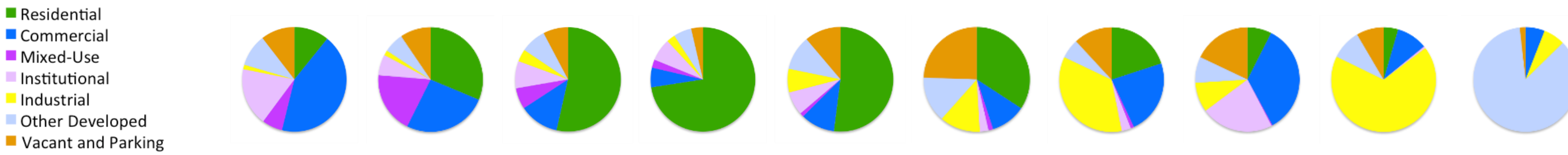
3.4.3 Performance of TOD Outputs

In addition to TOD inputs, we also consider TOD outputs in terms of travel behaviour and demographics as well as additional descriptive statistics such as median household income, education, and a graphical representation of land use mix that also includes the 'other developed' and 'vacant and parking' land use types (Table 3-6). Like Table 3-4, station type variable means are displayed alongside each measure's variance from the sample average reported in the final column. A t-test is performed to test the statistical significance of each station type's deviation from this sample average.

In terms of transit use, the mode share of transit for commuting trips is highest in urban station types and peaks in Inner Urban Neighbourhoods. However transit's mode share declines in the most urban locations where the proportion of walking increases. For example, approximately 41% of trips are made by foot among those living in Urban Commercial Core stations, an amount that is 619% greater than the sample average.

Cycling's mode share is comparatively low across all station types, but is highest in urban locations and peaks at 3% in Inner Urban Neighbourhoods. In general, the higher level of alternative mode use in urban locations is reflected in lower household VKT. On the other hand, the use of all alternative modes is considerably higher in more urban implementations of TOD and lower in suburban stations, all of which exhibit higher levels of household automobile travel as measured by VKT.

Table 3-6. Land Use Mix and Performance of TOD Outputs

Measure (Average)	1. Urban Commercial Core	2. Urban Mixed-Use Core	3. Inner Urban Neighbourhood	4. Urban Neighbourhood	5. Suburban Neighbourhood	6. Outer Suburban Neighbourhood	7. Suburban Centre	8. Outer Suburban Commerce Park	9. Outer Suburban Industrial Park	10. Airport[1]	Average (Class Std. Dev.)
Land Use Mix											
											
Commute Mode Share											
% Transit.	0.30*** (17%)	0.35** (36%)	0.36*** (37%)	0.32*** (23%)	0.21*** (-18%)	0.14*** (-45%)	0.26 (-1%)	0.13*** (-50%)	0.16*** (-38%)	-	0.26 (0.14)
% Walk	0.41*** (619%)	0.30*** (437%)	0.11*** (92%)	0.03*** (-40%)	0.02*** (-56%)	0.02*** (-63%)	0.03*** (-51%)	0.08 (41%)	0.02*** (-72%)	-	0.06 (0.10)
% Cycle	0.02* (166%)	0.02 (112%)	0.03*** (245%)	0.01 (52%)	0.00*** (-77%)	0.00*** (-97%)	0.00*** (-98%)	0.00*** (-94%)	0.00*** (-86%)	-	0.01 (0.02)
Travel Characteristics											
HHVKT	11.51*** (-57%)	10.12*** (-62%)	19.19*** (-29%)	25.08** (-7%)	33.12*** (23%)	38.89** (44%)	22.63* (-12%)	28.18 (5%)	22.76 (-16%)		26.95 (15.18)
Socio-Economic Characteristics											
Avg. Median Hhld. Income ($)	57,353*** (-23%)	61,008** (-18%)	63,898*** (-14%)	79,934 (7%)	78,867** (6%)	79,275 (6%)	69,150** (-7%)	60,704 (-19%)	79,255 (6%)	-	74,587 (22,119)
% Bachelor's Degree Plus	0.74*** (27%)	0.76*** (30%)	0.62** (7%)	0.58 (0%)	0.57** (-2%)	0.56 (-4%)	0.54*** (-7%)	0.51 (-12%)	0.55 (-6%)	-	0.58 (0.11)
Demographics											
% 20-35 Years Old	0.41*** (78%)	0.40*** (73%)	0.28*** (20%)	0.20** (-14%)	0.20*** (-14%)	0.21*** (-11%)	0.23 (-1%)	0.27 (18%)	0.23 (-1%)	-	0.23 (0.08)
% 50-65 Years Old	0.16** (-15%)	0.15*** (-20%)	0.18*** (-7%)	0.20 (4%)	0.20*** (5%)	0.19 (0%)	0.19 (1%)	0.17 (-9%)	0.18 (-8%)	-	0.19 (0.03)
	n=11	*n*=8	*n*=43	*n*=92	*n*=115	*n*=22	*n*=47	*n*=13	*n*=18	*n*=3	*n*=372

Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller; 1) qualitative assessment

More urban locations are marked by significantly higher proportions of young individuals in the echo boomer cohort between the ages of 20-35 and those who have achieved a Bachelors degree or higher. In the Urban Commercial Core and Mixed-Use Core station types the proportion of echo boomers make up around 40% of the total population, and approximately 75% of the population has obtained a university education. On the other hand, baby boomers make up a smaller proportion of the population in these areas compared to more suburban station types. Median incomes are higher in suburban neighbourhood station types and decline as stations become more urban. However, while measures of household income suggest urban individuals make less than their suburban counterparts, the preponderance of young and highly educated individuals in urban locations means rates of single person households are also much higher in these station types.

3.4.4 Station Types and the TOD Concept

Examining the 10 stations across the typology, it is clear that more urban station types best reflect TOD as a concept. They feature higher densities and explicit and implicit land use mixing, greater levels of pedestrian access, and the highest regional transit accessibility. Furthermore, while the tests performed in Table 3-6 do not establish the direction of causality, such stations are associated with higher rates of transit and alternative mode use and lower household VKT, as well as an apparent attractiveness to younger and highly-educated individuals. Still, this is not to say their implementations of TOD are perfect. The typology considers the ‘D’ variables in an aggregate sense, and it may be the case that more micro-scale interventions are required to maximize the potential of the concept in these areas such as by improving urban design, providing better pedestrian connections to the transit station, and ensuring that development is truly transit-oriented and not merely transit-adjacent.

The medium-density Suburban Neighbourhood and Suburban Centre station types also exhibit some elements of TOD, featuring medium densities and respectable rates of transit use. But Outer Suburban Neighbourhoods feature very low densities and poor walking connectivity that results from the prevalence of loop and cul-de-sac street designs. The situation is similar for Outer Suburban Commerce and Industrial Parks. Here an emphasis on employment supports their designation as important trip destinations, but overall densities are low and an automobile-oriented design means the pedestrian environment is lacking.

Compared to a pure conceptualization of TOD, there is clearly room for improvement in suburban stations. Still, considering their high proportions of vacant land, and in some cases large commercial and industrial parcels, many suburban stations stand as ideal locations for policy interventions that prioritize the implementation of TOD concepts to improve urban design, improve land use and development mix, increase the potential for transit and alternative mode use, and better balance their role on the transit network as a generator and attractor of transit trips. If implemented, such changes would cause them to move across the hierarchy of stations to begin to resemble the characteristics of more urban neighbourhoods.

Nevertheless, the TOD typology as implemented here measures a particular station area's alignment with ideal-type TOD characteristics where higher scores attributed to the 'D' variables are assumed to be more indicative of a pure TOD concept. Any potential policy interventions to promote TOD must be sensitive to existing conditions and it may be that the type of TOD seen in Suburban Neighbourhood stations for example is deemed appropriate, or at least acceptable. Furthermore, it should again be clarified that performance measures from Table 4 consider rates of transit use from the 2011 National Household Survey in existing station areas with rapid transit, as well as those that presently have transit service, but do not have rapid transit. Transit mode share may improve when such service becomes available, but there nevertheless still appears to be some relationship between the built environment contexts of particular station area types captured by the typology and outcome variables such as transit use.

Nevertheless, it should be clarified that the analysis thus far cannot imply causality between station TOD input context and performance outcomes. Instead, the analysis suggests that different bundles of TOD characteristics measured by the 'D' variables, or a lack thereof, in particular station catchment areas are associated with higher or lower observed outcomes. Still, the results demonstrate that the typology model accurately captures differences in station-area TOD inputs that are replicated in differences in travel behaviour and socio-economic and demographic indicators, offering a foundation for more detailed investigations in the future.

3.5 CONCLUSIONS

Through the promotion of high density, mixed-use, and pedestrian friendly development oriented to rapid transit, the concept of TOD has been championed as a potential solution for maximizing the potential return on investment for existing and future rapid transit infrastructure. However, it is clear that not all implementations of TOD are equal across every present and future station catchment area in a rapid transit network. This has implications for research, wherein the unequal distribution of station area TOD input contexts should result in heterogeneous outcomes. Such heterogeneity also results in considerable complexity for planners and policymakers interested in a positive assessment of the general character of an existing neighbourhood around a transit station or a normative assessment of an area’s TOD potential

In response, the proposed method reduces this complexity and allows it to be better incorporated it into research and practice. By estimating a typology of TOD according to the ‘D’ variables, the method classifies TOD conditions into more homogeneous groups. The resulting typology reduces planning complexity, thereby enabling a more empirical evaluation of TOD around existing and proposed rapid transit stations and facilitating context-sensitive solutions for TOD implementation. Furthermore, compared to traditional hierarchical clustering techniques, the use of latent class analysis model-based clustering allows for more systematic decisions to be made regarding the number of station types and offers easily interpretable results. Latent class methods also permit the explicit accommodation of covariate relationships among manifest variables, offering a higher degree of precision in accommodating complex spatial relationships common in geographic datasets.

Applications of the model to the case of rapid transit and land use planning in the Greater Golden Horseshoe reveals 10 distinct station types among a sample of 372 transit station areas throughout the region. High-level performance assessments reveal that stations ranking high in measures such as density, walkability, and mixed land uses were associated with higher rates of transit, walking, and cycling, lower household VKT, and greater representation of young and highly-educated individuals. Such results demonstrate that the model accurately captures differences in both TOD inputs and associated TOD outcomes.

With this as a base, future research can utilize the method for more detailed examinations of station area TOD. Potential uses for the typology include comparisons between cities and the incorporation of heterogeneous land use and transportation contexts into models that estimate relationships between the built form and travel behavior or the land value effects of rapid transit and TOD. The method can also be used for scenario testing of different alignments for planned infrastructure to ensure that projects fully capitalize on existing TOD conditions and future potential. One application of the tool for benchmarking existing TOD conditions for existing and future infrastructure is presented in Appendix A.

However, as with any model there are limitations to the approach primarily related to modeling assumptions and data requirements and availability. TOD is also operationalized at a high level, and stations that appear to exemplify TOD may still benefit from more micro-scale TOD planning. Furthermore, the typology generally assumes that larger values of particular TOD indicators are more desirable and provide a case for policy intervention. Instead it may be that planners, policymakers, or local residents deem the existing scale and nature of development in particular station areas appropriate or desirable, or at least acceptable when considering all factors that feed into the transportation and land use planning process. In more suburban contexts in particular, plans to alter the established built form to be more reflective of the TOD characteristics of urban station types in the present typology may be met with intense criticism from current residents.

Nevertheless, such limitations are more than overcome by the positive properties of the approach and its resulting benefits. The present paper improves on previous research in this area by proposing a method for deriving TOD typologies that are statistically rigorous, geographically rich, easily interpretable, and readily transferable. By offering an advanced benchmarking platform against which existing TOD can be better evaluated and implemented, its application to cities and regions can help to reduce complexity for planning, policy, and research and ultimately ensure that scarce funds for rapid transit are spent in a way that maximizes the potential return on investment.

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CHAPTER 4

UNBUNDLING THE HEDONIC PRICE EFFECTS OF RAPID TRANSIT AND TRANSIT-ORIENTED DEVELOPMENT IN TORONTO

ABSTRACT

Theory posits that rapid transit projects that increase accessibility and reduce transportation costs should result in a localized land value uplift (LVU) benefit for parcels of land near a station. A rich history of research has tested this hypothesis, generally operationalizing transit accessibility indirectly through a parcel's distance from a transit station. However, a growing body of research has also demonstrated LVU effects from transit-oriented development (TOD) as individuals sort themselves into locations that best match their preferences and willingness to pay. In an age of coordinated land use and land use planning for rapid transit, this bundle of goods results in separate and potentially self-reinforcing drivers of LVU in transit station areas that measures of proximity alone cannot isolate. In response, the present paper utilizes spatial hedonic methods to capture LUV, but in contrast to previous studies, it incorporates a method that distils station area TOD contexts into a latent categorical variable that captures heterogeneous TOD submarket effects. Interactions between these submarkets and a distance variable reveals significant capitalization of transit and TOD into the value of single-detached homes in Toronto, though this capitalization differs by station type and time period.

4.1 INTRODUCTION

Determining the amount of land value uplift (LVU) produced by rapid transit infrastructure is of great importance to planners and policymakers. In the most basic sense, LVU acts as a proxy that provides tangible evidence of a rapid transit project's larger transportation and land use benefits.

Transportation is generally understood to entail a cost in terms of time, money, and even stress. In the standard urban model from Alonso (1964) Muth (1969) and Mills (1972), or the AMM model, the spatial diffusion of such transportation costs stands as a primary driver of differences in land values over space. A particular outcome of the AMM model to rapid transit postulates that at spatial equilibrium, and assuming an open development market, areas with high levels of relative accessibility or low transportation costs should also exhibit high land values and higher density development.

This theory forms the broad basis for expectations of LVU around rapid transit stations. But because most transit trips generally begin and end on foot, the spatial extent of such LVU should generally dissipate over a short distance, typically operationalized as 800 metres (1/2 mile) or a 10-minute walk from a station (Guerra et al., 2013; Higgins & Kanaroglou, 2015a). This should result in a detectable peaking of land values around stations.

To test these theoretical expectations, researchers typically use a property's proximity to a transit station as a proxy for accessibility to statistically model this peaking of land values over space. From this, many previous studies have indeed confirmed the notion of LVU as it relates to rapid transit. However, many others have found no significant land value effects for rapid transit for some transit lines or station areas while others have found negative land value effects, running counter to expectations.

What produces such diversity in research outcomes? Higgins and Kanaroglou (2015a) reviewed more than 100 studies in North America to explore this issue in greater detail, but from this, there are two factors that should inform expectations of LVU as it relates to rapid transit. First, it must be noted that the value placed on accessibility that derives from any single mode is understood relative to the transportation costs associated with other options for travel between given origin and destination pairs. In an urban area where the costs of automobile commuting are high, it would be reasonable to assume that the accessibility benefits offered by rapid transit relative to the automobile should indeed meet model expectations and result in a peaking of land values around stations.

However, a second issue relates to simultaneous price effects from transit-oriented development (TOD), which generally refers to high-density, mixed-use, amenity-rich, and pedestrian-friendly development around rapid transit stations. In terms of LVU, the type of lifestyle offered through TOD implementations is said to be particularly valued by specific cohorts of the population, namely young professionals, empty-nesters, and recent immigrants (Cervero et al., 2004; Dittmar et al., 2004), especially in the age of the 'consumer city' detailed by Glaeser et al. (2001). Indeed, previous literature has demonstrated positive land value changes associated with TOD (Bartholomew & Ewing, 2011).

Essentially, transit accessibility and TOD result in a bundle of goods around transit stations, one that is simultaneous and potentially self-reinforcing. As per Higgins and Kanaroglou (2015a), conceptualizing the price effects associated with such bundles of goods requires the adoption of a second spatial equilibrium framework that compliments the AMM model, namely Tiebout's (1956) theory of spatial sorting based on individual preferences. Here individuals are understood to self-select their location based on the fit between their preferences and different competing bundles of public and private goods.

If not explicitly recognized and controlled for, the LVU effects of rapid transit and TOD in the urban land market can pose problems for research wherein different bundles result in unexplained heterogeneity in study results. Much of the previous literature on the LVU effects of rapid transit has proceeded in this manner, working from the AMM model to examine only a property's distance from a transit station as the primary facet through which accessibility benefits are revealed. (Higgins and Kanaroglou, 2015a). This is problematic as such an approach omits any additional LVU effects that result from heterogeneity in station area TOD contexts and furthermore, risks construing any captured TOD effects as transit accessibility.

However, if known *a priori*, the spatial submarkets that result from these bundles of goods can enter a hedonic model directly and reveal their implicit price. Recent research from Atkinson-Palombo (2010) and Duncan (2011) has attempted to better capture this heterogeneity in station area accessibility and TOD directly. The present research continues this tradition.

Still, we break from previous research by hypothesizing that different bundles of TOD characteristics interact with transit accessibility to create locally self-reinforcing spatial submarkets. From this, we improve on previous approaches by directly modelling the simultaneity of transit access and TOD to attempt to unbundle their joint and self-reinforcing land value effects.

Using the example of the Yonge-University-Spadina (Line 1) and Sheppard (Line 4) heavy rail transit (HRT) lines in the City of Toronto, we utilize spatial hedonic regression to isolate the effects of transit and TOD on single-detached home values. To overcome the issue of heterogeneity in implementations of station area TOD the present research responds to the criticisms raised by Higgins and Kanaroglou (2015a) by adopting the TOD typology method proposed by Higgins and Kanaroglou (2015b) to control for TOD directly. Results show significant LVU effects for transit and TOD, though these effects vary by station type. This suggests that transit access and TOD create different bundles of local goods and that sorting is at least partly responsible for the increases in land value seen within them.

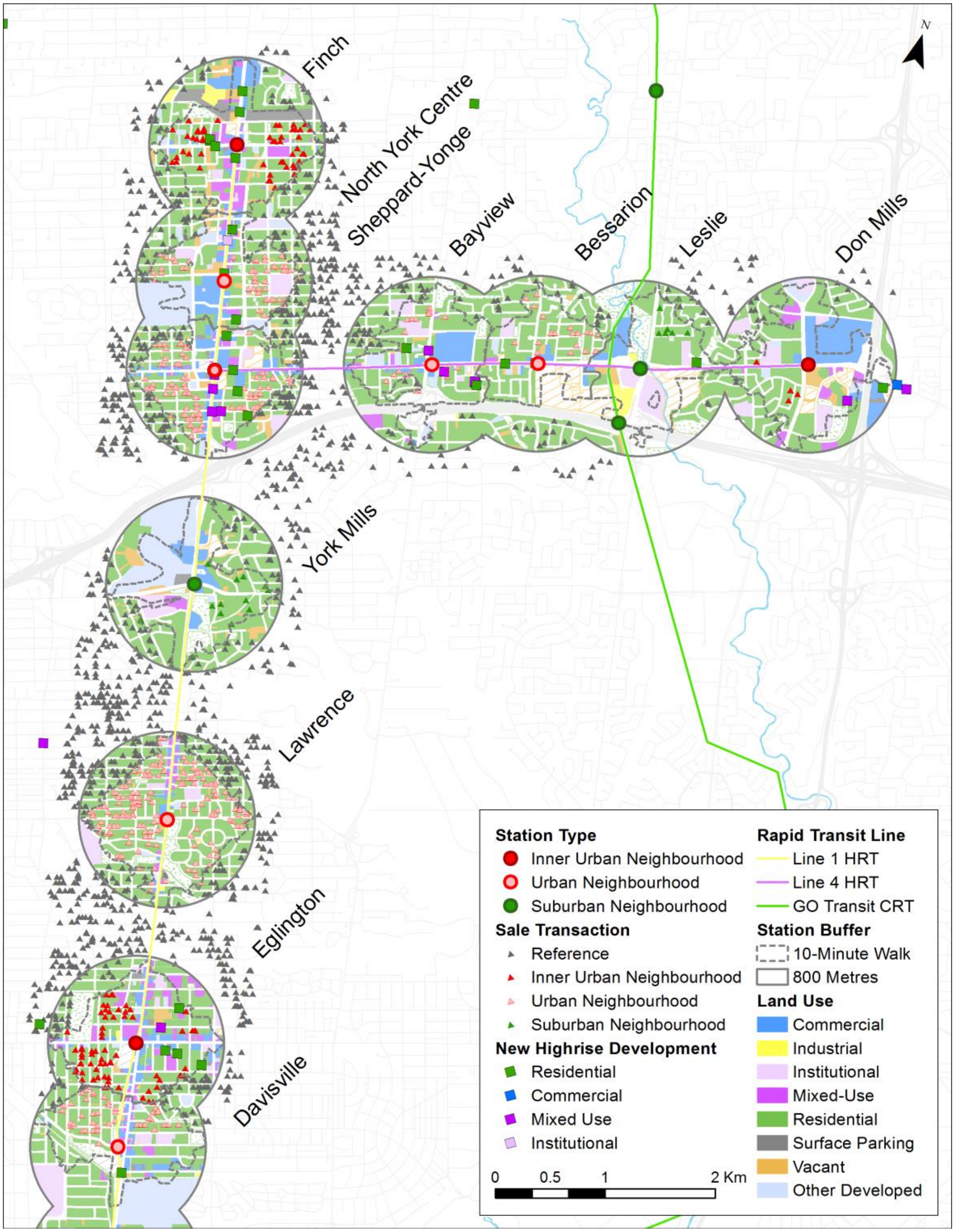
4.2 BACKGROUND

4.2.1 Study Area

The study area consists of two intersecting HRT lines in the City of Toronto (Figure 4-1). Line 1 runs north-south and travels into the heart of the city's central business district. The seven Line 1 stations in the present study area have been in service since at least 1974. Ridership at Line 1 stations within the study area was 357,910, or about 38,000 per kilometre of track on an average weekday between 2012-2013. Line 4 feeds into Line 1 and is the city's most recent HRT line with service beginning in November of 2002. At 5 stops over 5.5 kilometres, Line 4 is short and ridership is relatively low at 49,440 or about 9,000 per kilometre on an average weekday.

The study area also includes one commuter rail transit (CRT) station on GO Transit's Richmond Hill Line, which began service in 1978 and offers service to the central business district. The station is about 500 metres from Leslie subway station and located beneath highway 401. No ridership information for this station is available, but with 286 parking spaces the station is relatively small and at 10,000 daily passengers, ridership on the line itself is lowest among all GO CRT lines and represents only 5% of GO's CRT network total as of 2014.

Figure 4-1. Study Area and Sale Transactions by Station Type (2010-2014 Sample)



4.3 DATA AND METHODS

The present study adopts a repeat cross sectional approach. Real estate transaction data for single-detached homes within the study area have been obtained over two time periods: 2001 to 2003, and 2010 to 2014. For the latter time period, this includes records of roughly 2,000 transactions for homes located within 1km of the Line 1 and Line 4 subway lines in Toronto. Records were purchased from Teranet Inc. and the Municipal Property Assessment Corporation. In the earlier time period we utilize a larger dataset from Farber and Páez (2007) and Páez et al. (2008), but to maintain consistency with the more recent sample we use only transactions that occurred within the same geographic study area, a total of roughly 3,000.

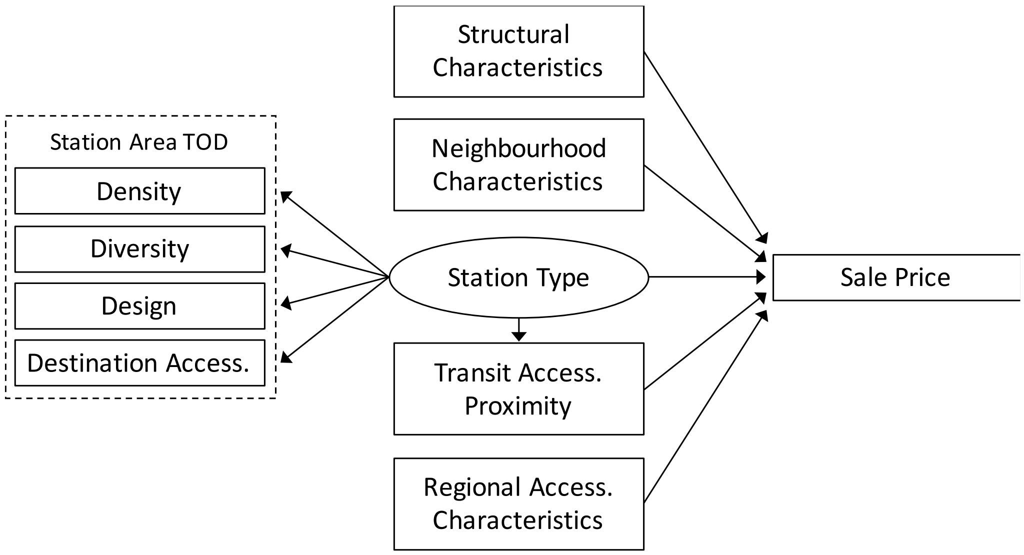
Estimating the land value impacts of rapid transit accessibility and TOD from transacted house prices requires the use of hedonic multiple regression. The method, first popularized by Rosen (1974), postulates that the value of a good is determined by its utility-bearing attributes, and regressing the attributes of a good on its price reveals the implicit value placed on these attributes at market equilibrium. With real estate transaction data, revealing the capitalization of transit access and TOD into land values requires the researcher to control for all the characteristics that make up the price of the transaction including the attributes of the structure, the parcel of land, and its relative location.

To accomplish this we adopt the model structure depicted in Figure 4-2. Here independent variables reflecting structural and neighbourhood characteristics and a home's location in terms of its access to regional employment centres are regressed on the dependent variable of sale price to control for their effects. Like other studies in this area, we also operationalize transit accessibility as a parcel's proximity to a transit station and model this effect directly.

However, to control for the LVU effects of TOD among a set of heterogeneous station areas we adopt a two-stage approach wherein the TOD characteristics of each station catchment area inform a measurement model. Using latent class analysis, the measurement model distils several measured attributes of TOD into a latent categorical variable that corresponds to more homogeneous station types. From this, the categorical variable corresponding to each station type enters the model directly to isolate the value placed on different bundles of TOD characteristics. An interaction term is also introduced to isolate any self-reinforcing effects of station proximity within each station type. For comparison, we also estimate models that adopt a more traditional approach by considering only a home's proximity to transit. The following subsections offer a brief explanation of model variables, expected relationships between transit and TOD, spatial hedonic methods, and descriptive statistics.

In all cases, model functional form is specified as log-linear, with a logarithmic transformation of the dependent variable done to increase normality and reduce heteroskedasticity. Such a functional form offers easily interpretable results and is more robust to omitted variables than a Box-Cox transformation (Kuminoff et al., 2010).

Figure 4-2. Model Structure



4.3.1 Structural, Parcel, and Neighbourhood Characteristics

Each transaction record contains a number of key structural and parcel characteristics associated with the home. This includes floor, basement, and parcel area, the number of bedrooms, full and half bathrooms, the age of the structure, the presence of air conditioning or a pool, the presence and type of garage, and the type of heating.

To control for a property's location in space, each transaction is linked with the general characteristics of the surrounding neighbourhood as represented by the Dissemination Area (DA) in which each house falls. DAs are the smallest unit of Canadian census geography and are generally analogous to a city block. Median household income is used to act as a proxy for overall neighbourhood characteristics and is derived from the 2011 Canadian National Household Survey, the voluntary replacement for the long-form census.

4.3.2 Regional Accessibility

Many stations within the study are located around highway access points that provide automobile accessibility to a significant number of regional destinations, though the travel time and stress impacts of congestion reduce the overall extent of this accessibility (Higgins et al., Under Review). Because homes go to the highest bidder, the price of this accessibility should be reflected in a home's value, even if the residents of the home primarily utilize transit. To control for this access we create a measure of regional interaction potential:

$$EMPGRAV_{ij} = \ln\left(\sum_{\forall j \neq i} \frac{(Pop_i)(Emp_j)}{TT_{ij}^2}\right) \tag{1}$$

Where Pop_i is the total population in the dissemination area *i* in which each parcel is located; Emp_j is the total employment in census tract j, and TT_{ij}^2 is the total travel time between *i* and *j*.

Travel time is calculated as the peak period travel time between i and j on a geographic road network linked to speed readings for commercial vehicles at different times of the day obtained from INRIX, Inc. To measure accessibility at peak periods, trips between i and j were assumed to begin at 8AM on a typical Monday morning in 2012. Travel times are capped at a maximum of 45 minutes, the point at which more than 70% of drivers in daily congestion become dissatisfied with their commutes according to Higgins et al. (Under Review). The result is a measure that reflects a home's overall location in the region relative to major employment centres based on travel by personal automobile while considering the travel time impacts of congestion. Because employment data are not available for the early time period, models in this cross section use the same 2012 data.

4.3.3 Transit Access and Station Area TOD Context

To control for different packages of TOD, the present paper adopts the methodology proposed by Higgins and Kanaroglou (2015b). Specifically, this involves using latent class cluster analysis to control for TOD inputs in transit station areas. TOD is operationalized by quantifying four of the five primary 'D' variables proposed by Ewing and Cervero (2010) according to the definitions presented in Table 4-1. The fifth 'D', which considers a station's spatial catchment area, is operationalized according to either an 800m theoretical buffer around stations, or the functional spatial area covered by a 10-minute walk using the road network (excluding roads that are not pedestrian accessible) and pedestrian paths where available.

In contrast to the typology presented in Higgins and Kanaroglou (2015b), which assumed a full build-out of future projects proposed throughout the region alongside existing rapid transit and thus altered accessibility measures and station catchment areas, the present analysis is based off of a typology estimated for only existing stations. However, to keep the station typologies directly comparable, station type membership in the present paper is predicted based off of the existing model solution in Higgins and Kanaroglou (2015b), a property afforded by latent class model-based clustering. The end result is a set of three distinct station types within our study area: 3 Inner Urban Neighbourhood stations, 6 Urban Neighbourhood Stations, and 3 Suburban Neighbourhood stations.

Table 4-1. Station Typology Variables and Definitions

1. *Density: Population and Employment*
   Reflects density and the intensity of land use development in a station area. Calculated as total Population + Employment / Hectare within each station area's 800m theoretical buffer
2. *Diversity: Development Mix*
   Reflects the balance between population and employment in a station area. Calculated as the ratio of Employment to Population + Employment within each station area's 800m theoretical buffer
3. *Design: Street Connectivity*
   Measures overall street connectivity and the quality of pedestrian access to the transit station. Calculated as the ratio of a station's 10-minute walk buffer on the local road network to its 800m theoretical buffer. In this case all station buffers were permitted to overlap to give a measure of overall street connectivity in the neighbourhood.
4. *Destination Accessibility: Interaction Potential*
   Regional station accessibility and interaction potential, or measure of gravity considering population, employment, and travel time. For station areas oriented to population (Development Mix <.5), total interaction potential is calculated as:

$$POPEMPGRAV_{ij} = \ln\left(\sum_{\forall j \neq i} \frac{(Pop_i)(Emp_j)}{TT_{ij}^2}\right)$$

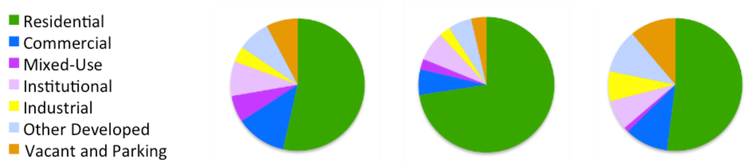
   Where:
   Pop_i = the total population in the labour force in station i within a 10-minute walk
   Emp_j = the total employment in station j within a 10-minute walk
   TT_{ij} = the travel time on transit between stations i and j squared
5. *Diversity: Land Use Mix*
   The proportion of residential, commercial, institutional, mixed, and industrial land in each station area's 800m theoretical buffer. Commercial and institutional land are combined into a single category.

Table 4-2 displays latent class model results for each station type compared to averages for all 372 stations in the full cluster model in Higgins and Kanaroglou (2015b). Here coefficients correspond to each station type's mean for a given measure of TOD. Numbers in parentheses reflect the deviation in percentage terms of this value from the sample mean reported in the right hand column. Also in this column are within-class variances for each class mean. The latent class model assumes these variances are constant across classes to ensure the resulting typology of station-area TOD is maximally homogeneous within class and maximally heterogeneous across classes.

Table 4-2. Station Area TOD Characteristics by Station Type

TOD Measure (Average)	Inner Urban Neighbourhood	Urban Neighbourhood	Suburban Neighbourhood	Class Variance (Average)
Accessibility				
Interaction	17.61***	16.48***	14.94***	1.54***
Potential	(12%)	(5%)	(-5%)	(15.67)
Land Use				
Normalized	112***	68***	41***	1.34***
Density	(27%)	(-23%)	(-53%)	(88)
Development	0.34***	0.18***	0.28***	0.03***
Mix	(-13%)	(-54%)	(-28%)	(0.39)
Walk	0.56***	0.55***	0.45***	0.01***
Connectivity	(18%)	(15%)	(-5%)	(0.48)
Land Use Mix				
Residential	0.49***	0.67***	0.44***	0.01***
	(16%)	(63%)	(7%)	(0.41)
Commercial/	0.19***	0.12***	0.15***	0.01***
Institutional	(5%)	(-34%)	(-16%)	(0.18)
Mixed-Use	0.06***	0.02***	0.01***	0.00***
	(139%)	(-3%)	(-44%)	(0.02)
Industrial	0.04***	0.02***	0.06***	0.01***
	(-64%)	(-80%)	(-54%)	(0.11)

Land Use Overview



Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller

Greater discussion of latent class model results can be found in Higgins and Kanaroglou (2015b). But briefly, results from the typology suggest that Inner Urban Neighbourhoods are most reflective of TOD as a concept, offering the greatest levels of high-density, mixed-use, and pedestrian friendly development around rapid transit. This generally decreases as stations move from urban to suburban, though compared to all 10 station types in Higgins and Kanaroglou (2015b), all station types in the study exhibit of some elements of TOD. The research will attempt to derive how differences among these TOD characteristics are capitalized into the housing market.

4.3.4 Expected Land Value Uplift Effects

4.3.4.1 Transit and TOD

It is hypothesized in this research that transit access and TOD present a bundle of station area characteristics that can produce simultaneous LVU effects. Furthermore, their simultaneity means they create a synergistic or positive feedback loop effect that causes land values to peak at a greater rate than would be the case for transit access alone.

We argue this relationship between transit and TOD results in three LVU scenarios. In some station contexts without TOD, transit accessibility may be large enough that it is valued and produces to clear changes in LVU as predicted by the AMM model. However, other stations high in both transit accessibility and TOD should result in an even greater peaking of land values around a station as individuals bid up prices based on transportation cost and preferences for lifestyle characteristics and local amenities. Finally, in other contexts transit may not provide much of a relative accessibility benefit compared to other modes, but land values may still change due to the presence of TOD.

Using the guidance of the AMM model, previous research has largely considered the effects of transit accessibility and TOD concurrently in one composite or global measure, usually through a home's proximity to a station. If accessibility alone is affecting land values in a station area, this approach is appropriate. But in an age of coordinated transportation and land use planning, such an assumption may be unrealistic in many contexts.

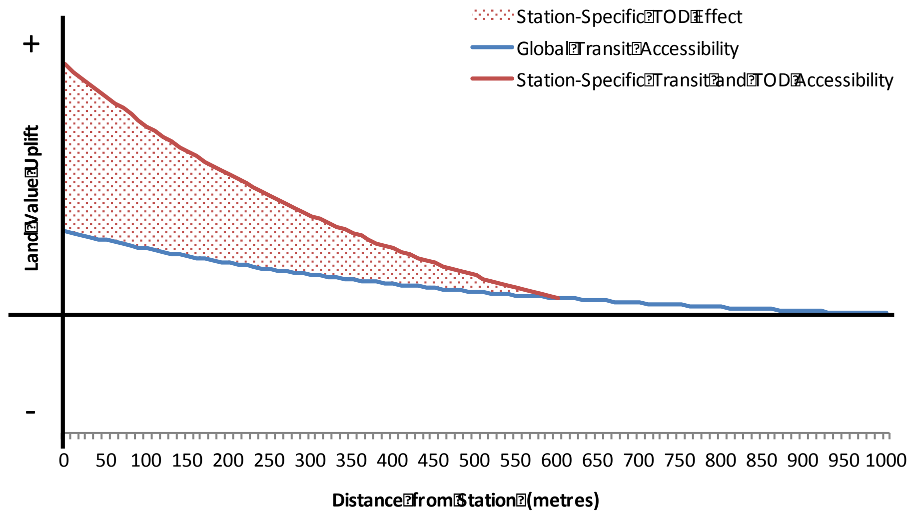
In response, our research seeks to unbundle the LVU effects of transit access and TOD by using two types of measures: proximity and the station area TOD typology. By representing broadly homogeneous station types, we hypothesize that the typology controls for different bundles of TOD and the spatial submarkets that should result. This includes different levels of transit accessibility, density, mixed land uses, local station area employment, and walkability.

Controlling for such TOD factors in the area where a home is located should free more traditional measures of proximity to a station to act as a true proxy for transit accessibility as predicted by the AMM model. If transit is indeed valued by owners of single-detached homes, this variable should have a negative sign where prices decrease as a home's distance from a station increases. Note this is an aggregate or global level of basic transit accessibility common to all HRT subway stations, an effect that should be relatively homogeneous across our small sample of interconnected stations.

Finally, if implementations of TOD radiate outwards from the transit station, it is reasonable to assume that a home's proximity to TOD is also important. Here an interaction effect between station proximity and station area TOD should account for any such additional synergies or multiplier effects between station-specific transit accessibility and proximity to any TOD amenities.

The combined result is theorized to resemble that in Figure 4-3, where the measure of global transit accessibility produces a negative non-linear relationship wherein land values decrease the further a home is away from a station. A station-specific TOD effect should represent the more localized value placed on a location within walking distance of different packages of TOD characteristics over and above base transit accessibility. Finally, the interaction effect measures the rate at which this additional localized TOD effect decays over space as distance from the station increases.

Figure 4-3. Expected Relationship between Land Values and Transit and TOD



4.3.4.2 Temporal Effects

In addition to expectations of LVU in a single cross section, we also hypothesize that LVU should increase in value over time between samples, for two reasons. First is growth in the city in general, which added 130,000 residents between 2001 and 2011. But within this growth is the coming of age of the echo-boomer cohort, where a significant number of young individuals between the ages of 20-25 years old are entering the housing market.

As detailed in Higgins and Kanaroglou (2015b), there is a strong association between more urban implementations of TOD in the typology and high proportions of these individuals, suggesting that some degree of submarket sorting is indeed occurring within these station types.

A second factor is an overall increase in transportation cost for automobile due to both consistently high levels of regional congestion, but also a decrease in available parking in the central business district and many other areas throughout the city as these lands have been converted to higher-density uses. These trends should result in a higher willingness to pay for transit access. This is to some extent reflected in ridership trends, with rides per capita growing from 169 to 191 between 2001 and 2011.

However, a lack of available data for the early time period means the extension of the TOD typology to the early cross section is at best conceptually tenuous. Aside from population, the bulk of the typology was estimated using data from 2011-2014 and the characteristics of these stations have changed over time. As shown in Figure 4-1, stations such as Eglinton, those along the northern section of Line 1 and several stations on Line 4 are now home to several new residential, commercial, and mixed-use condominium projects that did not exist in the earlier cross section. Nevertheless, the absence of microdata for these changes means we must assume that station types have remained constant across samples. This renders station-specific model estimates and temporal comparisons between them as descriptive only.

4.3.5 Spatial and Temporal Effects

To control for temporal effects in the real estate market such as seasonal trends, inflation, and other factors we incorporate a series of quarterly dummy variables into the model. For spatial trends, it was hoped that explicitly controlling for TOD spatial submarkets would reduce the need to control for any additional unobserved spatial effects in the data. However, model diagnostics revealed the continued existence of spatial autocorrelation after estimation. Furthermore, diagnostics also indicated the presence of residual heteroskedasticity. In response, a spatial weights matrix based on a 'queen' system of spatial contiguity was created and models were re-run with spatial lag and spatial error terms using the KP heteroskedasticcity-consistent estimator for robust standard errors.

4.3.6 Descriptive Statistics

Basic descriptive statistics for the variables included in the hedonic model can be seen in Table 3. Average sale prices in each station type are over $1 million with median household incomes above $100,000, making the study area comparatively wealthy.

Table 4-3. Descriptive Statistics

	Model 1: 2010-2014		Model 2: 2001-2003	
Variable	*Mean (Prop.)*	*Std. Dev.*	*Mean (Prop.)*	*Std. Dev.*
Sale Price ($, thou.)	1,243.92	637.08	579.93	317.33
Transit Proximity and TOD				
Station Distance (metres)	772.75	253.82	780.95	252.97
10-Minute Walk (0-1)	(0.28)		(0.27)	
10-Min. Walk * Station Dist.	465.95	127.65	470.64	131.20
Inner Urban Nhbd. (0-1)	(0.06)		(0.07)	
Inner Urban * Station Dist.	459.49	115.55	469.50	120.19
Urban Nhbd. (0-1)	(0.20)		(0.18)	
Urban Nhbd. * Station Dist.	466.07	130.65	456.95	135.17
Suburban Nhbd. (0-1)	(0.01)		(0.02)	
Suburb. Nhbd. * Station Dist.	505.60	139.00	532.20	116.67
GO Suburb. Nhbd. (0-1)	(0.00)		(0.01)	
GO Sub. Nhbd. * Stn. Dist.	477.51	93.69	459.18	86.90
Structural Characteristics				
Structure Age (years)	57.19	30.17	63.07	25.94
Lot Area (metres^2)	529.76	420.99	537.28	328.20
Floor Area (feet^2)	2,075.00	1,050.47	1,936.15	979.35
Finished Basement Area (feet^2)	654.30	502.13	481.36	485.37
No. Bedrooms	3.42	0.89	3.33	0.89
No. Full Baths	2.25	1.22	1.98	1.10
No. Half Baths	0.71	0.64	0.65	0.62
Attached Garage (0-1)	(0.34)		(0.34)	
Detached Garage (0-1)	(0.28)		(0.33)	
Air Conditioning (0-1)	(0.65)		-	
Heat – Forced Air (0-1)	(0.74)		(0.71)	
Pool (0-1)	(0.06)		(0.06)	
Median Household Income ($, thou.)	130.07	73.03	98.48	44.05
Distance to nearest School (metres)	462.12	211.60	492.15	223.45
Distance to nearest Park (metres)	211.30	132.72	213.98	137.08
Within 100m Hwy. (0-1)	(0.01)		(0.01)	
Regional Accessibility				
Emp. Interaction Potential	15.94	1.32	15.89	1.14
Quarter of Sale				
Omitted for Brevity (0-1)				
N		2,028		3,019

4.4 MODEL RESULTS

Model results are reported in Table 4-4 for two sets of models across six columns. Models 1a, 1b, and 1c correspond to the most recent cross section of transactions that occurred between 2010 and 2014. Models 2a, 2b, and 2c correspond to the early sample of sales that occurred between 2001 and 2003. In both cases, the first model within each cross sectional group adopts a traditional structure in which only a home's distance to a transit station is considered and assumes all stations are homogeneous in their characteristics.

The second model in each group advances this specification by considering a separate interacted effect for properties within a 10-minute walk of a station, where a peaking of land values should be more pronounced. In both cases, the focus on only proximity means potentially heterogeneous LVU effects of transit and TOD across different transit station contexts are masked by global estimates. In contrast, the third model in each cross section adopts the expanded structure depicted in Figure 4-2, where different bundles of transit access and TOD are assumed to constitute different spatial submarkets in which both factors are valued differently by homeowners.

Table 4-4. Spatial Hedonic Model Results

Variable	Model 1a: 2010-2014 Coefficient	Model 1b: 2010-2014 Coefficient	Model 1c: 2010-2014 Coefficient	Model 2a: 2001-2003 Coefficient	Model 2b: 2001-2003 Coefficient	Model 2c: 2001-2003 Coefficient
Transit Proximity and TOD						
Station Distance	0.000007	0.000072 *	0.000071 *	-0.000004	0.000061 *	0.000060 *
10-Minute Walk (0-1)	-	0.139981 **	-	-	0.171071 ***	-
10-Min. Walk * Station Dist.	-	-0.000220 **	-	-	-0.000294 ***	-
Inner Urban Nhbd. (0-1)	-	-	0.027230	-	-	0.165259 **
Inner Urban * Station Dist.	-	-	0.000009	-	-	-0.000277 **
Urban Nhbd. (0-1)	-	-	0.170408 ***	-	-	0.149065 ***
Urban Nhbd. * Station Dist.	-	-	-0.000278 **	-	-	-0.000248 ***
Suburban Nhbd. (0-1)	-	-	0.063584	-	-	0.513801 ***
Suburb. Nhbd. * Station Dist.	-	-	-0.000140	-	-	-0.000954 ***
GO Suburb. Nhbd. (0-1)	-	-	-0.846191	-	-	0.158073 *
GO Sub. Nhbd. * Stn. Dist.	-	-	0.001366	-	-	-0.000399 ***
Structural Characteristics						
Structure Age	-0.010006 ***	-0.009916 ***	-0.009905 ***	-0.002893 **	-0.002980 **	-0.003016 **
Structure Age^2	0.000093 ***	0.000092 ***	0.000092 ***	0.000036 ***	0.000036 ***	0.000036 ***
Lot Area	0.000111 ***	0.000114 ***	0.000115 ***	0.000066 **	0.000072 **	0.000072 **
Floor Area	0.000132 ***	0.000132 ***	0.000132 ***	0.000175 ***	0.000174 ***	0.000173 ***
Finished Basement Area	0.000046 ***	0.000045 ***	0.000044 **	-0.000051 ***	-0.000052 ***	-0.000053 ***
No. Bedrooms	-0.010176	-0.009797	-0.009769	0.013442 *	0.015029 **	0.015061 **
No. Full Baths	0.017244 **	0.017077 **	0.016484 **	0.061665 ***	0.061460 ***	0.061509 ***
No. Half Baths	0.036062 ***	0.036074 ***	0.036881 ***	0.065251 ***	0.064449 ***	0.064589 ***
Attached Garage (0-1)	0.022586	0.023123	0.024049	-0.005997	-0.005370	-0.004430
Detached Garage (0-1)	0.034562 **	0.032906 **	0.032204 **	0.017830 *	0.017212 *	0.017311 *
Air Conditioning (0-1)	0.003157	0.003245	0.002725	-	-	-
Heat – Forced Air (0-1)	-0.013502	-0.012500	-0.011527	-0.021269 **	-0.018650 *	-0.019480 *
Pool (0-1)	0.081149 ***	0.082307 ***	0.082497 ***	0.032472 *	0.031192	0.032778 *

Continued…

Neighbourhood Characteristics						
Median Household Income	0.000001 ***	0.000001 ***	0.000001 ***	0.000001 ***	0.000001 ***	0.000001 ***
Distance to nearest School	0.000018	0.000018	0.000019	0.000055 **	0.000063 **	0.000059 **
Distance to nearest Park	-0.000020	-0.000022	-0.000023	0.000080 **	0.000075 *	0.000074 *
Within 100m Hwy. (0-1)	-0.212184 ***	-0.207815 ***	-0.189450 ***	-0.202986 ***	-0.201184 ***	-0.195362 ***
Regional Accessibility						
Emp. Interaction Potential	0.007617 *	0.007992 *	0.008097 *	0.008906 **	0.009749 **	0.009569 **
Time of Sale						
Year 1 Quarter 1	-0.486825 ***	-0.487382 ***	-0.486778 ***	-0.218663 ***	-0.219622 ***	-0.220072 ***
Year 1 Quarter 2	-0.431046 ***	-0.431572 ***	-0.431269 ***	-0.210668 ***	-0.210345 ***	-0.209184 ***
Year 1 Quarter 3	-0.437584 ***	-0.437865 ***	-0.438035 ***	-0.182173 ***	-0.182938 ***	-0.182199 ***
Year 1 Quarter 4	-0.466523 ***	-0.465522 ***	-0.463705 ***	-0.179701 ***	-0.180271 ***	-0.180399 ***
Year 2 Quarter 1	-0.453166 ***	-0.456497 ***	-0.456931 ***	-0.165327 ***	-0.166786 ***	-0.167166 ***
Year 2 Quarter 2	-0.368064 ***	-0.368945 ***	-0.365798 ***	-0.131324 ***	-0.130983 ***	-0.129560 ***
Year 2 Quarter 3	-0.325950 ***	-0.324519 ***	-0.323979 ***	-0.044367 **	-0.045445 ***	-0.044097 **
Year 2 Quarter 4	-0.303441 ***	-0.303084 ***	-0.303585 ***	-0.039589 **	-0.042489 **	-0.041266 **
Year 3 Quarter 1	-0.263089 ***	-0.264885 ***	-0.264266 ***	-0.042866 **	-0.043767 **	-0.042601 **
Year 3 Quarter 2	-0.223421 ***	-0.225736 ***	-0.223120 ***	-0.025757	-0.024899	-0.024977
Year 3 Quarter 3	-0.218300 ***	-0.218188 ***	-0.217000 ***	-0.001678	-0.002151	-0.000929
Year 3 Quarter 4	-0.228373 ***	-0.228126 ***	-0.226810 ***	*(reference)*	*(reference)*	*(reference)*
Year 4 Quarter 1	-0.252452 ***	-0.251127 ***	-0.251703 ***	-	-	-
Year 4 Quarter 2	-0.165543 ***	-0.166238 ***	-0.165831 ***	-	-	-
Year 4 Quarter 3	-0.123017 ***	-0.124186 ***	-0.125927 ***	-	-	-
Year 4 Quarter 4	-0.088473	-0.088458	-0.090462	-	-	-
Year 5 Quarter 1	-0.120236 *	-0.121289 *	-0.110905	-	-	-
Year 5 Quarter 2	-0.043456	-0.043647	-0.043188	-	-	-
Year 5 Quarter 3	*(reference)*	*(reference)*	*(reference)*	-	-	-
Constant	8.276658 ***	8.241056 ***	8.242818 ***	7.524306 ***	7.557958 ***	7.563716 ***
W_lnSalePrice	0.397310 ***	0.394956 ***	0.394643 ***	0.370995 ***	0.362144 ***	0.362284 ***
Lambda	0.090140 **	0.093417 **	0.088536 **	0.177810 ***	0.188675 ***	0.186867 ***
N	2,028	2,028	2,028	3,019	3,019	3,019
Pseudo-R^2	0.718	0.712	0.721	0.749	0.750	0.750

Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller

Model results for structural, neighbourhood, regional accessibility, and quarterly time characteristics generally perform as expected, but for the sake of brevity we omit greater discussion of these impacts. Focusing on the key variables of interest in the *Transit Proximity and TOD* group for model 1a, we can see from the lack of statistical significance on the *Station Distance* variable that a home's proximity to its nearest TTC rapid transit access point is not valued. A similar result is seen in model 2a in the earlier time period. While coefficients across both models take opposite signs, they cannot statistically be determined to be different from zero. This lack of statistical significance runs counter to the theoretical expectations of the AMM model in the Toronto context, as access to the TTC subway system should be capitalized into home values, particularly when considering the high levels of absolute and relative accessibility offered by the system between origins and destinations in the city.

However, re-estimation with an interaction specification to capture more localized LVU among properties within a 10-minute walk of a station in models 1b and 2b reveals the expected strong and significant negative relationship between price and proximity across both cross sections. The reference group consists of homes outside this buffer. As plotted in Figure 4-4, a location within a 10-minute walk is associated with a price increase of up to 15% in the recent time period, and up to 19% in the earlier time period (using the formula $100[exp(c) - 1]$, where c is the coefficient in question). This effect decreases at a rate of 0.02 and 0.03 percent per metre within each model respectively to intersect the base transit proximity measure at distance of about 500 metres from the station.

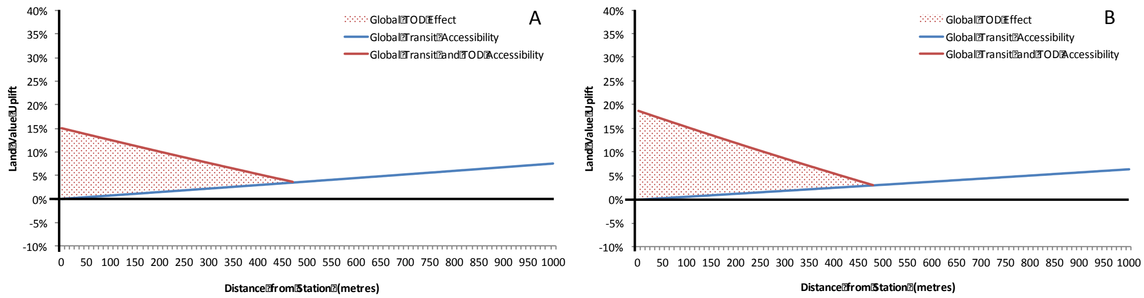
Such results may be construed as significant indicators that transit accessibility is being priced into the land market. But how much of this effect is due to transit access, how much to TOD, and are these LVU amounts really consistent across all station contexts?

Models 1c and 2c seek to unbundle these influences and within the most recent cross section, we can see that there are indeed heterogeneous station proximity and station type effects informing land values around *Urban Neighbourhood* stations. The coefficient on the dummy variable corresponding to whether a single-detached home is located within a 10-minute walk of an *Urban Neighbourhood* station indicates that these homes sold at a premium of 19% compared to the reference group, all else being equal. This corresponds to the value placed on this particular submarket, where *Urban Neighbourhood* stations reflect a good implementation of TOD by featuring higher densities, a mixing of land uses, high levels of pedestrian accessibility, and some amenities offered by station-area commercial development.

However, there is an additional relationship between proximity to a subway station and a location within the catchment area of this station type. The coefficient corresponding to the interaction between station distance and the *Urban Neighbourhood* dummy indicates that relative to the rest of the sample, homes immediately proximate the station achieve the maximum benefit of 19% described above, after which this benefit decays over space as distance from the station increases. The rate of decay is approximately 2.8% every 100 metres farther from a station.

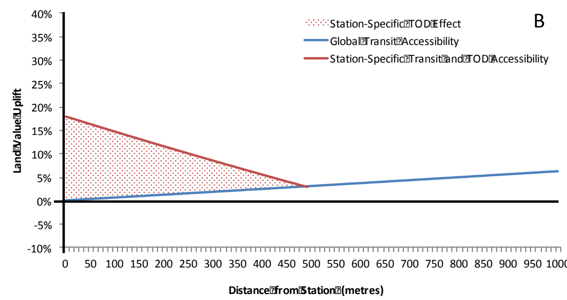
Figure 4-4. Land Value Uplift by Station Type (A: 2010-2014; B: 2001-2003)

Models 1b and 2b: Global Transit and TOD Effects

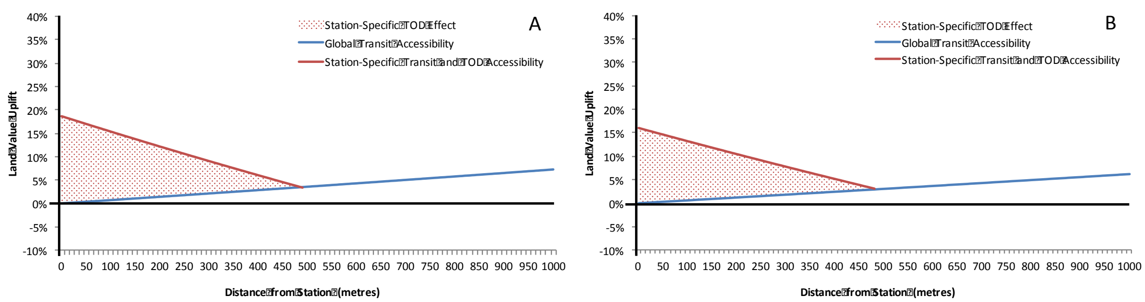


Models 1c and 2c: Inner Urban Neighbourhood HRT Stations

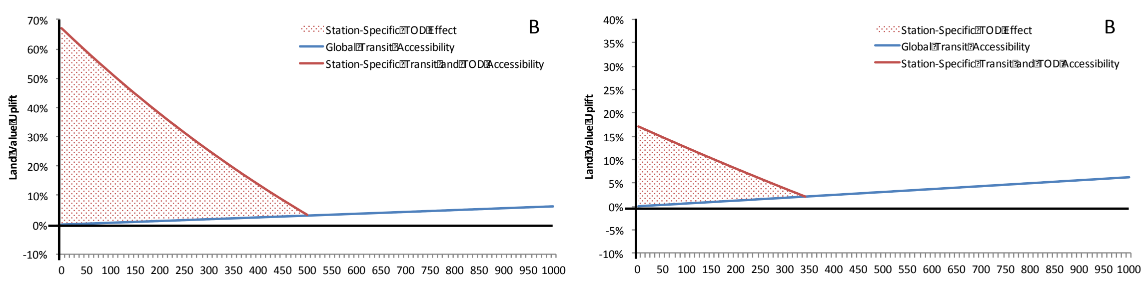
ns



Models 1c and 2c: Urban Neighbourhood HRT Stations



Model 2c: Suburban Neighbourhood Stations (Left: HRT; Right: CRT)



What about the base LVU effects of access to rapid transit? It was originally hypothesized that after controlling for TOD, the global station proximity variable would be freed from any confounding TOD submarket effects to reflect the value premium placed on more homogeneous transit access across all station types. But as the station proximity variable in Model 1c demonstrates, a home's basic proximity to a station is positive and statistically significant at the 10% level. Again this is the opposite effect theorized, as after controlling for TOD and TOD proximity, land values actually increase as distance from a station increases. This suggests a general disamenity for transit access among homes in our sample, although the coefficient is small at an increase of 0.7% every 100 metres farther from a station. Taken together, these effects result in LVU up to a distance of approximately 500 metres as depicted in Figure 4-4.

Results for the earlier time period show more consistent relationships between station types and station-specific transit access and TOD proximity effects. Like Model 1c, compared to the reference group of homes outside a 10-minte walk, a location within an *Urban Neighbourhood* station exhibits LVU of up to approximately 16%, decreasing at a rate of 0.025% every metre and intersecting the global proximity measure at about 500 metres (Figure 4-4). But unlike the recent cross section, results for *Inner Urban Neighbourhood* and *Suburban Neighbourhood* stations are also significant. In the former, homes around the three Inner Urban Neighbourhood stations are worth up to approximately 18 percent, decreasing 0.027% every metre to a distance of about 500 metres. In the latter, the model suggests that homes around the two Suburban

Neighbourhood stations are worth 67 percent more than the reference group, decreasing by 0.095% every metre to intersect the base effect at about 500 metres.

Homes around the Oriole GO CRT *Suburban Neighbourhood* station also see LVU of up to 17% compared to the reference group, decreasing by 0.039% to a distance of 350 metres. While significant only at the 10% level, this suggests a smaller catchment area and more muted capitalization for commuter rail service compared to sampled subway stations. Again however it should be noted that the assumption of constant station types between time periods is likely unrealistic, rendering the stratification of stations into TOD types and associated LVU coefficients arbitrary across all Model 2 specifications. As we discuss below, it seems plausible that temporal differences in station context explain some of the differences seen across time period.

4.5 DISCUSSION AND CONCLUSIONS

4.5.1 Station Type Temporal Differences

At face value, differences among cross sections in Models 1c and 2c appear to show a decrease in the value placed on a location in an *Inner Urban Neighbourhood* or *Suburban Neighbourhood* type of station area over time, as both effects become insignificant in the more recent model. One reason for such changes is the weakness of the assumption of constant station types between models, as the characteristics of stations have changed between cross sections.

From the description of new high density development earlier in the paper, it seems plausible that if station area TOD data had been available for the earlier time period it may be that some *Urban Neighbourhood* stations would instead be less dense *Suburban Neighbourhoods*, and some *Urban Neighbourhood* stations would have become higher density *Inner Urban Neighbourhoods* as projects were completed after 2003. This would explain the similar coefficients found for the *Inner Urban* and *Urban Neighbourhood* station types in Model 2c, wherein these station types could have been relatively similar in the early cross section.

On the other hand, while the earlier cross sectional models are at best descriptive, it is worth considering differences among the *Urban Neighbourhood* stations in Models 1c and 2c, both of which showed consistently positive LVU effects. Assuming station area TOD characteristics were generally consistent across models, the increase in the magnitude of station-specific TOD and proximity to transit and TOD effects suggests that the maximum value placed on such locations increased over time, from 16% to 19%. This too seems plausible based on two larger transport cost and demographic trends that have occurred within the region over the course of the two samples.

However, it is important to note that such trends did not result in significant relationships for the other station types in Model 1c, nor the base global access measure in any specification. But without earlier data on TOD, such hypotheses cannot be confirmed without further research. Furthermore, such outcomes likely also relate to the bundled nature of localized transit access and TOD and unobserved sorting effects, topics we explore further below.

4.5.2 Transit Access and TOD: Unbundled?

In line with the trends noted above, one might expect a greater capitalization of transit access into home values across all stations. However, the base global proximity measure was found to be positive and statistically significant across Models 1b, 1c, 2b, and 2c. This suggests that transit access around sample stations is actually not capitalized into the housing market and outside of any synergistic effects with TOD, that it may even be a disamenity in the recent cross section.

There are several possible reasons for this disamenity effect. First, it may be that rapid transit is not capitalized over a distance longer than that covered by an approximate 10-minute walk on the street and pedestrian network. Still, a non-linear relationship wherein homes closer to the station see a greater benefit than those farther away should be captured by the log-linear specification of distance. Other specifications, such as the use of network distance measurements instead of straight-line distance for both general and interacted proximity measures consistently produced insignificant results and were omitted in favour of the approach presented here.

Another option is that counter to our expectations, the interaction approach does not actually isolate transit access from TOD in practice. Instead, it may be that the interaction term is still acting as a simultaneous measure of both transit access and proximity to TOD and that separate transit and TOD effects have in fact not been unbundled. Still, if this was the case, any relatively homogeneous accessibility effects within study area stations should be reflected in more consistent estimations for these interaction measures at other stations beyond just *Urban Neighbourhoods* in the recent cross section.

From this, a last possible reason is that the measures are indeed performing as expected and unbundling the LVU effects of TOD and transit access. However, like one of the transit and uplift expectation scenarios discussed earlier, it may very well be that there is no statistically significant capitalization of base global transit accessibility into single-detached home values around these stations despite the transportation cost trends in the Toronto region. This conclusion is supported by previous work from Saccomanno (1979), where the hedonic price associated with a composite multi-modal accessibility index was found to have decreased over 1961 to 1971 despite an overall increase in house prices. This work captures an overall decrease in locational advantage associated with accessibility as the Toronto region gradually expanded spatially around the private automobile, reducing the relative accessibility benefits of locations proximate to subway stations.

Nevertheless, because proximity is used as only a proxy for transit access, we cannot at this time confirm which of these hypotheses is correct. Future research should avoid this issue by employing more precise estimations of transit's absolute and relative accessibility effects. This can include travel times, congestion, parking costs, fuel costs, and fares, all of which can be incorporated into a measure of generalized transportation costs. Unfortunately for the present research such data are not available.

4.5.3 Sorting, Preferences, and TOD Submarkets

While the results for the *Urban Neighbourhood* station type are promising, it is interesting to not see any statistically significant LVU effects for the *Inner Urban* and *Suburban Neighbourhood* station types in Model 1c. One potential explanation for this relates to individual preferences that inform sorting into TOD submarkets and how those preferences are engrained in real estate transaction data. Such data are revealed preference in that a buyer's purchase decision in terms of price and location is based off of preferences that are unobserved to the researcher. In this sense, it may be that sales of single-detached homes are not the best type of property to model to reveal underlying LVU effects.

For example, while there are high levels of transit access and TOD amenities offered within the vicinity of an *Inner Urban Neighbourhood* type station, locations in close proximity are also likely to suffer some negative effects such as increased noise and the impacts of building shadows. From this it may be that individuals interested in a single-detached home within the study area are also looking to live in a neighbourhood that is not as intensely developed. Given the average cost of a home in this sample, it may also be that the price of such properties puts them out of reach to first-time buyers in the echo boomer cohort. Instead, a study of condominium sales may reveal an entirely different capitalization structure for transit and TOD. Unfortunately, greater inference into the role of individual preferences in locational decisions cannot be obtained through transaction data alone and would require more qualitative stated preference research undertaken on the factors guiding the homebuyer's purchase.

A second and related issue is that because these stations have become so intensely developed, there are simply not be enough transactions within the immediate proximity of a station to estimate significant price premium effects against a control group. Real estate market trends can also affect this, as the recent cross section has about 1,000 fewer total transactions despite covering a large time period. This lack of transactions seems particularly true for Suburban Neighbourhood type stations in Model 1c, where only 1-2% of the sample is within a 10-minute walk of either station.

4.5.4 Conclusion

Under the theoretical guidance of the AMM model and Tiebout's theory of sorting, it seems plausible that both rapid transit and associated TOD land use planning can result in significant price premiums for locations around stations. Until now research into rapid transit's LVU effects has largely considered this bundle of goods as a whole. Furthermore, working only through the lens of the AMM model, any LVU effects that are captured by proximity may construe these simultaneous TOD and access effects as only transit accessibility. This notion may explain why the results of previous studies have been so diverse.

In response, we recognize the potential for LVU effects from both transit accessibility and TOD, and have sought to unbundle the simultaneous and potentially self-reinforcing price effects of each. The TOD typology delineates more homogeneous station areas in terms of their TOD inputs, and controlling for these factors directly enables greater precision in terms of isolating any transit access effects common to all stations and any additional multiplier effects that accrue from station-specific TOD proximity.

While the model reported a global transit accessibility effect that was opposite than theorized, results do reveal strong and statistically significant LVU effects for a location within specific types of TOD submarkets and suggests that individual preferences are indeed guiding locational decisions wherein some home buyers are outbidding others for locations rich in characteristics associated with TOD. Furthermore, these preferences appear to outweigh any basic considerations of transit accessibility, which was actually found to exhibit a small but statistically significant disamenity effect across all stations. Thus, in as much as revealed preferences from single-detached home sales can be generalized, transit and TOD continue to be a localized and self-reinforcing bundle of goods, at least in some stations.

Still, our attempts to unbundle the LVU effects of transit and TOD have resulted in more questions for future research. Further study will be needed to analyze the capitalization of transit and TOD into different housing types, examine the individual preferences that inform spatial sorting decisions, and to achieve a greater separation of accessibility to transit and TOD through the use of more precise measures of transport cost.

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CHAPTER 5

VALUE PLANNING FOR RAPID TRANSIT: TOWARDS A METHOD FOR PREDICTING AND MAXIMIZING LAND VALUE UPLIFT AND CAPTURE IN STATION AREAS

ABSTRACT

Land value capture (LVC) has been used by both public and private actors to generate revenue for more than a century. For the public sector in particular, the rationale to engage in LVC to recapture the 'unearned increment' that accrues from a rapid transit project's land value uplift (LVU) benefits is strong. However, despite a rich history of research into the LVU effects of such projects, these works offer little guidance to planers and policymakers interested in answering basic questions about LVC. In response to this criticism, the paper proposes a value planning framework that fully conceptualizes the drivers of a transit project's LVU benefits and total capturable revenues. From there, it lays the foundations of a method for better predicting the value uplift that can occur from rapid transit in different land use and transportation contexts. Because little research has occurred on the separate LVU benefits that accrue from rapid transit accessibility and transit-oriented land use planning, the framework is at present conceptual. Nevertheless, future research in this area can begin to fully realize the potential of the framework and help to ensure the wider adoption of LVC as a solution for raising new sources of revenue for rapid transit in North America and around the world.

5.1 INTRODUCTION

Land value capture (LVC) for rapid transit infrastructure, wherein some of the land value benefits, or land value uplift (LVU) of a project are used to pay for the project itself, has a rich history. Its beginnings trace back to the use of the accessibility benefits provided by private streetcar services to unlock the potential value of suburban land held by property developers. Since that time, the idea of capitalizing on the reciprocal relationship between transit accessibility and land values has taken hold in the public sector as well, albeit with varying degrees of interest and opportunities over time.

Nevertheless, the rationale for engaging in LVC by the public sector in particular is strong. Guided by the theoretical expectations of the standard urban model or AMM model of Alonso (1964), Muth (1969), and Mills (1972), if rapid transit confers accessibility benefits that reduce transportation costs, land values around transit stations should increase. In this case however, any localized upside increases in land values that result from the public sector investment in rapid transit accrue to private land owners, resulting in what Hagman and Misczynski (1978) refer to as a 'windfall', or to use the terminology of J. S. Mill, an 'unearned increment'.

As Callies (1979, p. 156) explains, "any value thus conferred upon such neighboring property owners is arguably "unearned" since it results not from any effort by the owners, but rather is due to substantial expenditures (usually accompanied by heavy public debt) by a governmental entity customarily using general tax revenues. If the "unearned increment" can be thus "captured," the result should be a corresponding reduction in public costs. The current "taxpayers' revolt" over the high cost of government services makes such techniques worth pursuing."

In this sense, there is a rationale to engage in LVC alongside any public investment that requires substantial costs and results in localized land value benefits to nearby property owners. Indeed, Hagman and Misczynski (1978) detailed a long history of municipalities in the United States funding large portions of their budgets through localized special assessment districts (SADs) to pay for sewers, water, and other basic infrastructure.

The rationale may be strong, but what about the evidence of LVU? In line with the AMM model, a wealth of previous research has attempted to capture the relationship between transit accessibility and land values, with many studies finding expected relationships. However, as Higgins and Kanaroglou's (2015a) review of more than 100 studies that occurred in North America shows, others have found no significant relationship and some have actually found that proximity to a transit station results in a negative disamenity effect for nearby land.

Nevertheless, despite a wealth of research on LVU, few studies have attempted to extend their findings to inform the potential for LVC. This has led Smith and Gihring (2006, p. 751) to argue "it is now time for transit/land-use research to move from hypothesis testing to practical applications of value capture. Longitudinal models can help predict land-value increments over a period of time, yielding estimates of the total capturable revenues that would support the debt financing of transit improvement projects." Essentially, while many previous studies have demonstrated evidence of LVU, it is time for research to better benefit planning and policy by moving beyond testing the uplift hypothesis and closing the loop between private value uplift and public value capture.

This is a fair criticism, and some research has headed in this direction. McMillan and McDonald (2004) for example estimated that the increase in land values attributable to the Midway Line in Chicago amounted to 47% of the costs of the project. However, can such findings reasonably be extended to other areas? Is that how much land values would increase if a new subway line were to be built in Toronto? What if LRT was built instead? And what about any LVU effects from transit-oriented development (TOD)? While such information is crucial for planning and policy, Smith and Gihring's seemingly innocuous call for more applicable research belies considerable complexity.

This is primarily because there is a critical flaw in extending estimates of LVU to LVC: for LVC programs to achieve their maximum potential, the potential value increment must be known *a priori* by planners and policymakers, for two reasons. First, to be economically efficient and socially equitable, any LVC tool must be set at levels that reflect the actual value increment that accrues from the transit project. Second, previous research has shown that this process of value uplift can start to accrue as soon as a project is announced and stop locations are made public, meaning the baseline value against which LVC is judged starts to change almost immediately.

To provide some answer it may be appealing to use previous research in the same city or other cities to provide a baseline estimate of LVU. However, here again there are problems. Higgins and Kanaroglou (2015a) argued that some of the diversity in research outcomes in this area results from potentially limited accessibility effects for transit in automobile-oriented contexts and incomplete theoretical guidance that leaves the price effects of heterogeneous station-area TOD contexts uncontrolled. A consequence of this is that the context of previous studies of LVU are central to their outcomes, negating the ability to simply apply uplift coefficients from one area into estimates of LVU in another in any reliable way.

Still, this body of work does offer rough evidence that in the right circumstances, and surrounded by the right public policy, rapid transit can produce LVU. But is there a better way to derive more empirical estimations of this uplift and more rigorous extensions of such estimates to future infrastructure beyond simple approximation? To respond to the criticisms raised by Smith and Gihring in a way that recognizes the limitations to extending the previous literature noted above, the present research proposes a value planning framework around which future research in this area should be based.

Value planning is a planning model or approach that achieves two goals. First, it offers a more complete conceptualization of the land value impacts of rapid transit, and second, uses this conceptualization to propose a model for making more empirical extensions of previous LVU estimates to future infrastructure. Taken together, value planning permits not only more empirical estimates of LVU, but a maximization of the benefits of a rapid transit project and its total capturable land value impacts.

Note that LVC is part of value planning, but the concept as proposed is not the same as LVC. Value planning is a planning paradigm, an ethos that not only capitalizes on the relationship between rapid transit accessibility and land use, but constitutes a broader recognition of the many ways land value effects can be shaped by integrated land use and transportation planning. Essentially, value planning uses public policy to maximize public benefits associated with a project, but also to minimize net public costs by recapturing the capitalization of these benefits in the urban land market.

Furthermore, our focus is not on the specific LVC tools. LVC includes the use of strategies such as special assessment districts (SADs), development charges or impact fees, tax-increment financing (TIF), and transit joint development, and an overview of these tools can be found in Iacono et al. (2009). Instead, the present study seeks to establish a planning framework that can provide valuable information to planners and policymakers on the total amount that can potentially be captured. This in turn offers critical guidance on which tool is most appropriate, the rate at which the tool can be set, and the spatial decay in this rate over space.

Still, the shortcomings of present research into the LVU effects of rapid transit means that previous estimates of uplift for use as inputs into the framework are not widely available. A potential matrix of land value uplift coefficients reveals that much more remains unknown than known in this study area. Thus the goal of the paper is to present a call for study around a plan to ensure that future research into the LVU effects of rapid transit proceeds in a way that heeds the call of Smith and Gihring to offer the most generalizable results to planners and policymakers interested in closing the loop between LVU and LVC.

To proceed, we first situate value planning within the history of LVC approaches in North America. Next, we present the value planning framework in theory in terms of a focus on existing key enablers and policy levers or policy interventions to influence these key enablers. From this, we propose a method for deriving more context-sensitive estimates of existing LVU that in turn permit more empirical predictions of LVU in future station areas. Finally, we highlight the significant knowledge gaps that remain to be filled and discuss larger issues within the study area.

5.2 THE HISTORY OF LVC IN NORTH AMERICA

History has demonstrated at least three phases of interest in LVC for transit projects in North America. One of the earliest examples is the private provision of streetcar services in many cities in the United States around the turn of the twentieth century. In this case, transit was viewed as a loss-leader, a tool for private companies to couple with property development to provide accessibility to their suburban land and greatly increase the value and potential profitability of new development (Bernick & Cervero, 1997; Cushman, 1988a).

In the 1970s and 1980s, interest in LVC amongst the public sector grew based on the experiences with innovative ways to raise funds seen in cities like New York City, Toronto, and Montreal. In Toronto for example, a large-scale land leasing and air-rights program combined with a strong emphasis on transit-oriented development (TOD) undertaken after the construction of the city's first subway line in the 1950s proved successful in developing a high-density, transit-supportive corridor that paid off in high ridership and recovering the transit agency's costs of land acquisition.

With several large US cities embarking on landmark heavy and light rail rapid transit projects and leaving many opportunities for LVC foregone, experiences in Toronto became a focus of several studies (Allen, 1986; Cervero, 1986; Pill, 1988; ULI, 1979) and reports to the United States congress (Bower, 1979; Richmond, 1979) as a potential model for a larger implementation of LVC. However, Howard et al. (1985) argue that the institutional arrangements responsible for the successes seen in Canadian examples ultimately did not translate well to US cities. Still, that did not stop several other innovative, though smaller-scale value capture initiatives through transit joint development in cities like Washington, DC, Atlanta, New York City, Los Angeles, Boston, Portland, Denver, Miami, and even Toledo, OH (Cushman, 1988b; Howard, 1988; Howard, et al., 1985; Keefer, 1985).

Since then, Landis et al. (1991) and later Cervero (1994) published a review of transit joint development strategies for cost sharing and revenue sharing used at several transit agencies in the US. But it was not until recently that interest in LVC has again grown with a flurry of new research and reports, a special issue on LVC led by Zhao and Levinson (2012), an edited volume about LVC strategies by Ingram and Hong (2012), a book on experiences with LVC by Mathur (2014) and signs of growing interest in LVC among planners and policymakers as an innovative way to generate revenue for new transit projects.

From this experience, a pertinent question to ask is whether the use of LVC is worth it in terms of return on investment. Because the potential revenues from LVC differ by the tool chosen, it this question is difficult to answer. Mathur (2014) demonstrates that localized LVC tools like TIF and SAD zones offer the greatest potential revenues and revenue stability. For example, SADs around the Los Angeles Red Line subway raised 9% of the cost of the $1.5 billion project.

More recently, SADs around the Silver Line in Virginia were approved by 64% of property owners and are estimated to raise up to $1 billion, or 1/6th of the cost of the project (MacCleery & Peterson, 2012). Similarly, SADs around Seattle's streetcar are estimated to raise $25.7 million, or more than half of the project's cost. In contrast, impact fees can raise significant revenue, but can be unpredictable due to trends in the real estate market. Transit joint development can potentially internalize all of a project's LVU benefits, but is more volatile due to the piecemeal nature of available projects, market trends, and a potential lack of public sector mandate or expertise.

Still, such evidence suggests that some LVC strategies can raise significant amounts of new funding for rapid transit, and in an age of fiscal restraint, any tool that is revenue positive should be considered. But no matter which strategy is chosen, previous research provides little guidance to planners and policymakers interested in LVC as to the LVU effects that can accrue from rapid transit accessibility and TOD around existing and future transit stations. The value planning framework seeks to remedy this by proposing a method for better conceptualizing the drivers of LVU, associating different contextual bundles with estimates of LVU around existing stations, and extending these estimates of total capturable benefits around future station areas.

5.3 VALUE PLANNING IN THEORY

A rapid transit project is typically evaluated in policy and planning through the use of benefits-cost analysis (BCA), which is focused on a holistic assessment of the many social, environmental, economic and other benefits offered by a project, and a financial analysis (FA), which is narrowly focused on a project's costs and revenues associated with factors such as construction costs and anticipated fare revenues. Value planning is a hybrid of these approaches, emphasizing methods for generating revenue from a project's larger benefits to society, benefits that are capitalized into the value of land through the mechanisms detailed below.

5.3.1 Theoretical Land Value Benefits of Rapid Transit

A rapid transit project offers many potential and well-known benefits, from decreases in travel time, congestion, and greenhouse gas emissions to increases in social welfare, land use development, and neighbourhood revitalization. Each of these benefits has some intrinsic 'value' to society. But in terms of value capture, value is conceptualized in a monetary sense. This naturally raises the question of how a dollar value can be ascribed to a reduction in greenhouse gases and extracted from the market. But rather than establish the value of such benefits directly, the localized nature of transit service means many of them are capitalized directly into the urban land market. In this sense, the value of land acts as a proxy for the many localized benefits of a transit project.

How does this occur? Higgins and Kanaroglou (2015a) argue that understanding the magnitude and spatial dispersion of a rapid transit project's potential LVU benefits requires the use of two theoretical frameworks. First is the AMM model, which postulates that increases in relative accessibility from rapid transit should reduce transportation costs and increase land values and pressures for higher-density development around stations.

However, a second and complimentary framework is that of Tiebout's sorting hypothesis, wherein individuals self-select their spatial location based on the match between their preferences and different bundles of public and private goods. In this sense, individuals with a preference for the type of higher-density, mixed-use, amenity-rich, and pedestrian friendly development promoted by transit-oriented land use planning can also result in price effects around particular transit stations. Likewise, other benefits of rapid transit such as lower pollution can also be considered an amenity around which people may sort themselves. Changes to zoning ordinances to permit TOD can also increase land values as such changes alter the potential profitability of a parcel relative to others.

Taken together, the type of integrated transportation and land use planning that has increasingly become the norm for new transit projects in North America lends itself to the potential for integrated and potentially self-reinforcing land value impacts from transit accessibility and TOD. Likewise, if the public policy surrounding a rapid transit investment can create such increases in LVU, it stands to reason that supportive policy can also help to shape these benefits and maximize the potential for LVC. Value planning understands this link and the mechanisms through which it can work. Such mechanisms will be discussed below in terms of key enablers and policy levers.

5.3.2 Key Enablers and Policy Levers

While a rapid transit project can offer many benefits, key enablers influence the existence and magnitude of these benefits. Similarly, key enablers are in turn influenced by the policy levers available to planners and policymakers to alter project benefits. Key enablers can be condensed into two families: transit accessibility and land use. In practice, both types of key enablers are related to one another within the urban system, with transportation accessibility informing land use, land use influencing activity patterns, and activity patterns shaping accessibility. However, for the sake of conceptual clarity, we consider them separately.

5.3.2.1 Transit Accessibility

Transportation accessibility key enablers include the speed of travel, travel cost, and level of service. All of these factors affect the magnitude of accessibility benefits offered by a rapid transit project and thus one aspect of its LVU benefits per the AMM model. But because transit competes against other modal options for by-choice riders, these benefits must also be understood in a relative sense. Policy levers that shape these benefits include design and operational decisions made during project planning, such as a separate transit right-of-way, priority signalling at traffic lights, station spacing and average speed, the cost of transit fares, and service frequency. Other measures that can influence the magnitude of rapid transit's accessibility benefits relative to other modes include transportation demand management initiatives such as time-of-day pricing and increasing the cost of parking.

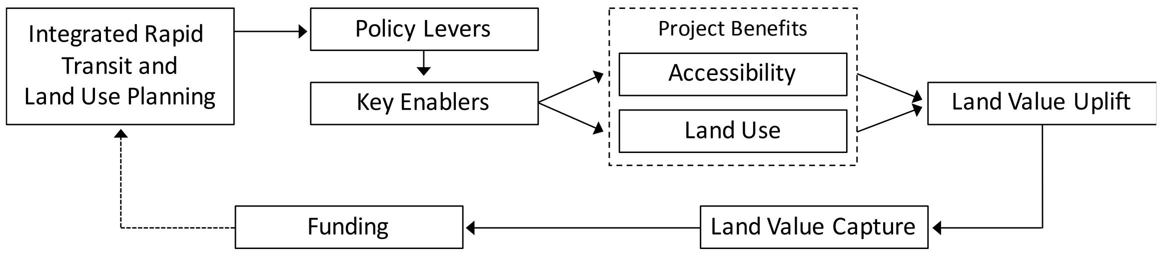
5.3.2.2 Transit-Oriented Development

Land use planning that promotes TOD can also increase the LVU effects of a rapid transit project. Land use key enablers are related to the 'D' variables of Ewing and Cervero (2010): density of development, diversity of land uses or development mix, urban design including the quality of space and pedestrian environment, and accessibility to destinations on the transit network. Each of these are affected by planning policy levers including zoning changes to permit higher densities and mixed-uses, reduced parking requirements, and the promotion of complete streets, as well as TOD design guidelines and density bonuses and other incentives. More programmatic initiatives that help TOD through assistance with financing or land assembly and other improvement grants can also help promote TOD. Such land use planning initiatives also stand to increase the competitive advantage of transit accessibility by reducing parking supply for automobiles and increasing the number of origins and destinations reachable by transit.

5.3.3 Conceptual Value Planning Framework

The conceptual value planning framework is presented in Figure 5-1. Here, integrated transit and land use planning associated with a new rapid transit project works through relevant policy levers to shape a project's key enablers. These key enablers in turn inform a project's transportation accessibility and land use benefits, which can result in LVU for parcels of land around a transit station. Rapid transit projects planned and constructed without consideration for LVC generally follow this process. But to recoup a portion of project costs, LVC tools can be used to generate funding that otherwise would have accrued to landowners around stations.

Figure 5-1. Conceptual Rapid Transit Value Planning Framework



Source: adapted from Harrison et al. (2014)

Value planning takes LVC a step further by closing the loop between LVC funding and project planning, with public policy consciously used in such a way that it maximizes project benefits and LVC revenues. Policy levers are used to unlock key enablers and maximize accessibility and TOD benefits, creating a positive feedback loop that can further drive up the LVU effects of transit and potential capturable revenues.

Note that as argued in the introduction, the conceptual argument for LVC associated with transit accessibility is clear. What is less clear is the rationale for engaging in LVC based on value uplift associated with transit-oriented land use planning. One argument here is that public policy interventions that permit TOD factors such as higher-densities can also increase the value of land within a defined area, much like transit accessibility. In particular, this is likely to be the case in urban markets where zoning constrains TOD, potentially leading to pend-up demand for such development. However, as the next section will demonstrate, the scale and magnitude of LVU caused by land use planning alone remains unknown.

5.4 A FRAMEWORK FOR ESTIMATING FUTURE LVU

While the basic value planning framework is outlined in Figure 5-1, a successful implementation of LVC still requires advance knowledge of a project's potential LVU impacts from transit accessibility and land use planning benefits. One solution is to adopt uplift coefficients from other studies to arrive at an approximation of total aggregate LVU. But as noted in the introduction, previous research in this area has proceeded in such a way that the context of a particular study area is central to its outcomes. This is because factors such as the accessibility benefits of transit relative to other options are not directly modelled, and because the price effects of transit-oriented land use have largely been left uncontrolled. As a consequence, the characteristics of these models largely negate the ability to apply previously estimated uplift coefficients to future transit projects and station areas.

In an effort to remedy some of these issues, Higgins and Kanaroglou (2015c) attempted to unbundle the hedonic price effects of transit accessibility and individual sorting into different TOD submarkets around a sample of subway stations in the City of Toronto. Station area TOD was controlled through the incorporation of a latent class typology of transit station area contexts estimated previously in Higgins and Kanaroglou (2015b). Using model interactions, the authors controlled for base levels of transit accessibility across all stations and any additional spatial effects that may result from sorting into different bundles of transit and TOD.

While such results are interesting in terms of finding evidence of heterogeneous drivers of LVU around existing stations, this approach provides a foundation for more empirical estimations of LVC in future station areas. Assuming contextual accessibility and TOD characteristics are controlled for in the TOD typology, and that their implicit price is revealed in previous hedonic models, this method can be extended to similar future station areas to derive more context-sensitive and empirical estimations of potential LVU and LVC within them. Furthermore, existing conditions can be used as a benchmark against which assessments of present key enablers and potential policy interventions can be based.

5.4.1 Land Value Uplift: More Unknown than Known

Recognizing the heterogeneity in station contexts along existing and future rapid transit lines, Table 5-1 adopts the TOD typology approach to associate uplift coefficients to station types. For simplicity, the number of station types is collapsed from 10 in Higgins and Kanaroglou (2015b) to the 4 most relevant types for LVC. By controlling for local context, this typology approach permits a more empirical application of uplift coefficients for different transit accessibility and TOD contexts from previous studies to similar station area contexts along future transit lines. Note while we have omitted information on the decay in these coefficients over space for the sake of simplicity, this is also crucial for predictions of LVC in future study areas and should be displayed in a companion table.

Still, looking at Table 5-1, it is clear that despite more than 40 years of research into the LVU effects of rapid transit, significant gaps in our knowledge of the potential uplift in future station areas remain. While the exercise above has noted existing conditions that stand to enable or constrain the LVU effects of the project and the key policy levers that can be used to maximize LVU, the actual value placed on these characteristics is largely unknown. This is because previous research has considered the LVU effects of both TOD and transit access simultaneously in a single bundle. As station context was not explicitly controlled for in a similar fashion to the TOD typology, the lack of context sensitivity in these studies means the uplift coefficients cannot be linked to the typology in any consistent manner.

Only the previous study by Higgins and Kanaroglou (2015c) has attempted to unbundle the simultaneous LVU effects of rapid transit and TOD, though their use of distance as a proxy for transit accessibility means they only achieved a partial unbundling of these effects. No research to date has been able to completely unbundle the LVU effects of TOD and transit accessibility. Furthermore, their research also leaves some comparative ambiguity in applying previous outcomes to LVC in future study areas. This is because the indirect specification of accessibility offers no direct information on the comparative performance of rapid transit against the private automobile for trips.

Furthermore, as only a cross section, the study does not reveal any changes in value placed on transit access or TOD submarkets over time. More research will be required to isolate any differences in value placed on these characteristics over the life of a project from announcement to construction and operations. This could be accomplished through a longitudinal study of LVU that estimates uplift from transit accessibility and TOD in many station types across several cities.

Table 5-1. Land Value Uplift Matrix

	Urban Centre				Urban Neighbourhood				Suburban Neighbourhood				Outer Suburban Neighbourhood			
Land Use Maximum Uplift Amount	HRT	LRT	BRT	CRT	HRT	LRT	BRT	CRT	HRT	LRT	BRT	CRT	HRT	LRT	BRT	CRT
Single Detached																
Partially Unbundled																
Transit Access. Only	-	-	-	-	*ns*	-	-	-	*ns*	-	-	*ns*	-	-	-	-
TOD + Transit Access.	-	-	-	-	18%	-	-	-	67%	-	-	17%	-	-	-	-
Fully Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Condominium																
Partially Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD + Transit Access.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fully Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Commercial																
Partially Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD + Transit Access.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fully Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vacant / Parking																
Partially Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD + Transit Access.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fully Unbundled																
Transit Access. Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOD Only	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes: -: not available; *ns*: not significant

5.5 CONCLUSION AND FUTURE DIRECTIONS

When public projects create localized land value benefits for private land owners, there is a rationale for the public sector to recapture some of this 'unearned increment.' Through tools such as TIFs, SADs, and joint development, LVC can be an important mechanism for raising additional funds for rapid transit infrastructure.

However, if LVC tools are to be both socially equitable and economically efficient, some idea of a project's prospective LVU benefits must be known before construction, or potentially even prior to alignment and station locations becoming public knowledge. To that end, Smith and Gihring argued that research should focus more on practical applications that close the loop between hypothesis testing of LVU in station areas to enable greater LVC.

But recent research has revealed joint LVU effects associated with rapid transit accessibility and transit-oriented land use planning and much of a large body of previous work in this area has been insensitive to such contextual factors within individual station areas. For the purposes of LVC around future stations, this means the amount and spatial distribution of potential LVU impacts associated with transit accessibility and TOD in particular contexts remains largely unknown.

In response, the present paper has proposed a value planning framework that can not only enable more empirical predictions of LVU, but maximize them through public policy. Nevertheless, the matrix of LVU coefficients for predicting LVC in future station areas is at present incomplete. As such, the paper presents a call for future study, one that can help ensure research in this area proceeds in a way that not only tests the hypothesis of LVU, but results in findings that can better inform the potential for LVC from future projects based on existing key enablers and potential policy interventions.

From this, for research to progress in this area it must begin to answer questions such as:

- How much LVU does a project create for different types of land use?
- How much of a discount in LVU exists between transit accessibility from a heavy rail subway compared to LRT for the same property types? How does this change across different station types? What is the decay in LVU over distance?
- How much is sorting into different bundles of TOD affecting land values? Furthermore, is TOD-related LVU separate from, or simultaneous to transit accessibility?
- What antecedent value is already present from individuals sorting themselves into different built environment submarkets in advance of rapid transit?
- Which LVC tools are most appropriate to recapture this LVU? Does the imposition of LVC tools reduce opportunities for land use change?
- What is the rationale for capturing the portion of station area LVU that accrues from transit-oriented land use planning?

To begin to answer these questions, research should adopt the typology approach and seek to fill in the gaps presented in the matrix of uplift values in Table 5-1. Rapid transit accessibility benefits and TOD should be separately specified to isolate their simultaneous LVU impacts. Furthermore, to estimate the absolute and relative accessibility benefits of rapid transit, generalized transportation cost measures should be used instead of operationalizing proximity as a proxy for accessibility. Finally, longitudinal studies can reveal changes in these values before, during construction, at operation, and at maturity for a transit project.

Still, even with these strategies, important knowledge gaps will continue to remain in our knowledge about LVU and LVC in station areas. This is due to shortcomings related to modelling assumptions, where additional factors implicit to the model erode strict comparability between different contexts. For example, factors implicit in a model of existing LVU include broader changes in individual preferences that place a value on transit access and TOD, as well as demographic larger trends that influence the impact of these preferences in the urban market. As such, despite better controlling for local context through the TOD typology, some factors will still be embedded within a study's findings and negate direct comparability.

Nevertheless, only in answering the questions posed above can researchers begin to heed the call of Smith and Gihring (2006) to move research on the LVU effects of rapid transit from hypothesis to application and support the capture of additional, and potentially significant amounts of revenue to finance rapid transit.

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CHAPTER 6

RAPID TRANSIT VALUE PLANNING IN PRACTICE: POTENTIAL VALUE UPLIFT AND CAPTURE FROM LIGHT RAIL TRANSIT IN HAMILTON, ONTARIO

ABSTRACT

Value planning for rapid transit involves the explicit recognition of the ways in which public policy interventions can influence the magnitude of a project's land value uplift (LVU) benefits and capturable revenues through the use of land value capture tools. While significant gaps remain in our knowledge of the LVU that accrues from rapid transit accessibility and transit-oriented development in different station contexts, the present paper offers a hypothetical application of value planning to the case of a future light rail transit line in Hamilton, Ontario. Assessments of the project's current transportation and land use key enablers are combined with potential policy interventions that maximize these key enablers to create three value planning scenarios. Using spatial hedonic models, levels of antecedent LVU are analyzed to establish benchmark measures of land values in advance of rapid transit. Next, using a database of parcel-level assessed values, uplift coefficients are applied to properties within different station area contexts. Results reveal that total aggregate LVU can range between 6% to 25% of total project costs, providing an attractive rationale for engaging in greater value planning in Hamilton and other cities in North America and around the world.

6.1 INTRODUCTION

Value planning for rapid transit involves not only the use of land value capture (LVC) to raise additional funding, but an explicit recognition of the ways in which public policy can increase the land value uplift (LVU) benefits of a transit project and maximize capturable revenues. Previous research by Higgins and Kanaroglou (2015d) has detailed a conceptual value planning framework that works from transit accessibility and transit-oriented development (TOD) key enablers that inform a rapid transit project's LVU benefits, as well as the policy levers or planning interventions that can be used to shape these benefits. The paper also outlines a work plan for producing research that can offer better information about the amount and spatial distribution of LVU benefits within particular transit station area contexts. By extension, this approach also permits more empirical estimates of potential LVU in future station areas with similar contextual environments.

The goal of the present paper is to demonstrate the potential utility of value planning as a policy and planning approach. Using the case of a light rail transit (LRT) line in planning in Hamilton, Ontario, the paper offers a hypothetical value planning exercise that seeks to derive context-sensitive estimations of potential total aggregate LVU in station areas according to several planning scenarios. While hypothetical, this exercise offers a rationale for further engaging in LVC as part of the rapid transit planning process and offers information that can be used to inform local LVC strategies.

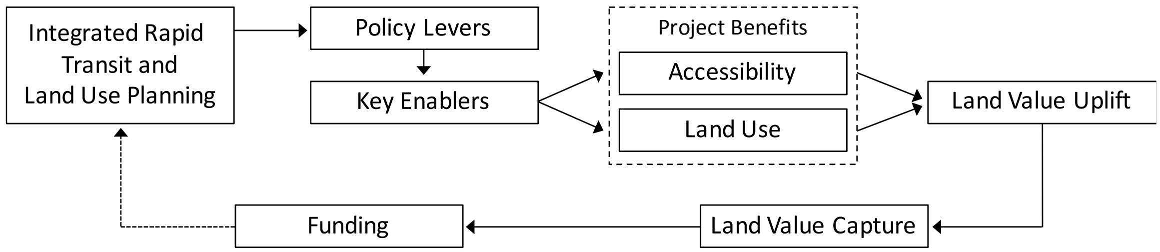
To proceed, we first offer background on the value planning framework followed by an examination of strengths and weaknesses in present key enablers of LVU benefits along the line. Next, we examine potential policy levers that can be used to maximize these benefits. Finally, we conduct spatial hedonic regression models to establish baseline conditions and use assessed values along the corridor to engage in an exercise that examines hypothetical LVU according to three planning scenarios. Results indicate that total aggregate uplift can potentially reflect a significant portion of project costs.

6.2 VALUE PLANNING IN THEORY

A rapid transit project and associated TOD land use planning can confer many social, economic, and environmental benefits, from decreases in travel time and emissions and the promotion of higher density, mixed-use, and pedestrian friendly development. But because of the nature of transit service, many of these benefits are localized within transit corridors and station catchment areas. As argued by Higgins and Kanaroglou (2015a), this can in turn result in higher prices for locations within these areas as individuals sort themselves into locations with greater transit accessibility and lower overall transportation costs as well as high levels of transit-oriented amenities and opportunities to express particular lifestyle choices.

But because any increases in land values that result from a significant public investment typically accrue to private land owners, there is a rationale to engage in LVC to recoup some of this localized value increase to pay larger public costs. This process of LVC is depicted in Figure 5-1. Here a project's policy levers shape the key enablers that influence a project's land use and transit accessibility benefits. Such benefits can then lead to changes in land values in station areas that can be captured through LVC.

Figure 6-1. Conceptual Rapid Transit Value Planning Framework



Source: Higgins and Kanaroglou (2015d)

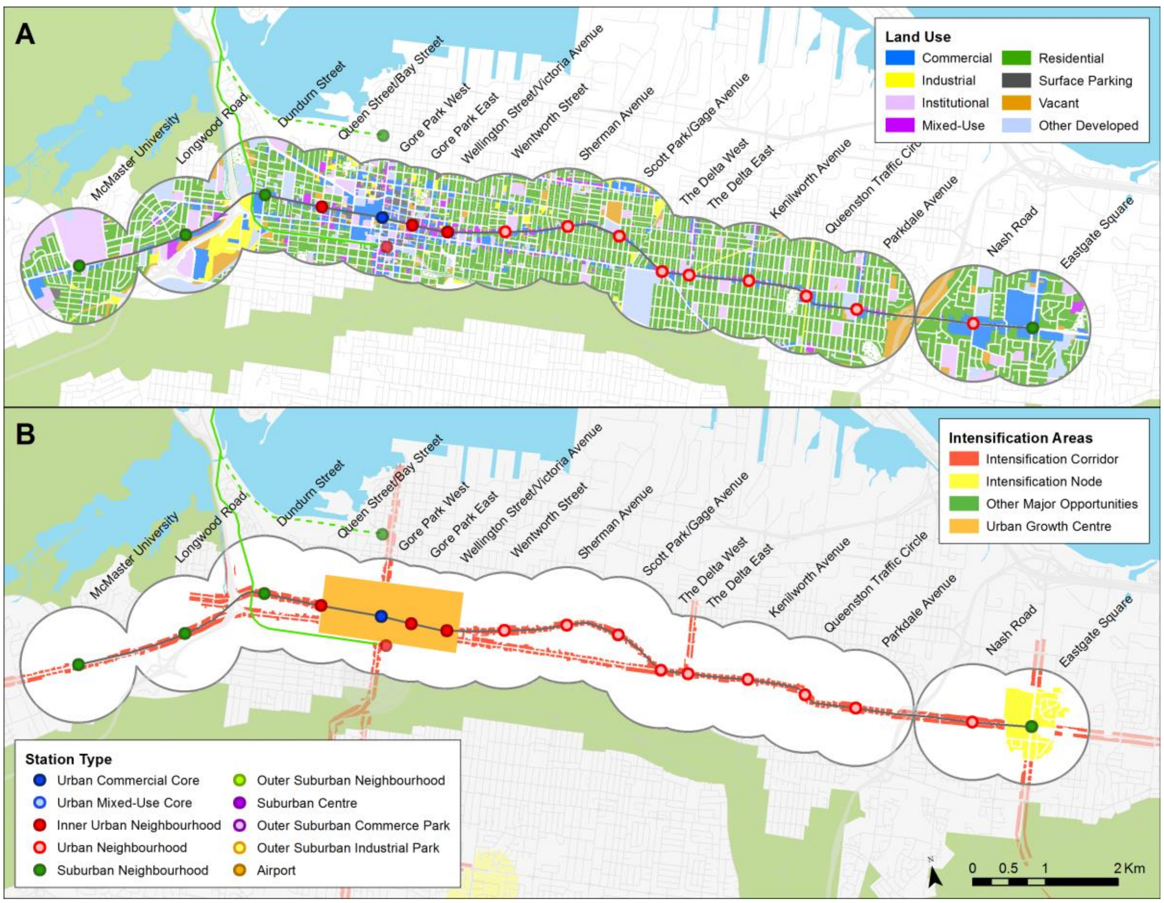
Value planning takes this process of LVC further by closing the loop between LVC and project planning. Existing conditions within a transit station area and the characteristics of the transit service can impact the scale of a project's potential LVU. However, policy interventions that improve existing conditions and increase benefits also stand to increase LVU, and thus a project's total capturable value impact. In essence, value planning constitutes a conscious recognition of the impacts of public policy interventions associated with rapid transit and TOD planning and uses them to create a positive feedback loop that can maximize a project's benefits and LVC revenues.

To demonstrate the potential of the value planning framework, the remainder of this paper turns to a case study application of the approach to explore the potential LVU benefits of transit accessibility and TOD in station areas along a planned LRT line in Hamilton, Ontario.

6.3 VALUE PLANNING IN PRACTICE: LRT IN HAMILTON

The Hamilton LRT is a planned 14km line estimated to cost approximately $1 billion (CAD). The line would travel east-west and connect McMaster University with the city's central business district and the Eastgate Square mall (Figure 6-2). To arrive at estimates of total potential capturable LVU, we first discuss existing conditions through key enablers and constraints and potential policy interventions. This information is then used to derive three uplift scenarios.

Figure 6-2. Land Use (A) and Intensification Areas (B) along the Prospective Hamilton LRT



6.3.1 Transportation Key Enablers and Constraints

6.3.1.1 Speed, Cost, and Level of Service

The LRT is projected to achieve average speeds of 33-35 kilometres per hour with a service frequency of 4 minutes. End-to-end travel time is estimated at 26 minutes with supportive transit signal priority/pre-emption measures. The preliminary benefits case from regional transportation planning agency Metrolinx (2010) argues that such speeds are crucial for achieving travel time savings, which are themselves central to achieving approximately $748 million in benefits for transit users and automobile drivers.

However, one constraint to the achievement of these benefits is Hamilton's extensive network of one-way streets. Coinciding with the removal of Hamilton's electric streetcars in the 1950s, traffic planners enacted a large-scale conversion of many of the city's main roads into one-way, high-speed, and multi-lane arterials designed to expedite automobile travel to and from the City's downtown and north-end industrial core. Today, a system of timed traffic signals and multi-lane thoroughfares continues to allow automobiles to travel parallel to the LRT corridor with relative ease.

Metrolinx (2010) took note of these characteristics and worked from an assumption of two-way street conversions in tandem with the LRT project. However, local planners and policymakers have at present withdrawn this element from the LRT planning process. While rapid transit will remove two westbound lanes from this network, alternative westbound one-way routes are designed to carry some of this redirected traffic flow. These planning decisions stand to erode the travel time and comparative accessibility benefits of rapid transit versus the private automobile.

Alongside the one-way network, the downtown core also features an abundance of cheap parking for automobiles, with approximately 25 percent of the land area of downtown dedicated to surface parking. While this is primarily a land use issue, it also erodes the comparative accessibility benefits of rapid transit for travel to these areas.

6.3.2 Land Use Key Enablers and Constraints

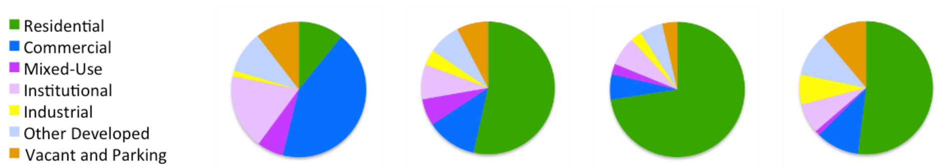
6.3.2.1 Station Area TOD Typology

According to the TOD typology estimated in Higgins and Kanaroglou (2015b), there are four types of station areas on the B-Line LRT corridor: 1 *Urban Commercial Core*, 3 *Inner Urban Neighbourhoods*, 9 *Urban Neighbourhoods*, and 4 *Suburban Neighbourhoods*. Table 6-1 displays latent class model output for these station types. Here it can be seen that the *Urban Commercial Core* station type features the highest proportions of commercial land use, very high density development, high levels of accessibility, walkability, and employment orientation as measured by development mix. This station will primarily serve the City of Hamilton's central business district.

From this, neighbourhood-type stations generally progress from urban to suburban, with *Inner Urban Neighbourhoods* featuring highest densities and levels of mixed-use development and *Suburban Neighbourhoods* exhibiting lower overall densities, accessibility, and walking connectivity.

Table 6-1. Hamilton LRT Prospective Station Types

TOD Measure (Average)	Urban Commercial Core	Inner Urban Neighbourhood	Urban Neighbourhood	Suburban Neighbourhood	Class Variance (Average)
Accessibility					
Interaction Potential	19.57*** (26%)	17.61*** (12%)	16.48*** (5%)	14.94*** (-5%)	1.54*** (15.67)
Land Use					
Normalized Density	501*** (468%)	112*** (27%)	68*** (-23%)	41*** (-53%)	1.34*** (88)
Development Mix	0.83*** (112%)	0.34*** (-13%)	0.18*** (-54%)	0.28*** (-28%)	0.03*** (0.39)
Walk Connectivity	0.61*** (28%)	0.56*** (18%)	0.55*** (15%)	0.45*** (-5%)	0.01*** (0.48)
Land Use Mix					
Residential	0.10*** (-75%)	0.49*** (16%)	0.67*** (63%)	0.44*** (7%)	0.01*** (0.41)
Commercial/ Institutional	0.57*** (216%)	0.19*** (5%)	0.12*** (-34%)	0.15*** (-16%)	0.01*** (0.18)
Mixed-Use	0.06*** (152%)	0.06*** (139%)	0.02*** (-3%)	0.01*** (-44%)	0.00*** (0.02)
Industrial	0.01*** (-88%)	0.04*** (-64%)	0.02*** (-80%)	0.06*** (-54%)	0.01*** (0.11)
Land Use Overview					



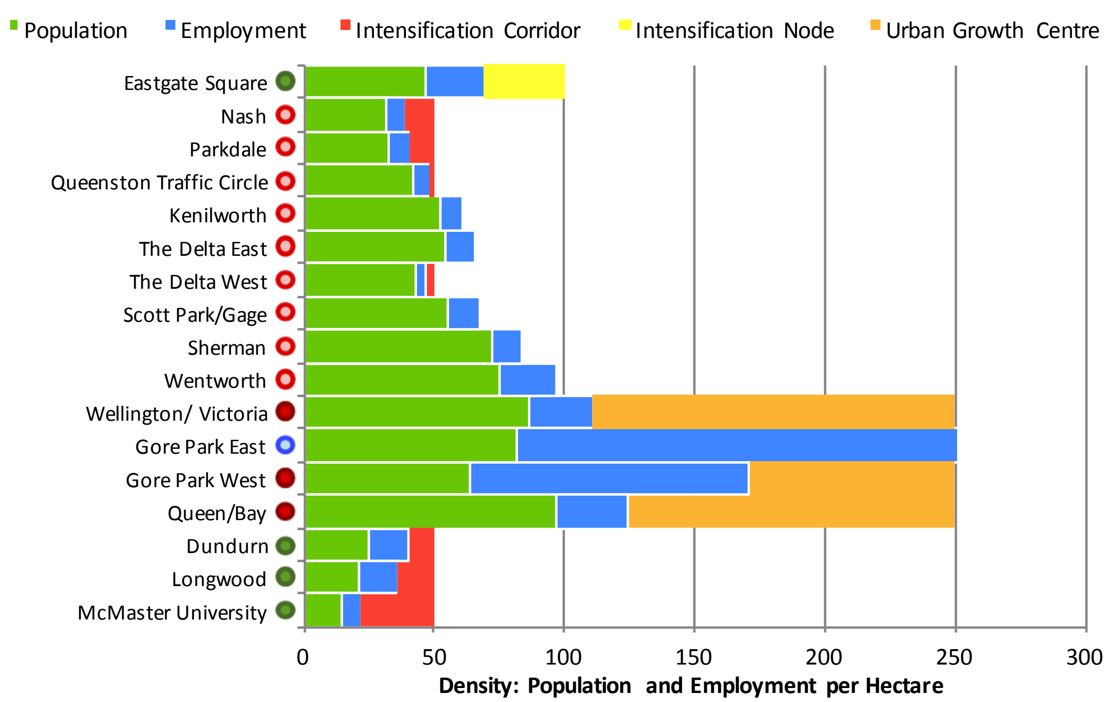
Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller

6.3.2.2 Station-Specific Densities

While the typology gives a broad overview of station types, densities in individual stations along the corridor vary (Figure 6-3). The general pattern along the line sees densities of employment and population peaking around the central business district at Gore Park West station. Outside of the downtown core, the line travels through many higher-density *Urban Neighbourhoods*. At both ends of the line the built environment becomes more suburban in character. Note that the particular dataset used to gauge employment totals in station areas appears to under-represent employment in post-secondary institutions. As such, the McMaster University station is likely higher than reported here.

Such densities appear favourable to rapid transit. However, Figure 6-3 also displays intensification targets for each station area, suggesting that there are a few areas that can benefit from specific measures to increase localized population and employment. This is a topic we explore further in the policy levers below.

Figure 6-3. Station-Specific Densities and Intensification Targets



6.3.2.3 Quality of Space

The eastern sections of the B-Line LRT corridor are affected by a number of social and demographic challenges that can affect redevelopment potential (DeLuca et al., 2012). Current physical conditions in many prospective station areas along the central and eastern sections of the B-Line corridor reflect these challenges and present obstacles to their attractiveness to developers, financers, and potential buyers of new TOD projects. Nevertheless, the western end of the corridor and downtown core have seen large increases in property values over the past several years. New investment and the revitalization of housing stock continues in these areas and construction of several commercial, condominium, and institutional projects is presently underway in the downtown core, reflecting its increasing attractiveness for developers and homeowners.

6.3.2.4 Redevelopment Potential

The B-Line LRT corridor does have a large amount of land available to facilitate continued development and redevelopment. The Canadian Urban Institute (2010) has estimated that there are more than 500 vacant parcels totalling 243 hectares located within a two-km radius of the proposed line, much of which consists of parking lots or vacant residential properties in the central and eastern sections. This total includes a significant amount of industrial brownfield land (115 hectares), but these parcels are generally located far from the corridor in the city's industrial north end. Excluding brownfield sites, there are 128 hectares available for development. For parking, the City of Hamilton owns 18 lots in the downtown core with more privately held, and the vast majority of these are located in the downtown core within 800 metres of the proposed LRT line. As such, there is a considerable amount of available land that will not require land assembly or expensive environmental remediation.

6.3.3 Transportation Policy Levers

6.3.3.1 Transit Signal Pre-emption

The benefits case identified transit signal pre-emption as critical to achieve projected operating speeds. As such, ensuring transit signal pre-emption and not just signal priority for the LRT is a key policy lever that the City of Hamilton can use to increase the accessibility benefits of the line and from this, the LVU generated from the project.

6.3.3.2 Two-Way Streets

Beyond signal pre-emption, if the one-way network remains intact, the ease of automobile travel along the LRT corridor will stand to reduce the competitive advantage of LRT in general and the locational advantage bestowed to land around future LRT stations more specifically. These factors should be expected to have a negative effect on LVU in LRT station areas. In response, two-way conversions should be given priority along with general streetscape and design improvements that make the built environment more welcoming and conducive to walking and transit use. The cost of such conversions could potentially be recouped through LVC.

6.3.4 Land Use Policy Levers

6.3.4.1 Zoning

Under regional planning initiatives enacted by the Province of Ontario, the City of Hamilton is mandated to achieve particular density targets. Existing intensification nodes and corridors along the LRT route are shown in panel B of Figure 6-2. The city's downtown Urban Growth Centre for example is designated to increase its density to a level of 250 people and jobs per hectare by 2031. No specific density targets for Intensification Nodes and Intensification Corridors are delineated by the province, but for the purposes of this exercise they are assumed to be levels of 100 and 50 people and jobs per hectare respectively.

From Figure 6-3, contrasting existing densities with these targets it can be seen that some station areas achieve targets, but others fall short. As such, an important policy lever for ensuring the B-Line corridor develops to become even more transit-oriented is to enact land use planning policies that strengthen the land use key enablers. To that end, the city has prepared draft corridor planning principles and design guidelines to this effect. But to have the largest impact, changes to zoning that permit higher densities, promote mixed uses and complete streets, and reduce automobile parking requirements should be enacted in the near term in advance of LRT.

In addition to creating a more dense transit corridor, such measures can also create higher quality implementations of TOD that strengthen the appeal of locations around transit stations. Furthermore, as the next section will detail, zoning changes can also reduce parking supply to positively affect transit accessibility.

6.3.4.2 Parking Supply

Hamilton's downtown core features a large amount of land dedicated to surface parking, which erodes the attractiveness of using transit to travel to this important destination. Surface parking lots do present an opportunity for new development, and Metrolinx (2010, p. 12) argues that as intensification in the downtown continues,

> "it is anticipated that the current supply of parking in the urban core will decrease while the cost of the remaining stalls increases, thus providing an additional incentive to find an alternative to the automobile."

However, to fully maximize the potential of transit, part of the city's land use planning initiatives should include minimizing parking in the downtown core and restricting parking supply for new development by instituting parking maximum standards as part of a comprehensive transit-oriented land use plan for the B-Line corridor.

6.4 POTENTIAL LAND VALUE UPLIFT

The benefits case prepared by Metrolinx estimated uplift of 2-4% for residential and commercial properties within a 500 m radius of stations and of 8-14% for vacant commercial properties. Industrial and institutional properties were assumed to not see any LVU. From this, the total capturable land value impact attributable to the line is estimated at between \$50 million on the low end to \$144 million on the high end. However, to demonstrate the potential of the value planning framework, we utilize parcel assessment data to provide a more detailed analysis of LVU as it pertains to different uplift scenarios for the B-Line LRT in Hamilton.

6.4.1 Existing Uplift

To assess potential LVU that may accrue from rapid transit and TOD, it is useful to first establish a baseline by examining whether any land value trends are presently occurring in future station areas. To accomplish this, we perform spatial hedonic regressions on a dataset of real estate transactions for single-detached homes that occurred between 2001 and 2004 located within 1km of the prospective LRT corridor. Because public planning for the B-Line LRT did not begin until 2007, this dataset provides a reference case against which future changes can be assessed.

6.4.1.1 Methods, Descriptive Statistics, and Model Results

Methods and data are similar to that in Higgins and Kanaroglou (2015c), including structural, neighbourhood, regional accessibility, and temporal control variables. However, this particular dataset has a reduced number of structural variables, with only the structure's age, parcel size and the total floor area available to represent the characteristics of the house. All homes are within 1 kilometre of the B-Line LRT corridor. Descriptive statistics are displayed in Table 6-2.

The first model adopts a traditional model structure, examining the relationship between sale price and proximity to future B-Line LRT stations. Model 2 expands on this by including an interaction term that isolates any price effects for properties within walking distance of any future station. To test the significance of the relationship between sale price and a location within different station TOD submarkets, Model 3 includes interaction specifications based on the TOD typology from Higgins and Kanaroglou (2015b).

Table 6-2 Descriptive Statistics

Variable	*Mean (Prop.)*	*Std. Dev.*
Sale Price ($)	136,477.15	55,043.86
Transit Proximity and TOD		
Station Distance (metres)	580.85	240.26
10-Minute Walk (0-1)	(0.57)	
10-Minute Walk * Station Distance	410.74	142.58
Urban Commercial Core (0-1)	(0.00)	
Urban Commercial Core * Station Distance	525.40	81.23
Inner Urban Neighbourhood (0-1)	(0.05)	
Inner Urban Neighbourhood * Station Distance	460.16	133.35
Urban Neighbourhood (0-1)	(0.41)	
Urban Neighbourhood * Station Distance	399.34	140.56
Suburban Neighbourhood (0-1)	(0.11)	
Suburban Neighbourhood * Station Distance	429.97	147.47
GO Suburb. Neighbourhood (0-1)	(0.01)	
GO Suburban Neighbourhood * Station Distance	360.84	240.55
Structural Characteristics		
Structure Age (years)	77.41	22.40
Lot Area (metres^2)	314.42	161.01
Floor Area (feet^2)	1,264.04	413.16
Median Household Income ($)	43,228.28	17,386.28
Distance to nearest School (metres)	298.94	139.31
Distance to nearest Park (metres)	270.07	176.49
Distance to Heavy Industry (metres)	1,156.02	619.89
Regional Accessibility		
Employment Interaction Potential	14.93	0.70
Quarter of Sale		
Omitted for Brevity (0-1)		
N		5,137

Are existing transit accessibility and TOD being capitalized into home values in advance of LRT? Results for Models 1 and 2 show no statistically significant price effects for proximity to any future transit station (Table 6-3). Likewise, Model 3, the most completely specified model, reveals that in most cases, locations within different types of LRT stations did not have any statistically significant land value effect, nor did proximity to the city's existing commuter rail station south of the central business district (CBD). The exceptions are locations within the *Urban Commercial Core* and *Suburban Neighbourhood* submarkets, where prices are roughly 83% lower, but only at the 10% significance level, and 21% higher than the reference group of homes respectively. The reference group consists of homes within 1 kilometre of the LRT corridor, but not within walking distance of a future station. Still, other than an apparent disamenity for immediate proximity to the CBD, the proximity variable that controls for distance to all stations and individual station types is insignificant.

There are of course limitations to this analysis based on the age of the data, its cross-sectional study design, a lack of comprehensive structural attributes, and the analysis of only single-detached homes. But the analysis nevertheless suggests that prices within the central corridor are generally flat respective to any amenity offered by existing bus transit and commuter rail service and built environment characteristics, providing a conceptual foundation on which any LVU effects that arise from the project can now be attributed to project implementation.

Still, a secondary issue concerns the price effects of TOD. The lack of an accessibility effect is consistent with theory given the LRT line did not exist during the study timeframe. However, locations within other TOD submarkets could have led to positive and significant LVU effects even without LRT. This prompts a question of 'when does TOD become TOD?' Can a TOD submarket exist prior to rapid transit? Or does transit unlock an area's potential? It seems plausible that the limited access point of a transit station can create a concentration of activity around the station that did not previously exist at the same level, a concentration that in turn can alter more qualitative aspects of TOD not captured by the typology such as different types of urban amenities and like-minded individuals. However, confirming such a hypothesis cannot be accomplished by the present paper and is an avenue for further research.

Table 6-3. LRT Corridor Spatial Hedonic Model Results (2001-2004)

	Model 1	Model 2	Model 3
Variable	*Coefficient*	*Coefficient*	*Coefficient*
Transit Proximity and TOD			
Station Distance	0.000016	0.000068	0.000044
10-Minute Walk (0-1)	-	0.056678	-
10-Min. Walk * Station Dist.	-	-0.000089	-
Urban Comm. Core (0-1)	-	-	-1.803284 *
Urb. Com Core * Station Dist.	-	-	0.003601 *
Inner Urban Nhbd. (0-1)	-	-	0.127826
Inner Urban * Station Dist.	-	-	-0.000232
Urban Nhbd. (0-1)	-	-	0.001126
Urban Nhbd. * Station Dist.	-	-	-0.000082
Suburban Nhbd. (0-1)	-	-	0.190653 ***
Suburb. Nhbd. * Station Dist.	-	-	-0.000115
GO Suburb. Nhbd. (0-1)	0.297413	0.304552	0.406787
GO Sub. Nhbd. * Stn. Dist.	-0.000466	-0.000477	-0.000690
Structural Characteristics			
Structure Age	-0.007075 ***	-0.007079 ***	-0.006478 ***
Structure Age^2	0.000024 ***	0.000024 ***	0.000020 ***
Lot Area	0.000271 ***	0.000270 ***	0.000254 ***
Floor Area	0.000271 ***	0.000271 ***	0.000270 ***
Neighbourhood and Regional Accessibility Characteristics			
Median Household Income	0.000003 ***	0.000003 ***	0.000003 ***
Distance from nearest School	-0.000036	-0.000043	-0.000051 *
Distance from nearest Park	-0.000008	-0.000010	-0.000012
Dist. from Industrial Core	0.000033 ***	0.000034 ***	0.000042 ***
Emp. Interaction Potential	-0.005716	-0.006090	-0.001273
Quarter of Sale			
Omitted for Brevity			
Constant	7.097093 ***	7.075443 ***	7.141156 ***
W_lnSalePrice	0.397487 ***	0.396318 ***	0.384753 ***
Lambda	0.496928 ***	0.498311 ***	0.378763 ***
N	5,137	5,137	5,137
Pseudo-R^2	0.741	0.741	0.759

Notes: * indicates statistical significance at the .10% level, ** at the .05% level, and *** at the .01% level or smaller

6.4.2 Illustrative Aggregate LVU Analysis

Estimation of a project's total potential LVU requires the value of each parcel within a station area, and one way to obtain such information is through municipal tax assessment rolls. In the Ontario context, this data is typically difficult and costly to obtain. However, the authors have access to an assessment database for the City of Hamilton for the year 2003 which we use to estimate aggregate uplift totals. To prepare the data, we first inflated assessed values to 2014 dollars using a house price index for the City of Hamilton. From July 2003 to September 2014, real estate values across the city have risen by approximately 78%. From this, the corridor contains a total of $8.5 billion in tax assessment within 800 metres of future B-Line LRT stations.

To estimate potential LVU from the project, these data were joined to a GIS parcel database and distances to the nearest future B-Line LRT station were calculated. Finally, assessed values were multiplied by LVU coefficients, which are assumed to decay at the same rate seen in the econometric analysis of station areas in Toronto in Higgins and Kanaroglou (2015c). For example, maximum LVU of 4% in a Suburban Neighbourhood for a home next to the LRT station will dissipate to 0% at a distance of 550 metres. For the analysis we have grouped assessed values into four broad classes: single-detached residential, condominium, commercial, and vacant.

To illustrate the value planning framework, we construct three uplift scenarios. The first is based on existing key enablers present along the B-Line corridor. Here we adopt similar uplift amounts to that used by Metrolinx, but use low-end estimates based on maintaining the city's network of one-way streets and a lack of planning changes to promote TOD. The second scenario adopts a normative approach, hypothesizing that policy levers are used to convert the one-way street network to two ways, which should increase the transport cost performance of rapid transit relative to the automobile. Furthermore, modest improvements to transit-oriented land use planning are made to promote some redevelopment in station areas and the downtown core.

Finally, the third scenario bases its assumption on a two-way street conversion, increasing intensification in the downtown core that reduces parking supply, and comprehensive land use planning and urban design measures that provide increased levels of TOD, land use mixing, and a greater distribution of employment and population along the line. With these initiatives in place, we adopt high-end estimates of LVU reflecting a transit-competitive corridor with high levels of amenity-rich TOD. In all three cases, the LVU amounts consider effects from transit access and TOD simultaneously. Future research should seek to further unbundle these amounts to facilitate a greater understanding of their contributions to total aggregate uplift and potential value capture.

From here, the question is what types of LVU coefficients will be adopted to represent such scenarios. Previous research by Higgins and Kanaroglou (2015d) exposed a present lack of information on the amount and spatial decay of LVU associated with different packages of transit accessibility and TOD suitable to be used for context-sensitive predictions of LVU in future station areas. Because of this, we must revert to more qualitative and bundled assumptions of value uplift associated with the case study's existing key enablers and potential policy interventions.

Hypothetical LVU coefficients are presented in Table 6-4. Here it can be seen that maximum LVU coefficients range from modest or non-existent in Scenario 1 to large in Scenario 3. However, as the review of more than 100 studies by Higgins and Kanaroglou (2015a) shows, even the optimistic assumptions in Scenario 3 have been found in practice in previous research, though again these studies considered the LVU effects of transit accessibility and TOD simultaneously. More accurate estimates of potential LVU rely on greater research conducted in line with the directions outlined by Higgins and Kanaroglou (2015d).

Still, to continue with the exercise, Table 6-4 presents total aggregate LVU by station area and property type. Among all property types, the results range from a low of $61.83 million to a high of $261 million in total aggregate capturable LVU benefits. Single-detached and commercial property types within the corridor are the largest contributors to total aggregate LVU, which suggests that LVC tools should target both to maximize value capture. In contrast, the small amounts of condominiums and vacant land or land dedicated to surface parking is small, though this is reflective of the city's built environment in 2003.

Nevertheless, with an estimated project cost of $1 billion, LVU estimates range from 6% to more than one-quarter of total cost for Scenarios 1 and 3 respectively. Furthermore, this analysis considers only land uses that already existed in 2003 and certainly changes have occurred in that time. But more importantly, this analysis only considers a static estimate of taxable assessment. If rapid transit and TOD land use planning spur greater development and redevelopment that results in the construction of more residential and condominium units and commercial establishments, these totals will only increase.

Of course, these estimates reflect only the total aggregate uplift that may occur as a result of the B-Line LRT. The amount that can actually be recaptured depends on the specific LVC policy tool chosen. Using existing municipal tax rates that range between 1.39% and 3.64% for residential and commercial properties respectively, a TIF zone that dedicates increases in taxable assessment within station areas would recover only a small portion of this total aggregate uplift. SADs on the other hand, could be negotiated to achieve a greater return, and joint development on city-owned properties could fully internalize the project's LVU.

Furthermore, this analysis occurs at one period in time. Uplift amounts are unlikely to be fixed over time as a project moves from announcement to construction and operations. Instead, it may be that land values along the B-Line LRT shift across all scenarios as the project matures and greater levels of development occur within station areas. Likewise, the assumption of a distance decay in value of 550 metres is conservative and may not reflect conditions on the ground in Hamilton once the LRT line begins operation, and extending this decay function can increase estimates of total capturable benefits. Further research is required to complete the matrix of uplift amounts in Higgins and Kanaroglou (2015d) according to different phases in the lifespan of a rapid transit project, rates of uplift, and their decay over space.

Table 6-4. Land Value Uplift by Scenario and Station

	Scenario 1: One-Way Streets, No TOD				Scenario 2: Two-Way Streets, Moderate TOD				Scenario 3: Two-Way Streets, High TOD			
	Single Detached	Condominium	Commercial	Vacant/ Parking	Single Detached	Condominium	Commercial	Vacant/ Parking	Single Detached	Condominium	Commercial	Vacant/ Parking
Station Type	Maximum Uplift				Maximum Uplift				Maximum Uplift			
Urb. Comm. Core	0%	2%	4%	4%	2%	4%	7%	7%	2%	15%	15%	20%
Inn. Urb. Neighb.	0%	4%	4%	4%	2%	7%	7%	7%	5%	15%	15%	20%
Urban Neighb.	2%	3%	3%	3%	4%	6%	6%	6%	10%	15%	10%	15%
Suburban Neighb.	4%	2%	2%	2%	6%	5%	4%	4%	15%	10%	6%	10%
Station	Total Uplift ($ Millions)				Total Uplift ($ Millions)				Total Uplift ($ Millions)			
Eastgate Square	1.86	0.39	1.56	0.02	2.79	0.97	3.12	0.04	6.98	1.94	4.68	0.10
Nash	2.08	0.56	0.83	0.00	3.12	1.41	1.66	0.01	7.81	2.82	2.49	0.02
Parkdale	1.64	0.05	0.44	0.00	3.28	0.09	0.87	0.01	8.20	0.24	1.45	0.01
Queenston	1.63	0.00	0.48	0.01	3.27	0.00	0.96	0.02	8.16	0.00	1.60	0.06
Kenilworth	2.35	0.05	0.45	0.03	4.70	0.10	0.91	0.05	11.75	0.24	1.51	0.13
The Delta East	1.74	0.13	0.28	0.01	3.49	0.26	0.56	0.02	8.72	0.66	0.93	0.06
The Delta West	1.44	0.10	0.22	0.01	2.88	0.20	0.44	0.01	7.21	0.50	0.74	0.03
Scott Park/Gage	1.99	0.21	0.17	0.01	3.97	0.41	0.33	0.01	9.94	1.03	0.55	0.04
Sherman	2.73	0.24	0.31	0.00	5.46	0.48	0.63	0.00	13.65	1.19	1.04	0.00
Wentworth	2.00	1.23	0.77	0.02	3.99	2.46	1.55	0.04	9.98	6.16	2.58	0.10
Wellington/Vict.	0.43	0.89	2.08	0.19	0.87	1.79	4.15	0.38	2.17	4.47	6.92	0.94
Gore Park East	0.00	1.81	1.38	0.06	0.91	3.16	2.42	0.11	2.27	6.78	5.18	0.30
Gore Park West	0.00	0.10	10.50	0.48	0.39	0.18	18.37	0.84	0.96	0.39	39.36	2.41
Queen/Bay	2.26	2.17	1.42	0.19	4.51	4.34	2.85	0.37	11.29	10.84	4.75	0.93
Dundurn	2.32	0.16	0.86	0.01	3.48	0.39	1.71	0.02	8.71	0.78	2.57	0.05
Longwood	2.50	0.44	0.49	0.00	3.75	1.10	0.97	0.01	9.38	2.21	1.46	0.02
McMaster U.	2.85	0.02	0.18	0.00	4.27	0.06	0.35	0.01	10.68	0.12	0.53	0.01
Total by Property	29.83	8.55	22.41	1.04	55.14	17.40	41.84	1.95	137.86	40.35	78.33	5.22
Total by Scenario	61.83				116.34				261.76			

6.5 CONCLUSIONS

Public policy interventions associated with integrated transportation and land use planning for a rapid transit project that produce increases in accessibility and TOD can in turn result in land value benefits for private land owners, and there is a strong rationale to recapture such benefits through LVC. Value planning takes the idea of LVC further by consciously incorporating the effects of policy on LVU into the planning process to maximize a project's total benefits and capturable revenues.

An illustrative application of the value planning framework to the case of LRT in Hamilton, Ontario reveals the potential capturable LVU benefits that may accrue based on different combinations of existing key enablers and potential policy levers. Total aggregate uplift amounts range from approximately 6% of total project costs to more than 25%. However, because much of the previous research into the LVU effects of rapid transit has been conducted in a manner that is insensitive to the separate but potentially simultaneous LVU effects of rapid transit and TOD, the coefficients used to estimate value uplift are based only on rough assumptions. Still, while a hypothetical exercise, they demonstrate the scale of returns that may be possible to achieve through policy and planning.

Future research should seek to further inform planning and policymaking for LVC by better separating out the LVU effects of transit accessibility and TOD associated with different transit modes and TOD contexts. Only then can the full potential of the value planning framework as a tool for offering more context-sensitive and empirical estimations of potential LVC be realized.

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CHAPTER 7

CONCLUSION

While there is a long history of using LVC to recapture some of the land value benefits that accrue from public investments, the tool has seen a resurgence in interest among planners and policymakers in Ontario, North America, and around the world. Faced with a seemingly perpetual need to raise greater funds for financing the construction and operation of rapid transit infrastructure, LVC stands as a promising solution for recapturing some of the localized LVU that can occur from the public project, an ‘unearned increment’ that has typically accrued to private land owners.

However, despite its apparent promise, the wider adoption of LVC as part of a financing package for future rapid transit projects relies on overcoming several theoretical, conceptual, and practical issues. Fundamental among them is the practical issue of knowing in advance the degree to which land values are likely to increase from a given project at different points in time, and the spatial decay in such benefits over space. This is because if LVC tools are to be implemented in a way that is socially equitable and economically efficient, they must be set at rates that reflect the actual LVU benefits that result from the policy intervention. Furthermore, these rates must be set relative to some benchmark, reflecting the spatial distribution of land values prior to the project.

Previous research into the LVU effects of rapid transit in other cities has been used in the past to provide some guidance. However, as Chapter 2 has demonstrated, the results of previous research are at best diverse, with many finding some degree of LVU, but others finding an insignificant or negative effect. At worst, previous results are potentially misleading for LVC.

This is because two theoretical issues plague the ability to extend the findings of past research on LVU in some contexts to predictions of LVU from new implementations of rapid transit in others. First, there is the potential for a lack of any accessibility benefit from rapid transit in contexts where automobile access is ubiquitous. Second, LVU benefits can also accrue from land use planning that promotes TOD. This can create heterogeneous spatial submarkets as individuals sort themselves into the particular bundles of land use and transportation characteristics that best fit their preferences.

This is problematic because despite integrated land use and transportation planning having become the norm in North America over the past several decades, research into the LVU effects of such projects has largely considered the simultaneous and self-reinforcing LVU impacts of transit and TOD in one bundled measure. Greater applicability of this research in general, and for LVC in particular, requires unbundling these effects and better controlling for station area context.

To that end, Chapter 3 responds to the criticisms raised in Chapter 2 to develop a method for better understanding heterogeneous station contexts and incorporating them into further research. Using latent class model-based clustering, it incorporates several measures of station area TOD into a typology of rapid transit station areas, thereby reducing the complexity of contextual environments in station catchment areas across a region. The resulting typology is useful as a tool for benchmarking and policy prescription in planning (Appendix A). But for the purposes of the present thesis, it also forms a foundation for enabling research into the LVU effects of rapid transit to be more conceptually complete, generalizable, and extendable to research into LVC.

From this, Chapter 4 seeks to test the theory of differential LVU effects from rapid transit accessibility and TOD using the case study of HRT in the City of Toronto. The chapter improves on previous research by explicitly modelling TOD submarket effects separate from what are theorized to be more homogeneous transit accessibility LVU impacts. Nevertheless, the use of proximity as a proxy for transit accessibility results in only a partial unbundling of the LVU effects from TOD and accessibility. Still, the results imply the existence of significant heterogeneity in LVU within different station area TOD contexts.

To return to extensions of such research to LVC, Chapter 5 develops a value planning framework that brings all previous chapters together into an approach for research, policy, and planning. While the notion of value planning for rapid transit is not a new idea, particularly in the Toronto region (Appendix B), the framework achieves two objectives. First, it explicitly conceptualizes the key enablers of LVU benefits associated with rapid transit and the policy levers that affect the absolute and relative magnitude of these key enablers. While such benefits can translate into capturable revenues through LVC tools, the framework then combines these elements into an approach that creates a positive feedback loop for maximizing a project's potential benefits and LVC revenues.

However, a lack of research into the unbundled LVU effects of transit accessibility and TOD means that the framework is at present only conceptual. Future research will be required to complete the matrix of uplift coefficients for different property types within different station contexts, and their rates of spatial decay. To accomplish this, Chapter 5 also offers directions to accomplish these goals, namely through better specifications of transit accessibility and an adoption of the TOD typology method to directly model the LVU effects of station area contextual and submarket heterogeneity.

While the value planning framework is incomplete, Chapter 6 presents a case of its application to a rapid transit project. Utilizing models of existing uplift and data on assessment values within the transit corridor, the chapter highlights the scale of possible capturable revenues that may result from different policy and planning scenarios. Although hypothetical, it offers rationale to engage in greater research into the unbundled LVU effects of transit and TOD, their extensions to LVC, and practical applications of LVC tools.

7.1 CONTRIBUTIONS TO KNOWLEDGE

In the course of accomplishing its objectives as outlined in the summary above, this dissertation has made several contributions to knowledge:

Significant heterogeneity in previous research on LVU effects of rapid transit

First, in completing the most comprehensive review of the literature to date, Chapter 2 has revealed significant heterogeneity in previous studies of rapid transit's LVU effects. Such research outcomes run counter to any generalized notion that rapid transit *will* increase land values around stations.

LVU is driven by both transit accessibility and TOD

In addition to revealing significant heterogeneity in research outcomes, Chapter 2 also provokes a reconsideration of the theoretical drivers of LVU. Previous research has largely been driven by the expectations of the AMM spatial equilibrium model, wherein reductions in transportation costs afforded by rapid transit should result in localized increases in land values. However, coordinated land use and transportation planning to promote TOD can also lead to land value increases. Accommodating such increases into models requires the adoption of a second spatial equilibrium model, that of Tiebout's sorting. Here individuals are said to self-select their location based on bundles of local goods. In terms of TOD, this should result in the creation of spatial submarkets around rapid transit stations.

Not all station area contexts are the same

In line with the above, Chapter 3 demonstrates that not all station area contexts are similar. This in and of itself is not surprising, as researchers, planners, and policymakers are faced with a diversity of station catchment area characteristics. To overcome this, the chapter outlines a method for creating station area TOD typologies based on built environment 'input' characteristics. Contrasting different station area types with performance 'outputs' reveals that while reducing complexity, the typology accurately captures TOD heterogeneity.

LVU is not constant across implementations of transit accessibility and TOD

If transit accessibility and TOD result in LVU impacts, these impacts should be different for different bundles of accessibility and TOD. Chapter 4 tests the hypothesis of base level access effects from the presence of rapid transit infrastructure that result in relatively homogeneous across neighbouring stations along a line, with additional LVU effects from different TOD submarkets as well as a property's location relative to the station access point. Results confirm expectations of heterogeneous outcomes, with a partial unbundling of access and TOD responsible for up to a 19% increase in values of single detached homes within a particular type of station area. In contrast, other station types reveal different amounts of uplift. Results offer a rationale for conducting future research that attempts to better unbundle simultaneous transit and TOD uplift effects.

Antecedent value from transit accessibility and TOD

Both studies of LVU and applications of LVC require a benchmark level against which aggregate land value changes are compared. Longitudinal studies can reveal this level, where land values are analyzed for trends in advance of the announcement and construction of a rapid transit project. Data limitations prevented Chapter 4 from obtaining a benchmark level of antecedent LVU in advance of the Line 1 and Line 4 HRT subways in Toronto. However, the analysis of LRT in Hamilton in Chapter 6 revealed some LVU effects within different station types in advance of the announcement of that project. Here, while homes located in *Suburban Neighbourhood* station types sold at a premium relative to the rest of the corridor, locations within other station types were not found to be significant. This suggests that future cross sectional or longitudinal studies in Hamilton and other cities and regions should contrast their findings with baseline conditions to arrive at net estimates of LVU and LVC that can be associated with new transit access and TOD interventions.

Foundations of a generalized framework for conceptualizing and better predicting LVC in future station areas

Chapter 5 presented a value planning framework for fully conceptualizing the benefits of rapid transit and how they impact land values within station areas and total capturable revenues. The framework also recognizes the role of the public sector in shaping these benefits. Taken together, the framework constitutes a positive feedback loop that can help planners and policymakers understand the potential for LVC given different packages of transportation and land use key enablers and their role in maximizing project benefits and thus capturable return on investment. Still, translating the value planning framework from theory to create a predictive model of LVU and LVC in practice is hindered by significant gaps in our knowledge of the land value impacts of transit and TOD.

Significant LVU and potential for LVC in the Toronto region and beyond

Chapter 5 revealed that more remains unknown than known about the LVU impacts of different bundles of transit accessibility and TOD. Nevertheless, a hypothetical application of the value planning framework to the case of light rail transit in Hamilton in Chapter 6 reveals the potential to achieve significant LVC revenues given different key enablers. Although based on planning assumptions and limited by available data, the line can potentially generate between 6% and 25% of total project costs depending on different uplift scenarios. However, the amount captured will depend on the specific LVC tool chosen and its design. While hypothetical, results provide a rationale for engaging in further study of the LVU benefits of transit and TOD to complete the matrix of LVU coefficients in Chapter 5. Only in doing so can research in this area offer greater guidance to planners and policymakers to promote a larger implementation of LVC in the Toronto region, North America, and around the world.

7.2 DIRECTIONS FOR FUTURE RESEARCH

Although the research makes a number of contributions to knowledge, several important questions remain to be answered in future research:

Unbundled LVU Effects of Transit and TOD in General

While more than 100 studies have occurred in more than 40 years in North America alone, more remains unknown than known about the separate LVU effects of transit access and TOD. Future research should seek to incorporate better specifications of transit accessibility and the TOD typology into spatial hedonic models to capture the distinct and interacted effects between these factors.

Unbundled LVU Effects for Different Transit Modes and Property Types

In line with the previous direction, more information is needed on the difference in capitalization of transit and TOD for different combinations of property types and transit modes. For example, what is the difference between transit and TOD LVU for single-detached homes served by LRT in low-density suburban versus high-density TOD station contexts, or commercial land uses in the central business district versus a low-density automobile-oriented suburban strip? Answering such questions will be crucial for further developing the matrix of LVU coefficients in Chapter 6.

Changes in LVU for access and TOD over time

Furthermore, greater knowledge is needed as to the effects of transit accessibility and TOD over time. In line with theory, amounts of LVU should fluctuate alongside larger structural changes in a study area. This can include changes in transportation costs, such as high gas prices or levels of congestion, or changes in demographics that see larger numbers of individuals particularly interested in transit-oriented lifestyles. Temporal changes also stand to reveal any antecedent value in TOD submarkets in advance of rapid transit, which serve as an important benchmark against which estimates of LVU and LVC can be based. In this sense, more information can be revealed about the LVU effects of transit and TOD in longitudinal study designs.

Implicit factors and comparative analyses

The matrix of LVU coefficients in Chapter 5 implies some level of comparability in research outcomes once transit access and TOD submarket effects are controlled for. However, true comparability in research outcomes requires an explicit adoption of a larger, more comparative study design, ideally across several cities or regions over time. Doing so can allow researchers to directly control for the more structural factors noted above that are implicit and unobserved in models of single study areas to reveal their impacts on LVU in different study areas across different stages of a rapid transit project.

Investigation and potential incorporation of individual preferences into LVU research

Research into the LVU effects of transit and TOD typically works from real estate transaction data, a revealed-preference dataset that contains no information on the purchaser of a property and the reasons why they selected a particular location. Hedonic models can to some extent reveal a general willingness to pay for certain attributes of the product and location selected. However, further research into the value placed on transit access in general, and the factors influencing the existence of TOD submarket effects in particular, will require greater information on the stated preferences of homebuyer. One way this can be accomplished is through surveys of individuals who have recently completed a real estate transaction.

LVU forecasting through integrated land use and transportation modelling

The present research has sought to examine LVU around existing infrastructure in the GTHA and provide information that can be used to derive context-sensitive estimations of LVU for similar station types in the future as part of the value planning framework. However, such estimations are predicated on assumptions of a constant spatial equilibrium across study areas, including a consistent influence from the unobserved factors mentioned above. A second method for obtaining context-sensitive estimations of LVU in future station areas is to use results from Chapter 4 as inputs into an integrated land use and transportation modelling framework, which incorporates the calculation of spatial equilibrium based on model inputs. Still, this potential solution also relies on a more accurate estimation of equilibrium conditions in Chapter 4 and their subsequent specification in the integrated modelling framework. Nevertheless, despite such challenges this constitutes a promising area for future study and application of research results.

When are the LVU effects of station-area TOD activated?

In Chapter 6, the TOD typology captured different TOD contexts in future station areas along a proposed light rail transit (LRT) corridor in Hamilton, Ontario. However, hedonic models revealed no capitalization for locations within them in advance of LRT. Such findings pose questions for research such as: when do such effects begin to accrue? Is it only with the inauguration of transit service, wherein the station access point creates a concentration of activity that results in a centre of gravity around which the amenities associated with TOD become activated? In essence, is the ‘T’ in TOD a necessary precursor for the creation of transit-oriented submarkets?

In terms of the TOD typology, it captures existing station area built environment contexts, but not more qualitative indicators associated with the concept. It may be that the inauguration of transit service alters these characteristics. For example, this may include growth in the number, type, and locations of pedestrian- and transit-oriented amenities that accrue around rapid transit service and accelerate the creation of a distinct TOD submarket of like-minded individuals. This may occur as these individuals become attracted to the lifestyle choices offered by such features within the existing built environment and bid up prices for locations within it. As with the other issues noted above, further research will be required to test these hypotheses.

APPENDIX A

AN APPLICATION OF LATENT TOD CLUSTERS FOR EVALUATING TRANSIT-ORIENTED DEVELOPMENT IN PRESENT AND FUTURE RAPID TRANSIT STATION AREAS IN TORONTO

Transit-oriented development (TOD), which is generally understood as the promotion of high density, mixed-use, amenity-rich, and pedestrian friendly development around rapid transit stations, has been hailed as a strategy for maximizing the potential of rapid transit investments. To examine the distribution of TOD characteristics, previous research by Higgins and Kanaroglou (2015b) constructed a typology of transit station area TOD in the Toronto region.

This appendix explores how such information can be incorporated into policy and planning as a benchmarking tool to analyze future conditions and help to design strategies to maximize the potential of future transit station areas along new projects in the Toronto region. This is accomplished through an overview of existing TOD conditions along several rapid transit projects in various stages of planning and an in-depth case study of the proposed Hurontario-Main light rail transit (LRT) in Mississauga and Brampton, Ontario. To begin, we first provide an overview of the policy and planning framework informing TOD planning in the region.

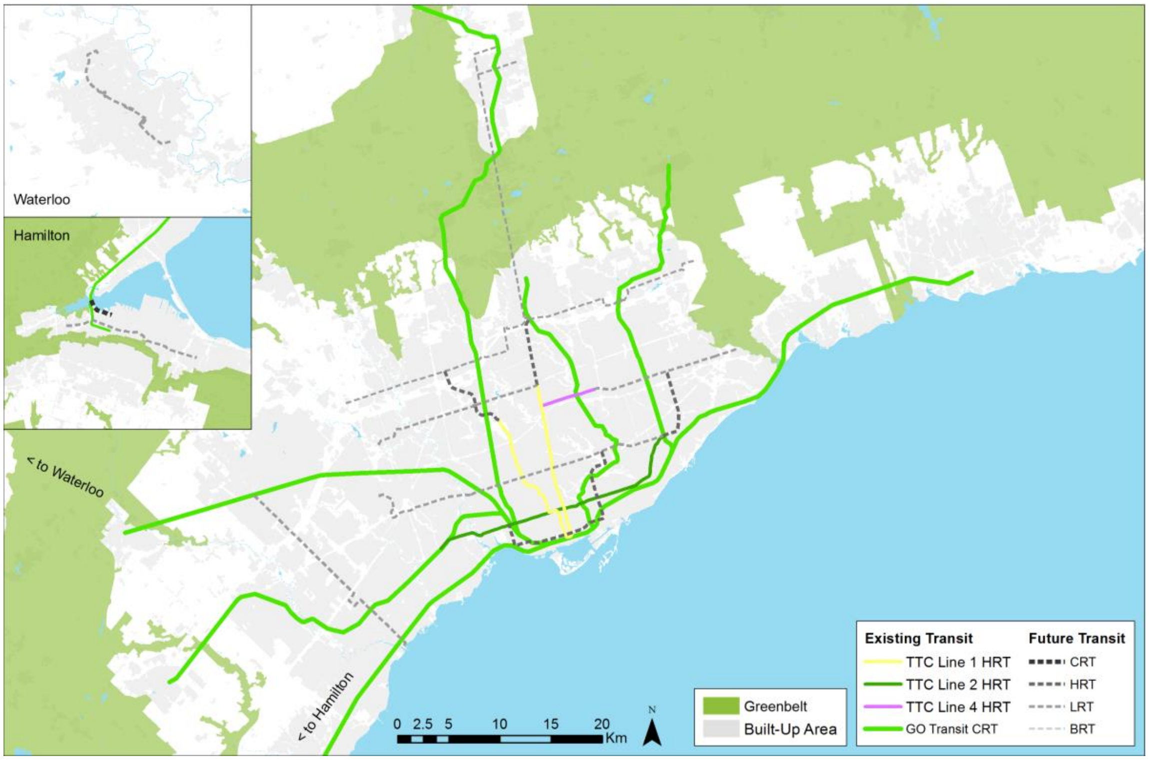
BACKGROUND

Present and Future Rapid Transit Infrastructure Projects in the Toronto Region

There are a number of future rapid transit lines in various stages of planning in the Toronto region, as well as several existing ones (Figure 3-1). This paper considers 18 separate projects: 3 existing and 4 planned heavy rail transit (HRT) lines, 7 commuter rail transit (CRT) lines with one extension under construction, 9 LRT lines under construction or in planning, and 2 bus rapid transit (BRT) lines currently being built.

Across these projects there are 372 individual transit station areas, which creates a source of complexity for positive assessments of current station area TOD characteristics and normative evaluations of potential policy interventions to encourage TOD within them. The TOD typology proposed in Higgins and Kanaroglou (2015b) reduces this complexity, and we employ it here to explore implications as a tool to aid transit-oriented policy and planning.

Figure A-1. Present and Future Rapid Transit in the Toronto Region



Regional TOD Planning and Policy Framework

It is useful to understand the planning paradigm that governs transit and TOD-related policy and planning in the Toronto region, which is formally referred to in Ontario policy and planning as the Greater Golden Horseshoe (GGH). Planning for transit and TOD generally occurs across three levels. At the bottom of the hierarchy are the municipalities of Ontario. The power vested in municipal government is quite small, though in terms of TOD they are primarily responsible for designing and implementing TOD-related policies through measures such as local land use plans and zoning ordinances and delivering transit service.

At the top of the hierarchy is the Province of Ontario, who sets broad policy and planning goals for municipalities across the province. Related to TOD this includes the imposition of the Greenbelt urban growth boundary around the municipalities of the Toronto region, and the design of the Places to Grow Act and its associated Growth Plan for the Greater Golden Horseshoe. The Growth Plan stipulates growth management regulations, such as minimum density targets in terms of jobs and population for new growth and targets for intensification within the existing built boundary for different municipalities in the region. Municipalities are responsible for delineating areas in which to concentrate new growth within their Official Plans, such as through designated ‘Intensification Corridors’, ‘Intensification Nodes’, and ‘Urban Growth Centres’ as well as ‘Major Transit Station Areas’ defined as 500 metres around a station. To ensure compliance with the Growth Plan, all municipal Official Plans within the GGH are submitted to the Province for approval.

Finally, an intermediary between the Province and its municipalities on the issue of public transit is Metrolinx, an agency of the Provincial Government designed to oversee the implementation of new investments in rapid transit and other transportation infrastructure throughout the region as part of the ‘Big Move’ regional transportation plan. All three of these provincial initiatives, the Greenbelt, Places to Grow Act and Growth Plan, and the Big Move come together to form the pillars of Province of Ontario’s ambitious transportation and land use planning framework for the GGH region. The promotion of TOD plays a large role within this framework for the reasons noted in the introduction, particularly not only for promoting more sustainable patterns of growth, but also to fully capitalize on new and existing infrastructure.

POLICY AND PLANNING IMPLICATIONS

To better illustrate the implications of the TOD typology for transit and land use planning in the GGH, the paper now turns to a brief evaluation of TOD along the existing and future transit lines across the region followed by a more detailed evaluation of TOD in stations along the proposed Hurontario-Main LRT.

Distribution of Station Types

The distribution of station types along existing and future rapid transit lines across the region is displayed in Table A-1. In assigning stations to lines, interchange stations are only counted once and allocated to the line that was or will be built first. For example, the three-stop Scarborough Line 2 Extension shares its terminus station with the Sheppard East LRT Phase 1. Because the LRT is projected to open in 2021 compared to approximately 2023 for the HRT extension if approved, this shared station is assigned to the total for the LRT route.

Results for existing infrastructure reflect expectations. GO Transit's CRT lines largely serve Suburban and Outer Suburban locations and terminate at the Toronto CBD. Several stations closer to the CBD are also urban in character, while others reflect the low-density industrial development that would be expected given that many of GO's service corridors are shared with commercial freight rail operations. A majority of GO's outer suburban stations feature large surface and structured parking lots that are appropriate for attracting riders in such markets. However their existing character is at present not reflective of TOD. In contrast, the Toronto Transit Commission's (TTC) HRT lines serve mainly higher-density urban and suburban areas as well as the CBD and the high-density mixed-use neighbourhoods surrounding it, all of which exemplify TOD.

Where the typology is particularly useful is in conceptualizing the characteristics of future station areas along proposed rapid transit lines. If present conditions persist, the Scarborough Line 2 subway extension for example will serve two Suburban Neighbourhood station areas, with a third Suburban Centre type shared with the Sheppard LRT Phase 1. The Vaughan subway extension, which is scheduled to open in 2017, serves two Suburban Centre stations, but also four low-density Outer Suburban Commerce and Industrial Parks. While this may not appear to be the most immediately complimentary context for operating HRT subway service, there are plans to transform several stations into a high-density 'new' downtown for Vaughan. Nevertheless, the typology makes clear that greater TOD around these stations, both in terms of supportive policy and planning and the actual construction of such development, will be required to achieve the greatest return on investment for such transit infrastructure. In contrast, the proposed Toronto Relief Line is designed to serve many high density and transit-oriented Inner Urban and Urban Neighbourhoods as well as two Urban Commercial Core stations in the Toronto CBD, offering an immediate market for TOD if constructed.

Among future LRT and BRT lines, the Eglinton LRT Phase 1, Sheppard LRT Phase 1, Hurontario-Main LRT, Hamilton B-Line, and Waterloo LRT traverse some segments that connect several Urban station types. Still, when considering all station area contexts these lines are generally more suburban in character, which is amenable to the choice of transit technology and also supports the planned phased implementation of some lines wherein the most urban and immediately transit-supportive service areas first. In general though, suburban contexts in many station areas along these lines reinforces the need for transit-oriented land use planning to ensure that stations become more transit supportive and maximize the potential return on investment.

But just where are such interventions required? Recognizing the heterogeneity in TOD within station areas along existing and future lines, a further strength of the typology is its ability to focus on particular station areas to identify specific stations or segments of TOD strength and weakness. This application is demonstrated using the case of the Hurontario-Main LRT below.

Table A-1. Station Typology by Existing and Future Rapid Transit

Row Labels	1. Urban Commercial Core	2. Urban Mixed-Use Core	3. Inner Urban Neighbourhood	4. Urban Neighbourhood	5. Suburban Neighbourhood	6. Outer Suburban Neighbourhood	7. Suburban Centre	8. Outer Suburban Commerce Park	9. Outer Suburban Industrial Park	10. Airport	Total
GO Transit Regional CRT											
Barrie	1[a]					7			1		8
Georgetown	1[a]		1	1	3	1			2		8
Lakeshore East	1[a]		1	1	3	3			1		9
Lakeshore West	1[a]		1	2	4	2			2		11
Milton	1[a]			1	2	2	2		1		8
Richmond Hill	1[a]				3	1					4
Stouffville	1[a]			1	5	2					8
TTC Subway/HRT											
Line 1 (Yonge-University-Spadina)	9	3	7	7	3		1				30
Line 2 (Bloor-Danforth)		2	11	14	3		1				31
Line 4 (Sheppard)			1	2	1						4
Future GO Transit CRT											
James Street North GO Extension					1						1
Future Subway/HRT											
Scarborough Line 2 Extension					2						2
Toronto Relief Line		2	8	2			1				13
Vaughan Line 1 Extension							2	3	1		6
Yonge North Line 1 Extension				3	3						6
Future LRT											
Eglinton LRT Phase 1			1	10	3		6	1	1		22
Eglinton LRT Phase 2				3	8	2	1			3	17
Finch West LRT Phase 1			3	4	5		5		1		18
Finch West LRT Phase 2				3	3		1		3		10
Sheppard East LRT Phase 1			2	7	9		7				25
Sheppard East LRT Phase 2					3						3
Hamilton B-Line LRT	1		3	8	5						17
Hurontario-Main LRT		1	5	8	7		4		1		26
Waterloo ION LRT			5	2	5	1	3	2	1		19
Future BRT											
VIVA Blue				4	17	2	2	2			27
VIVA Purple				2	15	3	10	4	4		38
Total	11	8	49	85	113	26	46	12	19	3	372

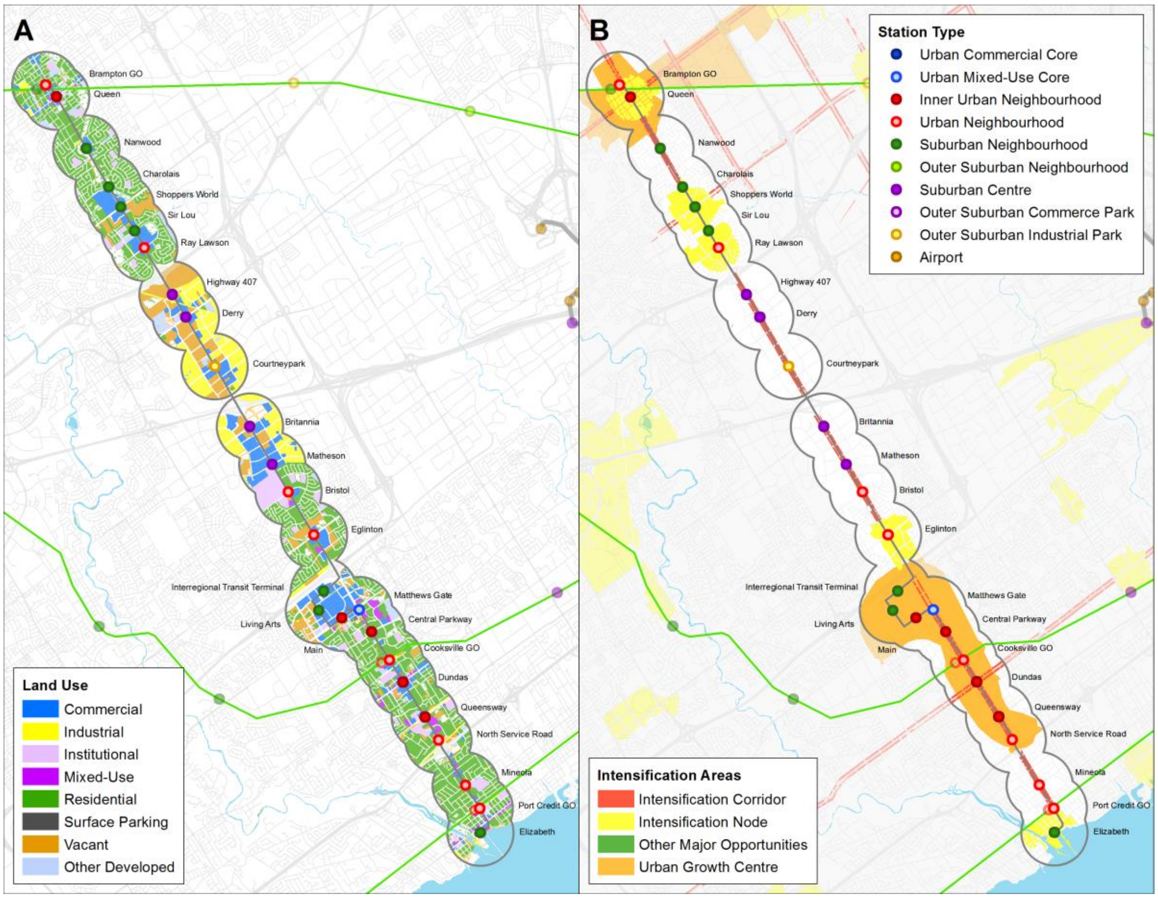
Notes: a) station is shared by all CRT lines and is counted only once in the grand total

CASE STUDY

Hurontario-Main LRT

The Hurontario-Main LRT is a proposed 23 kilometre line with an estimated cost of CAD $1.6 billion that travels from downtown Mississauga in the south to downtown Brampton in the north and offers connections to three GO Transit CRT stations. The line, its stations and station types, and station area land use characteristics are shown in Figure A-2 Panel A. Considering the station areas in which the line would operate, the typology makes clear that the southern segment of the LRT from Port Credit GO to Bristol would traverse a number of Urban and Inner Urban Neighbourhood stations as well as one Urban Mixed-Use Core in central Mississauga. From there, as the line continues north it begins to serve largely suburban stations, some of which consist of low density commercial and industrial areas, followed by more suburban neighbourhoods as the line approaches downtown Brampton.

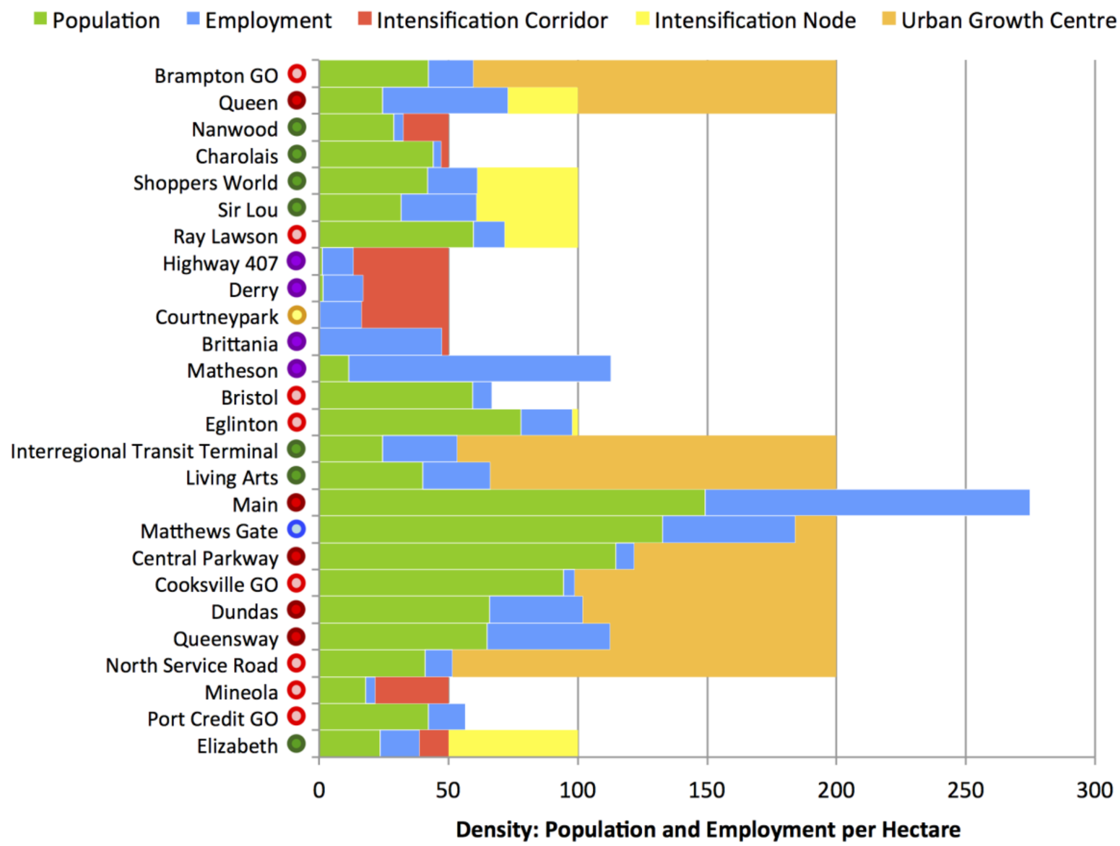
Figure A-2. Station Type and Station Area Land Use (A) and Intensification Areas (B)



Clearly many station contexts appear consistent with elements of TOD, particularly the southern segment of the line. Here TOD initiatives can build on existing strengths to fully realize the TOD concept in tandem with LRT. Other more suburban station areas however are likely to need considerable policy and planning interventions to promote TOD if they are to be maximally transit supportive. In that regard, the provincial Growth Plan for the Greater Golden Horseshoe and associated municipal Official Plans have delineated several areas in which urban growth is to be accommodated and prioritized (Figure A-2 Panel B). The ‘Urban Growth Centres’ of downtown Mississauga and Brampton are to grow to a target density of 200 people and jobs per hectare by 2031. Additional ‘Intensification Nodes’ are identified around the Port Credit GO station, the prospective Eglinton, Ray Lawson, and Shoppers World stations, and within downtown Brampton around the Brampton GO station. Each of these areas is designated as a ‘Mobility Hub’ within Metrolinx’s regional transportation plan and viewed as areas with significant development potential. Finally, the length of the proposed LRT line has been identified as a strategic ‘Intensification Corridor’ in which future growth should be prioritized.

How do existing conditions compare with density targets set forth in the Growth Plan? The TOD typology incorporates measures of population and employment density into the latent class model, but examining them directly is also illustrative of the potential changes that need to occur to achieve strategic land use and transportation goals. Total population and employment per hectare within each station’s catchment area is shown in Figure A-3. We also plot target density levels of 200 people and jobs per hectare for stations located in Urban Growth Centres. The Growth Plan for the Greater Golden Horseshoe does not mandate minimum density targets for Intensification Nodes and Corridors, but for illustrative purposes we assume density targets of 100 and 50 people and jobs per hectare respectively and plot accordingly.

Figure A-3. Hurontario-Main LRT Population and Employment Densities by Station



Here it can be seen that densities vary, sometimes substantially, and many stations will require policy and planning interventions to achieve mandatory and hypothetical target levels. In this regard, several planning initiatives have been completed and others in development that create 'master plans' that outline principles and guidelines for mobility hubs along the line. However, large-scale zoning changes to prioritize TOD along the Hurontario-Main LRT have not yet occurred, though the City of Brampton is presently engaged in an exercise to create a secondary plan that includes zoning changes along its portion of the line to transform the area from its present low-density and auto-oriented character into a dense, mixed-use, and transit supportive corridor. Whether such measures will be able to transform the Suburban Neighbourhood stations along the northern segment of the line into areas that reflect the characteristics of Urban Neighbourhood stations remains to be seen. In Mississauga, the authors are not yet aware of a similar initiative to formalize TOD principles and guidelines into zoning along that city's portion of the Hurontario-Main LRT, but the city's Official Plan contains a secondary plan for the downtown area that prioritizes higher density mixed-use and pedestrian-friendly development.

But while it appears that many stations stand to benefit from coordinated transportation and land use planning, others may need stronger interventions if they are to reach their full TOD potential. This is particularly the case for stations in the segment between Matheson and Highway 407, all of which are primarily home to low- to medium-density commercial and industrial land uses oriented to the private automobile. This segment does not feature any high-level intensification designations aside from a location within the Hurontario Intensification Corridor, though this does not entail a Provincial requirement to achieve any minimum density levels. Nevertheless, with large parcels and ample amounts of vacant land, there is potential to transform this segment of the LRT corridor into a more transit supportive environment. As such, to achieve a maximum return on investment for the Hurontario-Main LRT, TOD should be strongly encouraged around these stations through transit-oriented corridor secondary planning with relevant zoning amendments and other common TOD incentives.

One type of intensification area that has not yet been mentioned is that of 'Major Transit Station Areas', which could be a promising way to encourage further intensification around future stations in advance of rapid transit similar to the advance TOD planning in Phoenix detailed by Atkinson-Palombo and Kuby (2011). However, to date no Hurontario-Main LRT stations have been identified in either city's Official Plan. Furthermore, such designations also do not entail any minimum density targets, weakening their potential impact for promoting TOD.

Note that the above analysis is subject to two limitations. First, population and employment density targets in the Growth Plan for the Greater Golden Horseshoe are based on averages across a delineated area, not in individual station areas. Second, density numbers are affected by the modeling assumptions outlined in the methodology and the quality of available population and employment data.

Furthermore, comparing densities seen in Figure A-3 to a particular station's class within the TOD typology can reveal results that defy expectations. For example, with a density of 275 people and jobs per hectare, Main station features much higher densities than average Inner Urban Neighbourhood type stations at 118. However, density is only one part of the contextual factors that influence station type and the clustering of this particular station as an Urban Neighbourhood is a result of considering all factors simultaneously, such as walking connectivity and the distribution of land uses.

Finally, the case of the Hurontario-Main LRT demonstrates how the modeling assumptions used to estimate the typology can affect station classification. Figure A-2 shows two Suburban Neighbourhood stations (Living Arts and Interregional Transit

Terminal) around a major shopping centre in downtown Mississauga. This classification results in part from the low population and employment densities in the area due to significant amounts of vacant land and surface parking in the surrounding area. However, it is also a product of non-overlapping station area buffers, wherein short stop spacing means the catchment area for each station is small, and subsequently the area's major employment totals are assigned to Main station. An argument could be made to allow for overlapping station buffers, but this leads to a duplication of station context in the typology model that negates the ability to capture each station's unique catchment area relative to its location and role on the regional transit network.

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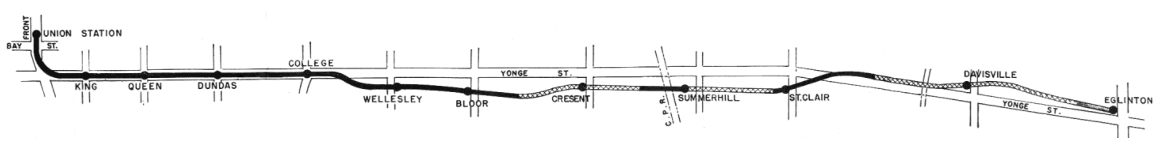
APPENDIX B

A HISTORY OF VALUE PLANNING IN ONTARIO

There is a strong but brief history of value planning at the TTC. Because of cut-and-cover subway construction techniques and decisions to minimize disruption to Yonge Street when building the first section of Line 1, the TTC acquired 22 city blocks worth of land at a cost of $3.9 million between 1949 and 1954 to enable the line to run beneath the side of the street (**Figure B-1**).

Figure B-1. **Cut-and-Cover Construction of Line 1**



In a manner similar to that used by Hong Kong's MTRC, this land was subsequently leased out by the TTC. By 1977, 17 blocks worth of land were leased, generating an annual rent of $500,000. This caused the TTC to note that its leasing program was so successful that lease income stood to completely cover, over a number of years, the Commission's costs of land acquisition (Richmond, 1979).

This experience caused sources such as Knight and Trygg (1977) and Huang (1996) to argue that Toronto and the TTC existed as a model for other cities in North America, with successes that included:

- Aggressive marketing of air rights and available excess land parcels by the transit commission;

- Liberal floor area ratios and density bonuses in station areas (no other areas of the city were zoned to allow such intensive development);
- Coordinated station design efforts with developers desiring direct access from office, retail, or apartment buildings; and
- City zoning classification changes in certain districts to permit much higher intensity development near transit stations.

Cut-and-cover construction techniques also required the TTC to acquire properties for the construction of the Bloor-Danforth subway line. However, to date the land use impacts of the line have been muted. This has been attributed to a lack of relevant up-zoning in coordination with the line in the different municipalities that formerly made up Metropolitan Toronto (until 1998 when all municipalities in Metro merged into the current City of Toronto). Nevertheless, some large-scale transit joint development projects occurred in cooperation with the TTC around High Park and Sheppard Stations (ULI, 1979).

Fundamental to these experiences appears to be a philosophy adopted within the TTC and Metropolitan Toronto to explicitly view projects for their total land value and financial impacts in a manner that has much in common with the present RTVPF. This is evidenced in interviews conducted by the Urban Land Institute in 1979 with the TTC, Metro councillors, and private sector developers about experiences with joint development in Toronto:

> In 1959, a Metro councilman suggested that lease or sale of surplus lands could recapture the costs of subway land acquisition. This suggestion officially launched a cost recovery program. The TTC examined other ways to raise revenues from its assets, inaugurating long-term leasing of its properties where appropriate, sharing costs with developers for connections to the stations, and operating subway concessions (ULI, 1979, p. 155).

A member of what was Metro's Subway Property Committee also commented that:

> "Joint development is actually a misnomer for what we have here. A more appropriate term might be common development by the public and private sectors. The public sector in this case engages in land banking and subsequently leases surplus land and rights to the private sector… An important aspect of public-private sector dealings is the Subway Property Committee's role. For example, once it had been determined that the right-of-way costs were to be recouped through the disposal of rights, it was the Subway Property Committee that suggested to Metro Toronto that land leasing would be preferable to land sales, and that the form of the lease would be such that it presented security to the developer and his prospective mortgage lenders. In addition, private developers see this committee (and, by extension, the TTC) as a hardnosed businessman, with whom they can negotiate, and who understands private sector business problems. The whole land disposition process attempts to confirm that opinion."

Furthermore, a representative of Cadillac Fairview followed up by noting that:

> "Such joint development is made easier because the TTC is undoubtedly a very business-like organization. It is certainly helpful to have an autonomous body that you can deal with, and that comprehends business issues in Toronto. At the negotiating table, each of us understands what the other is trying to achieve and the TTC negotiators are very shrewd. It is also to their credit that they understand not only a development's benefit to the TTC, but also its benefit to the city as a whole, and they attempt to see a project's full ramifications before making a decision."

Such examples are indicative of a value planning ethos within the TTC that resulted from the opportunities presented by new infrastructure projects, as well as its fiscal and political autonomy to act entrepreneurially in seizing these opportunities. However, this autonomy diminished over time as Metro Toronto and the Province of Ontario gradually took more responsibility for subsidizing the TTC's operations and infrastructure expansion. By 1962 it had become apparent that the TTC was no longer distant from the politics of Metro, with an editorial in the Globe and Mail noting that:

> "The legal fiction that the Toronto Transit commission is an autonomous body and not under the control of Metro Council is wearing thinner by the week." (Solomon, 2007, p. 15)

Despite its objections, the TTC quickly found its role politicized in Metro, with appointed officials overseeing operations amid strong and increasing pressure for service expansion in Metro's outer municipalities (Frisken, 2007). While the TTC had funded the Yonge-University line entirely from its own resources and reserves, Metro wanted further expansion and in 1958 agreed to fund 55% of the costs for the east-west Bloor-Danforth subway line (Frisken, 2007). This greatly eroded the financial and political independence of the TTC, as according to the Globe and Mail's editorial,

> "The basis of the TTC's former autonomy was that it was able to pay its own way; the system made operating profits and was able to finance its own development. The moment this happy state of affairs came to an end, and the Commission had to call upon Metro for financial help, autonomy vanished in practice, although the legal theory remained." (Solomon, 2007, p. 15)

As Frisken notes, with the municipalities now providing funds to subsidize service and expansion, ultimately "Metro Council would decide where it wanted subway lines to go. In doing so, it would often allow the political priorities of the Council's locally elected members to outweigh either land-use or transportation considerations" (Frisken, 2007, p. 98). According to Frisken, the final motion to end the TTC's economically responsible nature came in 1973, when under intense suburban pressure from Metro Council, the TTC agreed to drop its 2-zone fare system whereby suburban riders paid a double fare to enter the city, in favour of the flat fee for the whole network that is still in existence today. It was a financial disaster for the Commission and was the last year the TTC had been financially self-supporting, with operating deficits exploding to $11.3 million in 1973, $23.6 million in 1974 and up to $275 million by 1991 (Sewell, 2009).

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