POPULATION DEMOGRAPHICS AND TRANSIT USE PATTERNS IN URBAN AREAS ADJACENT TO SKYTRAIN LINES

by

Niko Vujevic
Bachelor of Arts, University of British Columbia, 2000.

CAPSTONE PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF URBAN STUDIES

In the Urban Studies Program

© Niko Vujevic, 2009

SIMON FRASER UNIVERSITY

Fall 2009

All rights reserved. This work may not be reproduced in whole or in part, by photocopy or other means, without permission of the author.
APPROVAL

Name: Niko Vujevic
Degree: Master of Urban Studies
Title of Thesis: Population Demographics and Transit use Patterns in Urban Areas Adjacent to SkyTrain Lines

Examinining Committee:
Chair: Dr. Patrick Smith

Dr. Peter Hall
Senior Supervisor
Assistant Professor, Urban Studies Program

Dr. Meg Holden
Supervisor
Assistant Professor, Urban Studies Program

Dr. Len Evenden
Examiner
Professor, Department of Geography

Date Defended/Approved: November 30, 2009
ABSTRACT

The SkyTrain system has been in operation in Metro Vancouver since 1986 when the Expo Line was opened. The Millennium Line was opened in 2002. The two transit lines have been used by the municipalities to encourage high density developments near the stations. The study examined whether there were significant differences in terms of neighbourhood design, density, diversity and demographics within 400 and 1,500m capture zones from stations. Data was compared on a regional and local level. The 1996, 2001 and 2006 Census data was analysed to find out how the neighbourhoods changed over a decade. The data indicates that the Expo Line neighbourhoods have a well established transit ridership base and much higher densities than the Millennium Line neighbourhoods or the wider Metro Vancouver area. Most importantly, the data showed that Millennium Line neighbourhoods have undergone a change since the line opened and attracted new transit riders.

Keywords: Urban; Transit; Planning; Development; SkyTrain; Population Demographics
DEDICATION

To my wife Tea, parents, friends and all other people who have supported me during many years of my education.
ACKNOWLEDGEMENTS

First and foremost I want to thank my supervisor Dr. Peter Hall for his support and guidance throughout the course of my research. His advice helped me keep my research focused and constantly moving towards the final goal. Another person at Simon Fraser University without whom this project would have stalled is Mr. Walter Piovesan with the Research Data Library. Without his assistance I would not have been able to find a large portion of the data used in my project.

Throughout the years, Solomon Wong has mentored me in the fine art of attractively and efficiently representing my ideas. So was the case this time, when he gave me a few suggestions on how to punch things up a notch. GIS guru Andy Yan has taught me many tricks and often given me pointers on how to resolve software and data problems. His enthusiasm for urban research and data crunching is a constant inspiration to me. Jocelyn Silvester, Karin Yeung and John Calimente have my gratitude for their efforts in proofreading my work and providing invaluable editorial comments. I appreciate the hours you spent reading my work.

I also want to thank Margarita Bratanic and Marko Dekovic for their support and help with the final production. Without your running around between different SFU campuses, I could not have completed my project from the opposite end of the globe.
Lastly I want to thank Veronica, my parents Miljana and Stipe, and especially my wife Tea for providing support and giving me a kick in the rear whenever I needed one.
# TABLE OF CONTENTS

Approval............................................................................................................... ii  
Abstract............................................................................................................... iii  
Dedication........................................................................................................... iv  
Acknowledgements ............................................................................................ v  
Table of Contents.............................................................................................. vii  
List of Figures .................................................................................................... ix  
List of Tables ...................................................................................................... xi  
Glossary............................................................................................................. xii  

Chapter 1: Introduction ...................................................................................... 1  
SKYTRAIN SYSTEM AND THE REGION ......................................................... 1  

Chapter 2: Literature Review ............................................................................. 4  
What defines TODs? ......................................................................................... 4  
Density 8  
Diversity 10  
Design 12  
Demographics and Other Factors...................................................................... 16  
Size of Study Area ........................................................................................... 21  
Key Questions ................................................................................................. 22  

Chapter 3: Methodology ................................................................................... 24  
Timeframe........................................................................................................ 24  
Study Area ....................................................................................................... 26  
Density, Diversity, Design, Demographics....................................................... 31  
   Density 31  
   Diversity 31  
   Design 32  
Neighbourhood Demographics....................................................................... 33  
Data Limitations............................................................................................... 34  

Chapter 4: Data Analysis .................................................................................. 37  
Density 37  
Diversity 41  
Design 46  
Demographics.................................................................................................. 49  
   Average Number of People per Household.................................................. 51
Population by Age Group ...................................................................................... 53  
Average Household Income .................................................................................. 54  
Dwelling Ownership .............................................................................................. 59  
Dwelling Values .................................................................................................... 62  
Transportation Modes ........................................................................................... 64  
Recommendations for Future Research ............................................................... 72  

Chapter 5: Conclusions ......................................................................................... 75  
Reference List ........................................................................................................ 79  
Appendix A ............................................................................................................. 85
LIST OF FIGURES

Figure 1: Joyce Station Area................................................................. 2
Figure 2: Gilmore Station Area ......................................................... 14
Figure 3: Vancouver Transportation System and SkyTrain Stations .......... 27
Figure 4: SkyTrain System Study - 400m Radius Capture Zone ................. 28
Figure 5: SkyTrain System Study - 1,500m Radius Capture Zone ............... 30
Figure 6: Population Densities - Residents per sq. km. ............................... 39
Figure 7: Percent Change in Population Density ..................................... 40
Figure 8: Metro Vancouver Residential Land Use Split, 2001 ...................... 43
Figure 9: Metro Vancouver Industrial and Commercial Land Use Split, 2001 .......... 44
Figure 10: Walkability in SkyTrain Station Areas (1,600m radius) ............... 48
Figure 11: Brentwood Station Area ................................................... 49
Figure 12: Average Number of People per Household ............................. 51
Figure 13: Percentage Change in Average Household Size ....................... 52
Figure 14: Proportion of Population by Age Group (1996 to 2006) ............... 54
Figure 15: Average Household Income .............................................. 56
Figure 16: Percentage Change in Average Household Income .................... 58
Figure 17: Percentage of Owned Dwellings ......................................... 60
Figure 18: Percentage Change in Dwelling Ownership ............................ 61
Figure 19: Average Dwelling Value .................................................... 63
Figure 20: Percentage Change in Average Dwelling Value ....................... 64
Figure 21: Percentage of Car Users as the Mode of Transportation .............. 65
Figure 22: Percentage of Public Transit Users as the Mode of Transportation ......... 68
Figure 23: Percentage Change in Public Transit Users ............................ 70
Figure 24: Analysis of Historical Orthographic Imagery ........................... 72
Figure 25: Example of Bird's Eye View Imagery .................................... 73
Figure 26: Excluded Enumeration Areas from the 1996 Census Data .......... 85
Figure 27: Excluded Dissemination Areas from the 2001 Census Data .......... 86
Figure 28: Excluded Dissemination Areas from the 2006 Census Data .......... 87
LIST OF TABLES

Table 1: Census Geographies Excluded From Calculations ............................. 88
<table>
<thead>
<tr>
<th>CTOD</th>
<th>Centre for Transit Oriented Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA</td>
<td>Dissemination Area</td>
</tr>
<tr>
<td>EA</td>
<td>Enumeration Area</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information Systems</td>
</tr>
<tr>
<td>GVRD</td>
<td>Greater Vancouver Regional District</td>
</tr>
<tr>
<td>TAD</td>
<td>Transit Adjacent Development</td>
</tr>
<tr>
<td>TOD</td>
<td>Transit Oriented Development</td>
</tr>
<tr>
<td>VCC</td>
<td>Vancouver Community College</td>
</tr>
</tbody>
</table>
CHAPTER 1: INTRODUCTION

SKYTRAIN SYSTEM AND THE REGION

SkyTrain system has been in operation since 1986 when it was opened during Expo ’86. The original Expo Line operates from Waterfront station in downtown Vancouver through Burnaby and New Westminster terminating at the King George station in Surrey. In total, twenty Expo line stations serve the four municipalities. In 2002, the Millennium line was brought into operation. The Millennium line originates at Vancouver Community College (VCC) Clarke station and continues through Vancouver, Burnaby, Coquitlam and New Westminster. The two lines intersect at Commercial Street/Broadway stations in Vancouver and at Columbia station in New Westminster. There are thirteen Millennium line stations serving the four municipalities. Some stations were developed around existing landmarks such as the Brentwood Station on the Millennium Line shown in Figure 11. In other cases, the newly constructed SkyTrain lines encouraged development in the area such as the neighbourhoods around Joyce Station (Figure 1) and Gilmore Station (Figure 2). The new Canada Line was opened on August 17, 2009 and runs from Downtown Vancouver to Richmond and Vancouver International Airport. Sixteen new stations and 19km of rail have been added to the SkyTrain network with the introduction of the new line.
The SkyTrain system runs over a 69km long rail network. Station spacing varies across the system depending on the surrounding neighbourhoods and areas. Distances between stations average out to approximately 1,500m.

In 2007, the system served approximately 210,000 passengers a day (unlinked boardings). Unlinked boardings refer to passengers travelling by SkyTrain only, rather than connecting from another mode such a bus. Unlinked boardings account for approximately 25% of all transit boardings in Metro Vancouver.

Figure 1: Joyce Station Area

The capstone project started with a literature review that covered academic and professional research involving transit system and surrounding urban developments. Majority of the research looked at the North American examples of transit oriented developments and their different characteristics.
Namely, the literature review identified four significant subject areas that the capstone project concentrated on: density, diversity, design and demographics. Data from various sources was analysed in order to find out how neighbourhoods around the Expo and Millennium lines compared to one another, and to the wider Metro Vancouver region. The Methodology section identifies specific data sets used in research and describes the procedures used in the analysis.

In short, data used in the analysis covers a ten year period that describes the study areas before and after the opening of the Millennium Line. The Expo Line is used as a benchmark for established transit oriented neighbourhoods against which the Millennium Line neighbourhoods can be compared. Specifically, the project looked at whether opening of the Millennium Line in 2002 had a significant impact on transit ridership rates in the surrounding neighbourhoods and the wider Metro Vancouver region.

How different are the Expo and Millennium Line neighbourhoods when comparing their urban design, densities, land use diversity and population demographics? Have these been the driving factors in attracting transit ridership, or has opening of the Millennium Line played a significant role in attracting new ridership to the SkyTrain system?
CHAPTER 2: LITERATURE REVIEW

In this chapter, selected academic and professional research on Transit Oriented Developments (TODs) will be reviewed. This will begin with an overview of the origins and definitions of TODs, and proceed to a summary of several specific studies dealing with different aspects of TOD development. In order to precisely define the research scope, studies of TODs on national, regional and station levels will be considered. As well, commonalities in urban design and population characteristics amongst TOD developments will be highlighted. The framework which emerges from this review will become the foundation for the methodology of the research detailed in subsequent chapters.

What defines TODs?

Over the last twenty years, a large body of academic research about TODs has amassed. Not surprising for an emerging field, there are differing opinions on the defining characteristics of TODs and many authors have contributed to the discourse by concentrating on one or another specific aspect in their research.

Peter Calthorpe is credited with having coined the term ‘transit oriented development’ in his 1993 book *The Next American Metropolis* in which he described "neighbourhoods of housing, parks, and schools placed within walking distance of shops, civic services, jobs and transit – a modern version of the
traditional town” (p. 16). Evans et al (2007) expanded the definition of TOD to include “moderate-to-high-density development, designed with pedestrian priority, located within an easy walk of a major transit stop” (p. 17-2). Variations in design of areas near transit stations are so great that several terms have been coined to describe different contexts as Evans et al note:

“The ‘transit oriented development’ term appears to have replaced ‘transit-focused development,’ perhaps to better characterize transit in a supporting rather than a starring role. The related term ‘transit joint development’ generally refers to development in which the transit agency is a land owner or major participant in the financing of the project. This term relates more to the project financials than development characteristics. More recently, “the term ‘transit-adjacent development’ has emerged as an analytical and sometimes derisive descriptor of projects that are located near transit nodes but do not embrace or take full advantage of their proximity to transit” (Cervero, 2003, as cited in Evans et al, 2007).

Having said that, depending on one’s viewpoint, in some cases transit stations with park and ride facilities are also considered as TODs. Nevertheless, most TODs are predicated upon the principle that residential development is a major component, and that residents will walk to the transit station rather than commute there by car.

There is not only a debate about what constitutes a TOD, but also a debate about the size of a TOD. Often, TODs are defined in terms of the distance that a person can walk in a set amount of time. According to Calthorpe
the “walking distance” is anything within 10 minutes walking from the transit station. This definition has fuelled a lively debate among transportation researchers about the distance that a pedestrian covers in 5 or 10 minutes.

Most academics quote assumed walking distances of 400 to 800m or 5 to 10 minutes of walking time (O’Sullivan and Morrall, 1996; Jones, 2001). O’Sullivan and Morrall looked at pedestrian behaviour and public transit access in Calgary and found that in the Central Business District (CBD) walking distances to transit averaged 326 ms while in suburban environments they averaged 651 ms. Overall, the system average was 422 ms. Prior to the introduction of LRT in Calgary, Lam and Morrall (1982) conducted a survey of the bus system and found that the average walking distance to a bus station was 327 ms. Interestingly, O’Sullivan and Morrall note that “following a 1987 survey of riders on the SkyTrain, British Columbia Transit established an LRT walking distance guideline of 900 m, which is twice the guideline it uses for walking distances to bus stops” (p. 20). The assumptions of 900m walking distance for SkyTrain stations is more than 10 minutes and quite large by comparison to other standards. This figure will be evaluated later in the study, in the context of the Lower Mainland and planning of SkyTrain TOD neighbourhoods.

Cervero (2001) researched how commuters access the Bay Area Rapid Transit (BART) system in the San Francisco Bay area and found that for commuting trips most people walked 1 km or less, took the bus for distances between 1 to 1.6 km and used a car to get to a park-and-ride for distances beyond 1.6 km. Kim et al. (2007) also analyzed the BART system and found the
average walking distance to be 0.76 km, thus demonstrating that LRT riders “walk farther than the industry guidelines suggest”. These findings also support what O’Sullivan and Morrall discovered in Calgary where transit users were willing to walk farther to access the LRT stations than bus stations.

Numerous studies show that walking times and distances vary greatly depending on the design of the neighbourhood and topography of the landscape. Wibowo and Olszewski (2005) argue for the inclusion of walking route characteristics in a “public transport accessibility measurement” in order to produce more precise and comprehensive studies that also capture the quality of the walking environment (p. 154). An in-depth study using this methodology would not only measure accessibility of transit stations located in hilly neighbourhoods, but also provide a better understanding of the impediments faced by the many different transit users.

The most widely accepted methodology for evaluating TODs involves measuring the characteristics of Calthorpe’s “modern version of the traditional town” (p. 16). Cervero and Kockelmann (1997) outlined three factors that influence travel demand which are defining for any TOD: Density, Diversity and Design. All three characteristics were a further elaboration of Calthorpe’s ideas and assumed that higher densities, diverse land uses and pedestrian friendly streets increased transit ridership rates and decreased vehicle miles travelled.
Density

Density in the context of TOD research can be expressed either as dwelling density or population density. Usually these two factors are linked. Logically, it would seem that density is the most influential factor for the successful development of a TOD if that means a large number of residents interested in using public transit. Cervero et al. (2004) conducted a survey of transit agencies in the US and found that the main goal of those agencies was to increase ridership levels and revenues through TODs. They examined US census data and found that residential densities within a mile (1.6km) of a station are directly correlated with transit commuter rates. For example, in the San Francisco area, for every increase of 10 dwelling units per acre, the level of transit commuters increased by 3.7%. The study also looked at the impact of commercial space on transit ridership in Arlington, Virginia. The authors found that “a doubling of building activity [occupancy] was associated with a 50% increase in [Washington, DC] Metrorail ridership” (p. 154). It is important to note that factors influencing development of TODs and transit ridership are related. For example, Ewing et al. (2002) found that increased densities also reduce car ownership/use and increase dependence on other modes of transportation. Car ownership has significant implications for development of TODs because of parking demands, and ways in which car ownership rates relate to household and dwelling sizes. These aspects will be discussed in some more detail along with neighbourhood demographics later in the work.
Density is also relevant on a regional scale and not just on a TOD scale. This is particularly evident in the relation between regional employment density and transit ridership. In their research, Arrington and Cervero (2008) found that “systems that generate the highest commuter ridership have a high percentage of regional jobs accessible by fast transit” (p. 3). Furthermore, when looking at work related transit trips, residents' proximity to the station has more impact on transit trip generation than land use diversity or urban design of the neighbourhood. However, Arrington and Cervero (2008) also discovered that employment densities at trip destination have more influence on transit use than residential densities at trip origin. The problem lies in collecting correct employment data within a TOD. What matters is that “unless density is above 7-10 dwelling units per acre, it is unlikely that the other Ds will have any effect, even in combination” (Arrington and Cervero, 2008, p. 15). It is intuitive that even if transit user rates are the same in a low density and a high density neighbourhood, a higher density neighbourhood will generate more transit users per square km (Evans et al, 2007). Therefore, higher density generates more transit ridership per station than a lower density area. Density benefits are enhanced through the “transit-supportive practice of clustering the highest density TOD components at or near the TOD’s transit stops, rather than spread out evenly over the site” (Evans et al, 2007, p.17-48). Density also has different impacts on generating transit ridership depending on the type of travel: work or non-work. How the 3Ds impact different types of travel will be discussed further in the work.
Diversity

Diverse land uses also impact transit ridership levels (Calthorpe, 1993). Various studies attribute different levels of significance to land use diversity and measure its impacts in as many different ways.

In his 2003 study, Andy Johnson suggested that urban planners have three primary land use planning tools at their disposal in order to increase transit ridership. First, planners can manipulate population and commercial densities along transit corridors. To optimize ridership, planners should "increase residential density in the areas near transit corridors, concentrate mixed-use development within an eighth of a mile [200 m] of the transit corridors, and channel a greater proportion of the retail development within a quarter mile [400m] of transit lines" (Johnson, 2003, p. 35). Johnson concludes that these measures would have a greater impact on increasing ridership levels than an increase in the level of transit service. He also observed that his analysis did not support office use in TOD neighbourhoods, rather these types of uses would remain in the CBD. Other authors such as Porter (1997) have proposed creating a small number of employment centres in the region served by the transit system. While some TODs would serve as employment generators, others would be primarily residential. In this case, the transit system would link a number of TODs with bi-directional flows of passengers within the network. These ideas concerning diversity of land use play out on a regional scale and primarily involve work related travel.
Some researchers have attempted to describe a link between diversity and design of TOD neighbourhoods. For instance, Susan Handy looked at the link between urban form and non-work travel behaviour (1996). She found that urban form, short distances, lack of barriers, and orientation of commercial areas all influence residents’ decision to walk within a TOD neighbourhood. Consequently, a single measure can mask differences between different types of accessibility and quantitative measures should not ignore qualitative characteristics of accessibility (Handy, 1996, p. 196). For non-work travel, residents value a greater range of destinations, but that results in increased travel. This travel can be neighbourhood based or regionally based, and can vary by mode depending on the characteristics of the trip. Clearly, there is a great difference in evaluating work and non-work travel.

Both work and non-work travel are influenced by both internal and external TOD factors that have varying effect according to different researchers. As a travel benefit for prospective TOD residents, Arrington and Cervero (2008) found that land use diversity was not considered as important as employment access (p. 3). Mixed uses allow residents to utilize transit services for a number of different trip purposes. Furthermore, mixed uses along with specific design features play a role in attracting new residents and visitors to the neighbourhood. Land use diversity is more important to TOD residents than people employed within the same TOD. Cervero’s earlier research (1996) showed that availability of a retail shop within 100m of a commuter’s home increased that person’s probability of taking transit by about 3%. Evans et al (2007) point out that TOD
projects with a greater land use diversity enable residents to conduct more of their daily business within their own community and by doing so decrease the amount of non-work travel. This is also the case in non-TOD mixed use communities where residents can conduct daily activities within their own neighbourhood. Cervero et al (2004) noted that while TODs can be designed as complete communities that can capture some trips internally, this might not be possible because of residents’ personal needs or desires. In so doing, they confirmed Cervero’s earlier work (1995) which discovered that transit users were more inclined to walk longer distances to access transit in mixed use developments than in low density neighbourhoods or areas with large parking lots. Handy pointed out that certain commercial establishments can be principally conducive to pedestrians, and because of that can influence area’s urban design (1996).

**Design**

As previously mentioned, design of TOD neighbourhoods is related to the neighbourhood’s densities and diversity of land uses found there. The 3Ds are not independent variables as they modify each other. Consequently, design features applicable to high density mixed use neighbourhoods are not necessarily applicable to lower density residential neighbourhoods. Generally, researchers have concentrated on specifying a set of urban design tools that are applicable to improving the pedestrian walking environment and conditions in terms of TOD density and land use diversity. The primary impetus for improving the walking environment is the simple fact that a large portion of transit users
who access and egress the stations are pedestrians (Evans et al. 2007). Improved walking environment and pedestrian oriented design are believed to encourage more walking within the TOD neighbourhood and thus increase the transit ridership. Indeed, some argue that walking distance is a measurable design element (Evans et al. 2007). Walking distance varies depending on the urban design and street environment that pedestrians encounter between their residence and transit station. The length of a street block, location of street intersections and street crossings, and walking paths other than street sidewalks have all been identified as design elements which affect walking distance (Evans et al. 2007). Schlossberg et al. (2004) studied four TOD stations in Portland, OR and four TOD stations in Silicon Valley, CA and evaluated which proportion of the 400m radius from the station was within an actual 400m walking distance. The study found similar ratios for Portland and Silicon Valley area stations which indicated that only between 19% and 62% of residences were within actual 400m walking distance from a station. Similar results were obtained when an 800m walking distance and an 800m radius were calculated. The significance of walking distance should not be underestimated. As Lund et al (2004) noted in their study of California TODs “over 90 percent of the surveyed rail commuters living near rail stations walked to the rail stations” (p. iii).

In the aforementioned study, various urban design features that influence transit ridership rates were also evaluated. It was established that street connectivity at trip destination has the strongest influence on TOD residents. The second most significant factor was the availability and price of parking in
station areas. In contrast, pedestrian realm improvements, such as street lights and street furniture, moderately influenced transit ridership and block characteristics were weakly correlated to ridership levels (Lund et al, 2004, p.67). Connectivity at trip destination was the only variable studied for which the relationship with transit user rates was statistically significant (Evans et al, 2007, p. 17-57). In summary, pedestrian friendly design and the quality of the urban environment do not encourage the growth of transit ridership rates. They are more successful at encouraging residents to walk to the transit station as a mode of access, or to walk within the TOD neighbourhood for non-work travel. As noted, availability of parking influences transit ridership rates and impacts the quality of urban environment and pedestrian realm. More importantly, it also impacts the number of transit users who drive to the transit station as the access mode.

**Figure 2: Gilmore Station Area**
Cervero (2001) considers large surface parking areas a disamenity to the community. He found that parking areas are not desirable in TODs because they decrease the quality of the pedestrian realm and negatively impact pedestrian access to transit stations. Conversely, decreasing the separation of land uses and converting some of the parking areas renders the pedestrian realm much more pleasant. Cervero (2001) also found that increased infill development and less parking areas increased residential property values. In a subsequent study, the same group discovered that properties nearer to rail stations were more highly valued than those in other areas (Cervero et al. 2004). An analysis of property prices in the Santa Clara Valley in California found that commercial properties near light rail stations (within 400m) were worth 24% more, and residential properties were worth 28% more than other similar properties (Cervero and Duncan, 2002). It is clear that property values do not necessarily directly relate to or influence transit ridership; nevertheless, they are among the attributes which should be considered when comparing TODs with one another.

In some cases, individual academics have reached different conclusions in their research projects based on the different approaches or methodologies they used in their work. This was the case with “Cervero (1993) [who] concluded that proximity might play a greater role in transit use, [while] Ewing and Cervero (2001) later produced evidence to support that transit use depends primarily on local densities and secondarily on the degree of land use mixing” (Hendricks, p. 20). As previously noted, TOD neighbourhood densities are the most influential factor in transit user rates because they define the size of the market and number
of potential users – denser neighbourhoods mean more people. Land use diversity and urban design are not as important in driving transit user rates and work related travel. However these two factors impact non-work travel in terms of how many new residents move to the neighbourhood and how many visitors are attracted because of amenities located in the area. The significance of population demographics in the study of TOD neighbourhoods will be discussed in the following section.

**Demographics and Other Factors**

It is questionable whether demographics impact transit ridership levels. Many studies have tried to establish a connection between demographics and transit ridership. Some researchers believe that there is a link between low income and transit use, while others contend that there is a process of “self-selection” whereby people who are interested in taking transit choose to live in locations where transit is more accessible. It is likely that both of these effects occur, even within the same system at the same time.

Arrington and Cervero (2008) point out that generalizing about TOD income levels is more difficult than drawing conclusions about household size and lifestyle types [because] apartment housing in older TODs often was built to serve lower income, transit dependent households, and some current TOD projects still are built to attract these households (p. 24).

In a 2004 US study, Centre for Transit Oriented Development (CTOD) found that median incomes in TOD neighbourhoods were on average lower than in surrounding metropolitan areas. While lower income earners may make up
the majority of transit users within a regional system, they do not necessarily reside near the transit stations. In some cases, property prices near transit stations have become unaffordable for a large number of transit users. Gossen (2005) looked at San Francisco area TODs and found that income levels of residents living within 400m of a transit station were higher on average than in any other urban area of the city. The highest proportion of low income earners was found in areas from 800 to 1,500m from transit stations. As Evans et al (2007) astutely observed “average reported 1995 household annual income was found to be approximately $25,000 for central area TODs, $31,000 for outlying TODs, and $37,000 for non-TODs” (p. 17-19). Seemingly, these two studies produce opposing findings. However, this is not the case. Wider TOD areas have lower average household income than non-TOD neighbourhoods. As well, the immediate area surrounding the station within a TOD tends to have higher average household income than the wider TOD neighbourhood. Lastly, average household incomes of a TOD also vary depending on the TOD location in relation to the CBD.

Household annual incomes can depend on intrinsic factors, such as property values, and extrinsic factors such as how the research area was defined and how data was aggregated. However, one important correlation has been found consistently across studies: lower income households tend to own a smaller number of cars (Cervero and Duncan, 2002; Deka, 2002; Tumlin and Millard-Ball, 2003).
Deka (2002) found that the association between transit availability and car ownership was statistically significant; however, the effect was mitigated by other demographic factors such as household income and size, and the number of driver's license holders in the household. The study also found that automobile ownership rates were inversely related to transit availability in trip origin neighbourhoods. Other studies, such as the 2004 CTOD study of US households, found ownership rates of 0.9 cars per household near train stations and 1.6 cars per household in other areas. Renne (2005) found that only 37% of TOD households owned two or more cars compared to 55% in other areas. Furthermore, according to research conducted for Fannie Mae’s Location Efficient Mortgage program, vehicle ownership falls rapidly as density increases, reaching an average of just one car per household when density climbs to 20 to 30 housing units per acre. (Tumlin and Millard-Ball, 2003). The CTOD (2004) study looked at the 2000 US Census and the US national TOD database and found the following demographic trends in TOD neighbourhoods:

- Households were smaller on average than in other parts of the region (51% of households were single person),
- The average age of residents was similar to the rest of the region,
- Median household incomes were lower than in other parts of the region,
- Home ownership rates were lower than the regional average,
- Car ownership rates were significantly lower than the regional average, and
- Significantly fewer residents commuted by car.

Household income is not only related to car ownership, but also associated with household size and home ownership rates (Cervero and Duncan,
Boroski et al (2002) cited the 1996 Collingwood Village Parking Study prepared by Bunt and Associates for Greystone Properties. The Bunt study is one of the few that provide us with some research on the SkyTrain system and its ridership. The study surveyed 4,000 households around 6 stations and found higher transit ridership rates and lower car ownership rates closer to SkyTrain stations. The study also found that household income, household size, and dwelling size were more predictive of car ownership than distance from the station. This study relied on a survey to collect car ownership data. Unfortunately, this particular data set is not collected by Statistics Canada in the national census. Later in this work, census data will be used to find out if there is any correlation between the 1996 Census Mode of Transportation data (car user rates) and proximity to the SkyTrain lines. The Bunt study is a valuable additional source of information because it describes the Expo Line before the construction of the Millennium Line through data collected by a survey, rather than a national census.

Another factor, which is of significance, is property values. Property values and the type of housing available in a TOD area are most often dependent on public policy and developers’ plans for the area. Other than land use and zoning, these factors are more difficult to identify. However, some researchers have looked at how urban design impacts property prices.

Walkability was looked at as a part of the CEOs for Cities – Walking the Walk study (2009). The study scrutinized in detail at the relationship between home values and walkability. Walkability was measured using the Walk Score
algorithm which measures the number of consumer destinations/amenities within a given walking distance of a residence. The study related the Walk Score data to more than 90,000 home sales in 15 US markets, and controlled for other factors influencing property values. The study concluded that a positive correlation existed between walkability and property values in 13 of the 15 markets studied. Furthermore, the study found that that higher than normal levels of walkability add anywhere from $4,000 to $34,000 to the value of a house compared to homes with average levels of walkability. Examining the relationship between walkability and property values along the SkyTrain lines will provide an additional level of comparison between different stations and TOD neighbourhoods.

Having said this, many researchers conclude that demographics don’t necessarily influence transit ridership levels as strongly as other factors. However, we can use demographics to look for similarities between different TODs and identify what specific TODs have in common. Two of the factors require further mention now because they are qualitatively different from the previously mentioned impacts on transit ridership levels. These are self-selection and relative travel times.

Arrington and Cervero (2008) note that self-selection and slow auto trip times are more important than the other factors discussed above. Self-selection refers to the notion that individuals actively seek to live in TOD neighbourhoods because of the proximity to a transit station and other amenities provided in the area. Thus, this is an individual lifestyle choice. This notion was supported by a
survey of San Francisco and San Diego residents in which 75% of respondents living within 800m of a transit station actively looked for a residence within the TOD (Chatman, 2005).

The relative travel time on transit vs. driving is a more important predictor of ridership than any of the 3Ds (Arrington and Cervero, 2008). Further studies (CTOD (2004), Renne (2005)) also found that relative travel time has an impact; however, the scale and impact of this factor vary greatly depending on the size and extensiveness of the transit system.

Size of Study Area

Finally, as the examples noted above demonstrated, the size of the study areas varies greatly depending on the type of research. Study areas ranged from all TODs on a national scale to individual TODs. For example, Reconnecting America’s CTOD conducted research in 2004 which involved nation-wide census data in 27 metropolitan regions. The study looked at 3341 stations on fixed guideway transit systems and defined the station areas with an 800m radius around stations. Other studies, such as the Walking the Walk (2009) or Gossen’s examination of San Francisco’s BART system (2005), expanded the study area to a one mile radius around transit stations. At the other end of spectrum, is a study conducted by Bruce Podobnik (2002) in which residents at Portland’s Orenco Station were surveyed. Podobnik conducted a house level survey to find out whether the TOD project was successful in fostering a sense community for its residents and decreasing their automobile use, and how the residents have responded to living in a high density
neighbourhood. Most frequently, studies that concentrate on one particular TOD include surveys that aim to find out residents' personal attitudes towards transit and their thinking behind the decision to live in a TOD neighbourhood.

**Key Questions**

The goal of the capstone project is to evaluate similarities and differences between two SkyTrain lines. Therefore it is important that the analysis takes regional scale into account when devising the research methodology. Factors and attributes of TOD neighbourhoods outlined in the studies discussed here provide a framework for the study methodology that will be discussed in detail in the subsequent section.

Based on the factors and attributes discussed in the Literature Review section, the project will look at similar data in Metro Vancouver region to find out if neighbourhoods around the two SkyTrain lines have characteristics of TODs. Second, the Expo and Millennium Line will be analysed to find out how neighbourhoods around the two lines have developed and how they compare. Lastly, the data will show whether the opening of the Millennium Line in 2002 had a significant impact on transit ridership rates in Metro Vancouver region. As a part of this analysis the following questions will be answered.

First of all, are residential densities within 400 and 1,500m of the SkyTrain lines significantly higher than in other areas of Metro Vancouver? In terms of urban planning, have neighbourhoods around the SkyTrain stations been strategically planned with transit-oriented and transit-supportive land uses? Do
TOD neighbourhoods around the SkyTrain stations provide more amenities and services for transit riders and area residents? In terms of neighbourhood demographics, are households in the vicinity of the SkyTrain stations significantly smaller than the Metro Vancouver average? In other studies, researchers have not found a link between the average age and TOD population, but is this also case in Vancouver? TODs around North America are characterized by lower household incomes and lower home ownership rates. Based on a personal knowledge of Metro Vancouver and the pattern of residential development, I believe that a significant difference exists between the neighbourhoods adjacent to the Expo and Millennium lines. Neighbourhoods around the Expo Line are home to residents with lower incomes and a larger number of renters. On the other hand neighbourhoods around the Millennium Line have seen a large number of condominium developments in recent years that have brought in new home owners with higher incomes to the area. Similarly, due to the amount of new development, property prices around the Millennium Line should be significantly higher than around the Expo Line.

Lastly, and most importantly, it is essential to look at the impact of the SkyTrain system on car user and transit ridership rates. Has opening of the Millennium Line helped persuade car commuters to abandon their vehicles for public transit. And if so, what is the magnitude of the increase in the public transit ridership in the neighbourhoods around the Millennium Line?
CHAPTER 3: METHODOLOGY

The previous chapter reviewed various studies which analyzed different aspects and scales of TOD developments. Specific questions emerged from the literature review that led to the comparison between the Expo and Millennium Lines. Cervero and Kockelmann (1997) state that density, design, and diversity influence travel demand, but how does construction of a new transit line play into the mix? By identifying the similarities and differences between two SkyTrain lines, we can clearly measure the impact that introduction of a new line to the system has on population demographics of adjacent neighbourhoods. In order to do this, previous studies and experience will be used to define a clear methodology that will guide the analysis of the SkyTrain system in the Metro Vancouver context. Information was gathered from several data sources to build as complete of a picture that includes the majority of important TOD neighbourhood measures and identifiers.

Timeframe

Longitudinal analysis of Census data is very important in this study. Specifically, data from the 1996, 2001 and 2006 Census has been scrutinised to determine how the transit user rates changed across Metro Vancouver and SkyTrain station areas over the ten year period of the study. Since the Expo Line was opened in 1986, it is rather difficult to go back and analyse data from before that time. Another complication is that significant changes have taken place in
the way that data is collected and how Enumeration/Dissemination Areas are defined. For instance, during the 2001 Canadian Census, terms were changed from Enumeration Areas to Dissemination Areas. At the same time geographical boundaries of these areas were redrawn, but area sizes remained of similar magnitude. Several Enumeration/Dissemination Areas were removed from the calculations because they skewed the data. For example, one such area covered a very large industrial area of the city, but had no population. Specific areas are identified and mapped in the Appendix.

The 1996 Census data will be both the starting point and the benchmark against which the two other census data sets will be compared. At this point in time, the Expo Line had been in operation for ten years and neighbourhoods around those SkyTrain stations could be considered mature. In 1986 Metrotown Centre was opened and over the next ten years many areas along the Expo Line were developed. The 1996 Census data also provided a demographic snapshot of neighbourhoods around Millennium Line stations before the line was opened in 2001. The 2001 and 2006 Census data sets will be used to determine how the station areas changed, and if there were any significant differences between the two SkyTrain lines.

It is important to note that a transit strike occurred during the 2001 Census data collection period. The Canadian Auto Workers Union led a four month long strike that disrupted bus services across Metro Vancouver. Coast Mountain Bus Co. drivers were ordered back to work after the British Columbia government passed legislation in early August of 2001 (Canadian Broadcasting Corporation,
During the strike, SkyTrain services were disrupted for short periods of time. Census data showing the commuter mode of transport will provide us with an idea of how transit ridership rates were affected by the strike. While the transit strike would have had an effect on commuter patterns, it is not likely that it had a significant effect on neighbourhood demographics.

**Study Area**

Having defined the time frame, it is important to further detail the geographic boundaries. The study area is defined as Metro Vancouver (GVRD) or Vancouver Census Metropolitan Area (CMA) according to Statistics Canada data collection boundaries. Fortunately, Statistics Canada CMA boundaries are coincident with Metro Vancouver boundaries which provides for hassle free data collection and analysis.

Vancouver CMA level data provides regional averages that will be set as benchmarks. Other levels of data will be compared against these benchmarks in the study. Two sets of radii will be drawn from SkyTrain lines to define transit user capture zones. These areas will provide a more detailed level of analysis that will show data for the two SkyTrain lines and individual stations along the lines.
For the purposes of the study, transit user capture zones have been set at 1,500 and 400m. The 400m station capture zone (Figure 4) was selected as the five minute walking distance from the SkyTrain lines. As previously noted, O’Sullivan and Morrall’s (1996) research in Calgary found average walking distances to transit stations to be just over 400m. In the 2003 study of California TODs, Lund et al (2004) distributed a survey to households within the walking distance from the station (400 to 500m) and found that “over 90 percent of the surveyed rail commuters walk to rail stations” (p. 48).

Another reason for examining demographics in 400 and 1,500m radii are economic differences. Gossen (2005) found significant differences in income
levels of San Francisco residents living within the first 400m from the station and of those living further away. It must be noted that in all of the data analysis of 400m zones, Broadway (Expo Line) and Commercial (Millennium Line) stations are treated as one station zone.

**Figure 4: SkyTrain System Study - 400m Radius Capture Zone**

The 1,500m capture zones (Figure 5) for SkyTrain system were selected for two main reasons. First, in his 2001 San Francisco study, Cervero found that the majority of LRT riders who lived from 1 to 1.6km of BART stations used buses as the mode of access for the system. Those living beyond the 1.6 km mark used cars to access the stations. Unfortunately, the Canadian Census does not distinguish between different types of transit users, or account for trip linking. Therefore, we cannot determine who takes the bus and who walks to
SkyTrain stations. However, the available census data distinguishes between work-related travel modes.

Based on the Cervero’s 2001 California study, we can hypothesise that transit users within 1,500m are influenced by SkyTrain. Also, there are a very limited number of park and ride facilities next to SkyTrain stations. This means that there is a very small likelihood of individuals linking car and SkyTrain trips, and identifying themselves as a transit user during the census. Therefore, Figure 5 shows all areas in Metro Vancouver selected for data analysis. Comparison of the 1,500m zone and all of Metro Vancouver will uncover any evident differences in neighbourhood demographics and transit user rates.

The Walking the Walk (2009) study used the Walk Score online measurement tool in their data analysis. Walk Score uses a walking radius of one mile as the limit of data analysis. Since this study will be using the same tool, we must set similar parameters.

In order to achieve an even finer resolution data analysis, the two capture zones were defined even further. It is necessary to calculate the data without Downtown and Surrey neighbourhoods for several reasons. First, since the two SkyTrain lines act as a loop, it is important for reasons of comparability to only analyse the data for areas within the loop. Second, Downtown area is significantly different from other study areas in terms of urban design. And third, Downtown and Surrey areas are the opposing ends of the SkyTrain system that by its location within the system have some gravitational pulls. In addition to removing Downtown Vancouver and Surrey areas from data analysis, a small
number of stations from the Millennium Line were removed as well. In particular VCC, Renfrew, Rupert and Sapperton stations were excluded from data analysis because they were either within or very close to the Expo Line capture zone. Many residences in the vicinity of VCC are also close to the Broadway station for example, so historically transit users would have gravitated towards Expo Line. Now, they just have an additional option available to them. The case is similar with the other three stations that are linked to the Expo Line with long serving bus lines such as #16 that travels along Renfrew Street to 29th Avenue station.

Figure 5: SkyTrain System Study - 1,500m Radius Capture Zone

It is also important to note that parts of East Richmond and Annacis Island were captured within the 1,500m zones. However these areas were removed
from the data sets because it was deemed that SkyTrain transit ridership capture from these areas was very limited due to large separations and river crossings.

**Density, Diversity, Design, Demographics**

**Density**

As previously noted, available 1996, 2001 and 2006 Census data was used to examine the 400 and 1,500m capture zones around SkyTrain stations. In each case population and dwelling densities were calculated. It is important to note that in many cases Enumeration or Dissemination Areas were intersected by the overlapping radii. Since Census data is aggregated at a relatively large geographic scale, it was necessary to carefully assess if there was any possibility of data skewing. Several Enumeration/Dissemination Areas were excluded from data analysis because they had comparatively large areas, low population numbers, and only small portions fell within the transit system capture zones. Specific areas are identified and mapped in the Appendix.

**Diversity**

Land use diversity data was calculated from a 2001 GVRD Land Use Zones data set that was available through the SFU Data Library. Land use areas polygons were trimmed in cases when they were intersected by the overlapping radii of transit system capture zones. By doing this, land use areas were recalculated based on the capture zones sets and data was compared to regional Metro Vancouver figures. This is a significant difference from the Enumeration/Dissemination Area methodology. While the land use data was
trimmed to the capture zone radius, Census data was not. Enumeration/Dissemination Areas were evaluated and added to the capture zone radius if the majority of the polygon fell within the study area boundary.

Urban areas surrounding the SkyTrain lines also did not have a large abundance of specific land uses found in the database. Since these land uses covered large areas of land regionally, but were not found locally they were excluded from the calculations. Specific land uses such as Agricultural, Harvesting and Research, and Protected Watersheds were removed from calculations after the land use data was aggregated by each separate case.

The lack of 1996 and 2006 land use data prevents us from performing a longitudinal analysis that would show changes in land use over time. Nevertheless, the 2001 land use data enables us to analyse and quantify the differences between the established Expo Line TOD neighbourhoods compared to the areas around the Millennium Line.

Design

Neighbourhood urban design was evaluated by calculating walkability for the 1,500m zones. Walkability for the 1,500m zone was calculated by using the Walk Score online measurement tool (www.walkscore.com). Walk Score tool measures neighbourhood walkability based on Google Maps and Google Business Directory. Neighbourhoods are measured on a scale of 0 to 100, with the hundred being the highest possible score. Points are based on the distance from an assigned point to the closest amenity in each category. For our
purposes, SkyTrain stations were always selected as the centre point. Amenities include facilities such as community centres, schools, stores and parks. If the closest amenity is located within 400m, the maximum number of points is assigned. Points are assigned up to a distance of one mile or 1,600m, after which no points are assigned. Points are summed up equally across all categories. Data is based on the 2009 Google Maps and Business Directory sources.

This method does not account for trails or other walking paths. However, it does provide a basis for comparison of station areas along the SkyTrain lines.

Neighbourhood Demographics

Several demographic attributes can be used to identify and compare TOD neighbourhoods. As noted previously, the CTOD (2004) study identified the following demographic characteristics of TOD neighbourhoods:

- Households were smaller on average than in other parts of the region (51% of households are single person),
- The average age of residents was similar to the rest of the region,
- Median household incomes were lower than in other parts of the region,
- Home ownership rates were lower than the regional average,
- Car ownership rates were significantly lower than the regional average, and
- Significantly fewer residents commuted by car.

Based on these demographic identifiers, identical Canadian Census data attributes will be analysed for the previously outlined geography levels and time frames. Unfortunately, car ownership rates are not collected during the
Canadian Census. However, mode of transportation data provides information about residents’ commute patterns and includes the differentiation between car drivers and car passengers.

Age of residents will be analysed to find out if there is a correlation between age and residence in TOD neighbourhoods. Data will be aggregated in three groups: 0 to 19, 20 to 64, and 65 and above. By calculating the proportion of residents in these three groups, we are able to look for patterns occurring in children and youth, working age population, and senior citizens.

Data Limitations

The majority of studies cited in the Literature Review section use US TOD examples and cite US Census Data. Unfortunately, even though many demographic indices collected during the US and Canadian Censuses are identical, a small number differ.

One of the best examples is the car ownership data. In US this particular data set is collected and reported, while in Canada it is not. The proportion of car users is in no way an identical comparison to car ownership rates. However, this is the closest indicator available through Canadian Census data and can serve as a comparative indicator of car availability to an individual for their daily commute. Another indicator that is not available through Canadian Census data is the average household age. In order to compare age indicators between different TOD study areas, three age groups were created. Along with these
specific examples of missing data, data availability issues were faced throughout
the data collection.

The data collection process itself presents some limitations because Stats
Canada changed the way in which they collect data, indicators and geographic
areas from one census year to another. For example, in the 1996 Census,
median household income is available as an indicator. However, this indicator is
not available in 2001 and 2006 data sets. In order to compensate for this,
average household income was used as the only income indicator used during all
three censuses in question. In addition, significant changes in geographic data
collection boundaries occurred between 1996 and 2001. From 1996 Census,
Enumeration Areas were changed into Dissemination Areas in 2001. As well, the
identifier number for each area was changed so there was little possibility of
tracking changes in a specific area throughout the three data collection periods.
Only minor changes occurred between 2001 and 2006 Census years. Census
data is available at several geographic levels. Census Tract level was assessed
and deemed too large for adequate analysis. The most detailed block level data
set is available only for the 2006 Census and only contains a small number of
indicators: area, population, number of dwellings, and number of owned
dwellings. Therefore, Enumeration/Dissemination Area level data was chosen
for analysis. It must be noted that even though this is the most suitable data set
for analysis, data has been removed from some Dissemination Areas because of
small sample sizes and privacy concerns. The missing data did not significantly
affect the analysis since Dissemination Area data was aggregated for each
station area and capture zones. As previously noted, the most significant impact on available Census data was caused by the 2001 bus strike in Metro Vancouver. The strike severely affected transit ridership rates in the region. Two other data availability issues were noted besides the missing Census data sets.

First, the 2001 GVRD Land Use data is the only data set of such kind available through SFU Data Library. Unsuccessful attempts were made to acquire similar data for 1996 and 2006 from Metro Vancouver staff. Therefore, only the available data was analysed. Second, walkability data is only available for 2009. The Walk Score engine relies on current business listings and has no available historical records that can provide us with a picture of how the neighbourhoods changed throughout the decade. Therefore present data was analysed and used as an indicator of available neighbourhood amenities and services.
CHAPTER 4: DATA ANALYSIS

Data analysis will encompass investigation outlined in the methodology section. Density, diversity, design and demographics were analysed to establish if SkyTrain station neighbourhoods resembled the characteristics of other TOD neighbourhoods throughout North America. Furthermore, data analysis was conducted to investigate similarities and differences between the Expo and Millennium Lines. The study revealed that the Expo and Millennium Line neighbourhoods had a lot in common, especially when compared to the wider Metro Vancouver region. The similarities between neighbourhoods became clearer after the construction of the Millennium Line. Specifically, densities in TOD neighbourhoods were significantly higher than in other Metro Vancouver areas. However, areas’ population demographics revealed some differences. The Expo Line neighbourhoods were home to a larger proportion of lower income residents compared to the Millennium Line neighbourhoods. Most importantly the analysis showed that opening of the Millennium Line had an impact on neighbourhood demographic changes and a significant increase in transit ridership.

Density

Population density was measured by calculating the number of residents in Census Enumeration and Dissemination areas per square km. Population densities in Metro Vancouver have grown slowly over the period covered by the
study at a rate of 13% between 1996 and 2006 (Figure 7). Nevertheless, population densities across the Metro Vancouver area remain below 1,000 people per square km (Figure 6). Importantly, it must be noted that population densities around SkyTrain stations are significantly higher than in Metro Vancouver as a whole. However, the population densities have also experienced greater changes than the city-wide rates, surprisingly in both directions. Population densities in the immediate vicinity (400m radius) of the Expo Line are very high at approximately 5,000 people per square km, while densities in the wider capture zone (1,500m radius) were slightly lower at approximately 4,000 people per square km. These densities were more than four times higher than the regional densities, and more than double the densities found in areas around the Millennium Line. The Expo Line data indicates the densest neighbourhoods are found in the immediate station vicinity, as is common with modern TOD planning principles. However, this is not the case with the Millennium Line stations. The Millennium Line data indicates that the immediate station vicinity areas remain relatively underdeveloped and underutilised compared to the wider capture zones (1,500m radius). The 400m capture zones along the Millennium Line recorded population densities of approximately 1,400 residents per square km in 2006, while the wider 1,500m capture zones recorded only slightly higher densities of approximately 1,800 residents per square km.
Lower population densities along the Millennium Line are not necessarily only an indicator of residential underdevelopment, but also an indicator of possible alternative land uses. However, in order to establish this we will need to look at the population density data along with land use data in the following section. As previously noted, population densities across the Metro Vancouver region have on average increased by about 13% between 1996 and 2006. Population density changes in the established Expo Line neighbourhoods were not as impressive, ranging from 0.8% in the immediate station vicinity to 7.2% in the wider Expo Line ridership capture zone during the same period. The data indicates that neighbourhood densification occurred in the first half of the decade after which the densities started declining at a low rate (Figure 7).
Population densities also decreased in the immediate vicinity of Millennium Line at a rate of 7%, and rate of approximately 3% in the wider capture zone between 1996 and 2001. There are two possible reasons for the population changes along the Millennium Line corridor. First, a small number of residents could have been displaced by the construction of the SkyTrain line itself along with new commercial and residential developments in the surrounding areas prior to 2001. After the completion of these projects, we see residents returning to the neighbourhoods and population increasing. Second, some minor shifting in the Enumeration/Dissemination Area boundaries between the different Census years could also account for the changes. Census boundaries were redrawn and shifted in each of the three Census collection periods and these could have impacted the calculations, especially in large geographic areas found along some sections of the SkyTrain lines.
Nevertheless, the most important revelation is that even though population densities in the wider capture zone along the Millennium Line only increased by 1%, they increased by approximately 32% in the immediate vicinity of the stations between 1996 and 2006. This sharp increase in population densities shows the magnitude of the development in areas less than 400m away from new Millennium Line stations. As previously noted, the population decreased in the first half of the decade in the same area at a rate of approximately 7%. In the second half of the decade, after opening of the Millennium Line, population skyrocketed at a rate of approximately 42%. Even though the magnitude of this increase is large, population densities along the Millennium Line remain much lower than along the Expo Line. Furthermore, the population increases are only limited to a small number of station areas whilst new residential developments were built on either greenfield or brownfield sites. Large tracts of land surrounding the Millennium Line remain undeveloped, or zoned to transit incompatible industrial land uses as will be shown in the subsequent section.

Diversity

The 2001 Metro Vancouver (GVRD) land use data provides us with a snapshot of the regional situation shortly after the Millennium Line was opened. Unfortunately, land use data for earlier and later time periods was not available in GIS format that was required to conduct the necessary data analysis. This means that our analysis will not be longitudinal and we will not be able to get a better understanding of how the land uses changed in the areas around the two SkyTrain lines throughout the decade. However, the available data does provide
us with adequate level of detail needed for a comparison between the Expo and
Millennium Lines, and the wider Metro Vancouver region. This particular data set
would be valuable to any future research on land use changes in the Metro
Vancouver region.

As noted in the methodology section, large areas of land such as
Agricultural, Harvest and Research, and Protected Watersheds were excluded
from the calculations. These land uses covered more than 37% of land
regionally, but were not found in areas around the SkyTrain lines and were
skewing some of the calculations. As Metro Vancouver covers a large area of
lands outside of urbanised areas, it encompasses large amounts of undeveloped
lands. These lands are zoned as Open and Undeveloped, and Recreation and
Protected Natural Areas. Together they account for more than 35% of all Metro
Vancouver land areas. Less than one third of Metro Vancouver lands are used
for transportation, institutional, commercial and residential land uses. The
situation is quite different in highly urbanised areas such as the neighbourhoods
found around the SkyTrain Lines. For the purposes of further discussion, all land
use figures quoted are taking into account a total excluding the three above
mentioned land uses.

A small amount of land remains open and undeveloped along the
SkyTrain lines. The 1,500m Expo Line capture zone contained approximately
3% of undeveloped land. Similarly, the 1,500m Millennium Line capture zone
contained approximately 7.5% of undeveloped land. These proportions are
much lower than the regional 23%. Discrepancies in the availability of
Recreation and Protected Natural Areas between the local and regional level are even higher. In Metro Vancouver, almost 35% of land is maintained under this land use. Comparatively, only a small portion of land remains zoned under this land use along the SkyTrain lines. Less than 9% of land is zoned for Recreation in the 1,500m Expo Line capture zone, while the number is somewhat higher around the Millennium Line at approximately 14%. Inversely, as it should be expected, a larger proportion of land is used for residential, commercial, industrial and institutional land uses along the SkyTrain lines than in the wider Metro Vancouver region. For example, while only 19% of the Metro Vancouver area is taken up by Single Family developments, approximately 55% and 35% of 1,500m Expo and Millennium capture zones respectively are taken up the by the same land use (Figure 8).

Figure 8: Metro Vancouver Residential Land Use Split, 2001
On a more detailed level, the comparison between the land uses around the two SkyTrain lines sheds some additional light on the differences between these neighbourhoods. In the wider 1,500m capture zone Expo Line has a much larger amount of land taken up by Single Family residential land uses at approximately 55%, compared to 35% around the Millennium Line. Similarly, High Rise Apartment developments account for denser development along the Expo Line taking up 1.8% of land, compared to only 0.8% along the Millennium Line. Differences in the proportion of other land uses between these two lines are not that great with the exception of Industrial land uses. The proportion of Industrial land uses along the Millennium Line is more than 3 times higher than that of the Expo Line with approximately 19% compared to 6% respectively.

Figure 9: Metro Vancouver Industrial and Commercial Land Use Split, 2001
Differences between the 400m and 1,500m capture zones around the SkyTrain stations are also significant and have to be addressed. As expected along the Expo Line, land uses in the immediate vicinity of the stations were characterised by higher densities. While the residential land use remained dominant, the margin was much lower compared to Metro Vancouver and other study areas. Specifically, the proportions of Commercial, High-rise Apartment, and Low-rise Apartment land uses in the 400m capture zone were double the proportions in the wider 1,500m zone. Inversely, the proportion of Industrial and Single Family land uses was lower. Surprisingly, this is not the case with land uses around the Millennium Line.

Differences in the proportion of residential land uses in two capture zones around the Millennium Line are similar to the ones found in the areas surrounding the Expo Line. However, the 400m capture zone around the Millennium Line contains approximately 23% and 34% of Commercial and Industrial land uses respectively. By comparison, these numbers are much lower in the wider 1,500m capture zone at 7% and 19% respectively. Considering the fact that the Expo Line has been in operation for more than 15 years at the time when the Millennium Line was opened, it should be expected that there were changes in the land uses over that 15 year period. Most notably, some of the sites around Joyce and Edmonds SkyTrain stations were developed and densified at that time. Unfortunately, historical land use data is not available to us that would provide us with a better picture of how the land uses changed. The 2001 GVRD Land Use data does bring up some interesting questions though.
Was there a specific strategic thinking behind locating new Millennium Line stations in highly industrialised and transit incompatible areas? Were these areas seen as potential future redevelopment sites, and if so how did this decision relate to the regional industrial lands protection policy?

On the other hand, the large proportion of Commercial land uses can be explained with the presence of two large regional shopping malls, Brentwood and Lougheed. In terms of transportation planning, even though these types of land uses are not the most desirable in a TOD neighbourhood, shopping malls are large trip generators (Lund et al, 2004). For example, regional shopping malls attract shoppers who live in the vicinity of another mall in what is referred to as “cross shopping” (Nelson et al, 2001). Therefore, it is logical to make them more accessible by transit and use them as transit hubs linking the SkyTrain and bus systems. Even though at first thought an oversupply of commercial space in a TOD might not be a good idea, it is good to have one or two regional shopping centres adjacent to the transit line because they act as transit ridership generators. In a TOD with a shopping mall, most residents will travel to the CBD for work, and other riders will use transit to visit the TOD’s commercial amenities and services.

**Design**

Walkability of neighbourhoods in 2006 is based on Walk Score online measurement tool (www.walkscore.com). This tool is a good indicator of availability of amenities and services in a particular neighbourhood. In turn, this
translates into how easy it is for residents to conduct most of their daily chores in proximity to their residence or if they need to travel further to fulfill their needs.

For comparison purposes, all of the SkyTrain stations in Metro Vancouver area were included in the data analysis. Predictably, Downtown Vancouver stations scored the highest (above 90 points) having a large number of amenities and services in a highly dense urban core. Interestingly, with the exception of Scott Road station, Surrey stations achieved above 65 points in walkability measurements (Figure 10). This is higher than the average of all SkyTrain station locations with average walkability of 66 points. The relatively high score of these three Surrey stations is likely due to a large concentration of shopping and other commercial amenities close to the stations. For example, three stations on the Expo Line outside Downtown Vancouver score 87 points: Broadway, Metrotown and Surrey Central. The highest scoring Millennium Line station is Brentwood with walkability of 73 points.
In terms of the specific study areas analysed within the 400m and 1,500m capture zones, the walkability average falls to 59 points. Stations along the Expo Line have a better availability of services than stations along the Millennium line averaging 64 compared to 52 points respectively. Four stations on the Expo Line (Broadway, Patterson, Metrotown and New Westminster) score well above the regional average, while only three stations on the Millennium Line (Gilmore, Brentwood, and Lougheed) score above the regional average. Stations located in industrial areas such as Sperling, Lake City and Braid lower the average walkability value of the Millennium Line neighbourhoods. It must be noted that three stations (Metrotown, Brentwood and Lougheed) that score particularly well in walkability analysis also have regional shopping malls adjacent to the SkyTrain stations. Even though local residents can find many services located in these shopping malls, these centres are not necessarily the most desirable in terms of
urban design. These large buildings can hinder connectivity and access within the neighbourhood since residents can only walk through them at specific times for example. Furthermore, they are often surrounded by large parking areas that are deemed undesirable by pedestrians (Cervero, 1995). One of the best examples of a large parking lot adjacent to a SkyTrain station is the Brentwood Station (Millennium Line) shown in Figure 11.

Figure 11: Brentwood Station Area

Demographics

Neighbourhood demographics are a great indicator of changes occurring to that particular area. Furthermore, demographics can be used to look at differences between city neighbourhoods. The following demographic characteristics and attributes will be used to compare neighbourhoods adjacent
to the Expo and Millennium lines to each other and the wider Metro Vancouver area:

- Average Number of People per Household
- Proportion of Population by Age
- Average Household Income
- Percentage of Owned Dwellings
- Percentage of Car Users
- Percentage of Public Transit Users

For each of the variables with the exception of Proportion of Population by Age, percentage change was calculated for periods between 1996 to 2001, 2001 to 2006, and 1996 to 2006. By segregating data in these three intervals, we are better able to analyse what changes occurred in the neighbourhoods prior to the construction and opening of the Millennium Line in 2002 and afterwards. In addition to analysing data between each of the Census years, examining the same data over the whole decade enables us to eliminate any possible data collection errors. In particular, this is the case with the car user and public transit ridership data that was affected by the 2001 bus driver strike in Metro Vancouver. The data analysis revealed similarities between the Expo and Millennium Line TOD neighbourhoods. Even though significant differences were noted in the magnitude of certain indicators, the study areas were characterized by lower average household incomes and higher proportion of transit users than the Metro Vancouver region.
**Average Number of People per Household**

The Average Number of People per Household is commonly used as the indicator of household size. It is important to examine whether the TOD households are smaller in comparison to the Metro Vancouver region because this it is linked to other indicators such as household income, car and home ownership rates (Cervero and Duncan, 2002).

**Figure 12: Average Number of People per Household**

The average number of people per household is relatively even throughout the Metro Vancouver region. Throughout the decade between 1996 and 2006 average number of people per household increased at a rate of 1% across the region (Figure 13). Even though the neighbourhoods in the 400m capture zone have slightly lower average number of people per household compared to the wider 1,500m capture zone, these differences are negligible.
The one thing worth noting is that the average number of people per household grew at a greater rate in neighbourhoods around the Expo Line than around the new Millennium Line. The average number of people per household in the 1,500m capture zones grew at a rate of 9% near the Expo Line, while it only grew at 5% near the Millennium Line. Slight decreases in the average number of people per household were recorded in three of the areas in the second half of the decade. It must be noted during the first half of the decade, the rate of change in the TOD neighbourhoods was much higher than 1% percentage change recorded in Metro Vancouver. A possible cause for this could be the much lower growth of the dwelling values that attracted additional residents to the TOD neighbourhoods during the same time frame.

Figure 13: Percentage Change in Average Household Size
Population by Age Group

The CTOD (2004) study found that the average age of TOD residents did not vary across the United States. Having said that, how do age groups in SkyTrain TOD neighbourhoods compare to Metro Vancouver?

Changes in the average age of the population were comparable across all of the capture zones in relation to the wider Metro Vancouver region. From 1996 to 2006, all of the analysed areas recorded a drop in the proportion of residents under 19 years of age. A change of 1% between each national census was recorded for the under 19 age group across Metro Vancouver (Figure 14). All of the capture zones adjacent to the SkyTrain lines experienced similar declines of 1 to 1.5% in the proportion of youths between censuses. However, the most notable change occurred in the 400m Millennium Line capture zone between 2001 and 2006. In the five years after opening of the Millennium Line, proportion of youths in the capture zone decreased by 4%.
At the same time areas around Millennium Line experienced a greater increase in the proportion of senior citizens than across the Metro Vancouver region. Another fact must be noted. In all census years, all of the areas adjacent to the SkyTrain lines had a lower proportion of children and teens compared to the Metro Vancouver region. On average, the proportion of youths in SkyTrain neighbourhoods was by 3% lower than the regional average.

**Average Household Income**

As noted previously, average household income is linked to other indicators such as the average household size, car and home ownership rates (Cervero and Duncan, 2002). The average household income indicator was used in the analysis because the median household income was not available for all three Census periods. The 2004 CTOD study found that median household
incomes were lower in the TOD neighbourhoods than metropolitan regions across the United States. Therefore, it is crucial to find out whether the SkyTrain TOD neighbourhoods have this in common with other North American TODs.

In terms of average household income, several significant facts were revealed during the data analysis. In 1996, average household income in Metro Vancouver was $48,950. As expected, income levels in the neighbourhoods around the Expo Line were lower than the regional average. Average household income in these neighbourhoods remained far lower than the regional averages throughout the decade between 1996 and 2006. In 1996, average household income was 18% lower in the 400m capture zone and 12% in the 1,500m capture zone compared to the regional average. This income gap continued to grow throughout the decade. In 2006, average household income was 26% lower in the 400m capture zone and 20% in the 1,500m capture zone compared to the regional average. It is also important to note that throughout this period, income levels in the 400m capture zone remained on average 7% lower than income levels in the wider 1,500m capture zone around the Expo Line. The data indicates that in neighbourhoods around the older Expo Line lower income individuals tend to live closer to the transit line.
In terms of percentage change in the average household income, neighbourhoods around the Expo Line experienced smaller changes than those recorded in Metro Vancouver. Between 1996 and 2001, average household income increased by 29% (Figure 16). During the same period, incomes increased by 20% in the 400m capture zone and by 19% in the wider 1,500m capture zone. In the second half of the decade between 2001 and 2006 income growth slowed down to 16% in Metro Vancouver. Growth in the neighbourhoods during this time was at a comparable level with incomes increasing by 13% in the 400m capture zone and by 15% in the wider 1,500m capture zone.

On the other hand, the situation in the neighbourhoods around the Millennium line was quite different. In 1996, prior to the construction and opening of the Millennium Line, income levels in the areas around the planned transit line
were slightly higher than the regional average. Average household income in the 400m capture zone was 8% higher than the regional average, while the income levels in the wider 1,500m capture zone were 4% higher than the regional average. After the opening of the Millennium Line in 2002, demographic picture of the neighbourhoods changed. Between 1996 and 2001, average household incomes in the neighbourhoods adjacent to the Millennium Line grew at a smaller rate than the regional income levels. As previously noted, average household income in Metro Vancouver increased by 29% between 1996 and 2001. During that period, incomes increased by 11% in the 400m capture zone and by 16% in the wider 1,500m capture zone. This rate of growth was not only lower than the regional rate, but also lower than the rate of growth experienced in neighbourhoods adjacent to the Expo Line. By 2001, average household income in Millennium Line neighbourhoods was 7% lower in the 400m capture zone and 6% in the 1,500m capture zone compared to the regional average. Between 2001 and 2006 things changed in the areas adjacent to the new Millennium Line. Percent change in the average household income of 21% was recorded in the 400m capture zone, compared to the 18% in the 1,500m capture zone. The 3% higher growth rate in the inner capture zone meant that by 2006, the average household incomes in these areas were for the first time higher than those of the 1,500m capture zones. In the 2006 Census, the 400m Millennium Line capture zone averaged household incomes of $71,000 compared to $70,000 in the 1,500 capture zone (Figure 15). New developments in the latter part of the decade brought in new and wealthier residents to the areas near the Millennium Line.
The increase in the average household income levels in areas closer to the Millennium Line stations are in line with Gossen’s (2005) findings in San Francisco. On average, the income levels were not higher than the Metro Vancouver average. However, I suspect that if we were to analyse specific neighbourhoods where new developments were concentrated, we would find significantly higher income levels than the regional average.

On the other hand, the average household income levels in the areas around the Expo Line are similar to the findings of Evans et al (2007). The differences in income levels between the Expo and Millennium Line neighbourhoods are likely partly due to the age and type of housing found in these areas. However, the scope of the study and quality of available data does not provide us with the ability to correlate these two factors. Nevertheless, the
The most important outcome of the income level analysis is that areas around the SkyTrain lines have lower average household incomes than other parts of Metro Vancouver. Furthermore, these areas also recorded a far lower rate of income growth at approximately 35% compared to the regional average of 49%. Between 1996 and 2006, household income in the Millennium Line capture zones went from being above the regional average to below it.

**Dwelling Ownership**

The 2004 CTOD study also found that home ownership rates in TOD areas were significantly lower than in other metropolitan areas. As such, this is another important identifier of a TOD neighbourhood. It is important to examine this data in the Metro Vancouver context, but also look for possible changes during the study period. While the Expo Line neighbourhoods contain a higher proportion of older stock rental housing, new developments around the Millennium Line have been characterized by high rise condominium developments.
In terms of dwelling ownership in Metro Vancouver region, for the most part, rates increased constantly between 1996 and 2006. Throughout the decade regional ownership rate increased by 9.5%, rising from 59% in 1996 to 65% in 2006 (Figure 18). In 1996, Metro Vancouver dwelling ownership rate was at 59% and higher than in any SkyTrain capture zone with the exception of the 400m Millennium Line capture zone where 61% of residents owned their dwellings. Over the next decade the situation changed and all of the neighbourhoods around the SkyTrain lines recorded lower dwelling ownership rates than the Metro Vancouver region.
Between 1996 and 2001 modest increases in the percentage of owned dwellings were recorded. Regionally the rate increased by 2.6%, while the rate of owned dwellings decreased in neighbourhoods around the Millennium Line. On the other hand, the ownership rate increased by 7% in the Expo Line 400m capture zone and 1% in the 1,500m capture zone. Rates continued to increase in the second half of the decade between 2001 and 2006. Interestingly, dwelling ownership rates increased the most around the Expo Line, while the recorded growth in neighbourhoods around the Millennium line was similar to the regional growth. Overall, between 1996 and 2006 neighbourhoods around the Expo Line experienced the greatest increase in the percentage of owned dwellings. Throughout the decade, the proportion of owned dwellings around the Expo Line increased by 23% in the 400m capture zone and 12% in the 1,500m capture zone.
zone. During the same time period, proportion of owned dwellings around the
Millennium Line increased by 2.7% in the 400m capture zone and 7.6% in the
1,500m capture zone. Despite the high growth in the proportion of owned
dwellings, the regional rate remained higher than the ones in the SkyTrain
neighbourhoods.

As previously mentioned, by 2006, dwelling ownership rate in Metro
Vancouver reached 65%. During the same census, the Millennium Line 1,500m
capture zone recorded a slightly lower ownership rate of 62%. On the other
hand, the Expo Line 1,500m capture zone recorded a much lower ownership rate
of 54%. These findings confirm results of other studies that indicate that home
ownership rates in TOD neighbourhoods are lower than the regional averages.

**Dwelling Values**

In terms of the average dwelling values, prices increased throughout the
decade in the Metro Vancouver region. Between 1996 and 2001, the Metro
Vancouver average dwelling values increased at a humble 6%. During the same
period all of the neighbourhoods around the SkyTrain lines experienced a drop in
property prices. The highest drop in prices of 8.6% was recorded in the
Millennium Line 400m capture zone. It is possible that property prices in this
area were devalued due to the construction of the Millennium Line.
In the second half of the decade, property prices increased across the region. Between 2001 and 2006, the highest increase in property prices of 86% was once again recorded in the Millennium Line 400m capture zone. During the same period, regional property prices grew at approximately 77% (Figure 20). The higher than average growth can be attributed to the new condominium developments around several Millennium Line stations.

After averaging growth rates throughout the study period, it was established that property prices in Metro Vancouver region grew by 87% in the ten year period. Property prices in SkyTrain neighbourhoods increased at a slightly lower rate throughout the same period. Most importantly, property prices around the Expo and Millennium lines increased at similar rates. Property prices within the 400m capture zone increased at approximately 70% around both SkyTrain lines. At the same time, property prices in the Expo and Millennium
Line 1,500m capture zones increased by 74.5% and 76.5% respectively. While the property prices are not generally used to identify TOD neighbourhoods, they are an indicator of changes. As noted the high increase in property prices in the immediate area adjacent to the Millennium Line between 2001 and 2006 can be attributed to new developments around the stations.

**Figure 20: Percentage Change in Average Dwelling Value**

![Percentage Change in Average Dwelling Value](image)

**Transportation Modes**

Mode of transportation is the most important demographic indicator available to us through the Census data that will indicate changes that are occurring in a neighbourhood as a result of a new transit line coming into operation. As previously noted, Expo Line was opened in 1986 and was in operation for ten years before the 1996 Census which is the starting point of our
study. Furthermore, a transit strike took place in the summer of 2001 during Census data collection that skewed the transit data in Metro Vancouver region. Finally, the Millennium Line was opened in 2002 and had no impact on the transit ridership data collected in 2001. However, the line had a significant impact on the 2006 Census data as the results will show. As noted previously, car ownership data is not collected in the Canadian Census and therefore both car and transit user data was analysed. The 2004 CTOD study found significantly lower car ownership rates in US TODs than the regional average. It is important to find out whether the Millennium Line was successful in attracting new transit ridership and persuading some commuters to switch from cars to SkyTrain.

Figure 21: Percentage of Car Users as the Mode of Transportation

First, we will look at the car user data as a mode of transportation to get to and from work in the Metro Vancouver region. This data is aggregated from car
driver and car passenger data available through the Canadian Census. Second, we will look at the public transit ridership data collected through the Census.

In terms of the proportion of car users in the Metro Vancouver region, numbers have remained relatively consistent throughout the research period. In 1996, 77% of people used a car to get to work (Figure 21). Neighbourhoods around the Expo Line recorded only 66% of residents who drove to work. On the other hand in neighbourhoods adjacent to where the Millennium Line was going to be built 81% of residents drove to work. There is no specific indicator as to why the proportion of car users was higher in the Millennium Line 1,500m capture zone than in the Metro Vancouver region. However, it should be noted that if we recall the average household income comparison, these areas were slightly wealthier than the Metro Vancouver regional averages. As well, there were no significant differences between the 400 and 1,500m capture zones around the future Millennium Line. However, the differences between the two Expo Line capture zones were quite significant.

In 1996, neighbourhoods within 400m of Expo stations had the smallest proportion of residents who used cars to get to work. Only 60% of residents in the 400m capture zone drove to work compared to 66% of residents in the 1,500m capture zone. The number of people who drove to work increased by 2001, primarily because of the effects of the transit strike that took place in Metro Vancouver in the summer of 2001.

Between 1996 and 2001, regional percentage of car users increased by almost 3% (Figure 22). Similar increase in the proportion of car users was
recorded in the 1,500m capture zones of both the Expo and Millennium lines. On the other hand, neighbourhoods within the 400m capture zone of both lines recorded increases of less than 1% in the proportion of car users. This is not entirely surprising when looking at the Expo Line since SkyTrain remained in operation throughout most of the strike period, operated by company management. However, this is somewhat surprising when looking at areas around the future Millennium Line since it did not come into operation until a year after the strike. Unfortunately our data does not provide any clues as to why the number of car users in this area only marginally increased during the strike. In order to evaluate the impacts of the new Millennium Line we will have to look to the 2006 Census data.

Between 1996 and 2006, the proportion of car users in Metro Vancouver decreased by approximately 3% to a rate of 74%. The proportion of car users decreased by an even larger rate in SkyTrain adjacent neighbourhoods. Two trends emerge from the data. First, the decrease in the proportion of car users in the 1,500m capture zone was higher than in the 400m capture zones around both SkyTrain lines. Second, the decrease in the proportion of car users in the capture zones around the Millennium Line was higher than in the areas around the Expo Line. The proportion of car users in the 400m capture zones of the Expo and Millennium lines decreased by 9% and 16% respectively. At the same time, the proportion of car users in the 1,500m capture zones of the Expo and Millennium lines decreased by 7% and 12% respectively. These facts indicate that the proximity to a transit line does have an impact on decreasing the number
of individuals who drive to work. Public transit data from the same period validates the decrease in the proportion of car users and provides some possible clues to the process of “self-selection” occurring in new developments around the Millennium Line.

Figure 22: Percentage of Public Transit Users as the Mode of Transportation

In 1996, 14% of Metro Vancouver commuters took transit to work on a daily basis. A slightly smaller proportion of commuters in the neighbourhoods around the future Millennium Line chose transit as their transportation mode as shown in Figure 22. On the other hand, a large proportion of individuals residing around the Expo Line commuted by transit to work. Most notably, 30% of commuters in the 400m capture zone of the Expo Line took transit to work, a rate more than double the Metro Vancouver figure. A slightly smaller proportion of 26% of commuters in the 1,500m capture zone used transit. As previously
noted, almost all of the areas of the city were impacted by the transit strike and transit ridership rates are severely understated in the 2001 Census data. However, by 2006, transit ridership recovered and the percentage change in the 1996 to 2006 is indicative of the impact that the Millennium Line had on transit ridership in the region and neighbourhoods around the new line (Figure 23).

Between 1996 and 2006 transit ridership increased in Metro Vancouver and neighbourhoods around the SkyTrain lines. While Metro Vancouver experienced a growth of 16.5% in the percentage of commuters who took public transit to work, neighbourhoods around the SkyTrain lines experienced an even greater rate of growth. In 2006, 16% of commuters in the Metro Vancouver region used public transit. Within the 400m Expo Line capture zone, 38% of commuters took transit, an increase of 23.5% from 1996. The wider 1,500m capture zone experienced a slightly smaller growth of 19%, rising to figure of 31% of commuters who took transit. In relation to the growth seen in the Metro Vancouver region and around the Expo Line, the increase in the proportion of commuters who used public transit close to the Millennium Line was even more impressive.

Between 1996 and 2006, 69% more commuters started using transit in the 1,500m capture zone of the Millennium line. By 2006, the proportion of commuters who used transit reached 22%, surpassing the Metro Vancouver regional average. Nevertheless, the most telling figures are seen in the 400m capture zone of the Millennium Line. During the same period, the percentage of commuters who used public transit increased by 105%, more than doubling from
1996 figure of 12%. In 2006, approximately 25% of commuters living in the immediate vicinity of the Millennium Line took transit to work. Even though the proportion of commuters who use public transit in the areas adjacent to the Millennium Line is still significantly lower than in the Expo Line neighbourhoods, the impact of the new transit line has been tremendous in the area.

Several findings must be reiterated at this point in time. Differences can be noted between the Expo and Millennium line neighbourhoods, especially in the 1996 to 2001 period. For example, the Expo Line neighbourhoods had a significantly lower proportion of children, whereas the Millennium Line showed rates more in line with the Metro Vancouver averages. This changed after 2001 when the neighbourhoods around the SkyTrain lines became more similar to one another. Similarly, dwelling ownership rates in the first half of the decade were
lower around the in the Expo Line neighbourhoods than the Millennium Line
neighbourhoods. However, this changed between 2001 and 2006 when dwelling
ownership rates significantly increased in the Expo Line TOD neighbourhoods.
Nevertheless, one difference remained constant throughout the study period.
The Expo Line TOD neighbourhoods have been characterized by lower average
household incomes compared to the Millennium Line areas that are in line with
the Metro Vancouver averages.

Taking into consideration population densities and car user rates in the
Millennium Line neighbourhoods, several things can be concluded. Considering
the fact that there was not a significant increase in population density in the
1,500m capture zone of the Millennium Line between 1996 and 2006, the new
Millennium Line contributed to the modal shift from cars to public transit in a
significant proportion of commuters. During the same period of time, population
density in the 400m capture zone of the Millennium Line increased by
approximately 32%, indicating significant developments and influx of new
residents to the area. Considering this and the fact that the proportion of car
users in the two Millennium Line capture zones decreased at a relatively similar
rate, one can conclude that a majority of new residents in the 400m capture zone
are transit commuters. This particular set of data shows that a large proportion
of residents who moved into the new developments in the vicinity of the
Millennium Line did it through “self-selection” because they wanted to live in a
TOD neighbourhood.
Recommendations for Future Research

Several data collection methodologies were considered for the project but were not used in order to keep the scope focused. Two of these data analysis tools are discussed in the subsequent paragraphs.

Figure 24: Analysis of Historical Orthographic Imagery

First valuable tool that could be used in future TOD studies is the historical satellite imagery available in the Google Earth software. This tool enables academics to quickly look through different stages in the development of a TOD neighbourhood and identify specific changes occurring in time. As the above example shows, one can analyse images that show how an area looked like before and after the construction of a transit station. Generally, the available imagery resolution is of high quality that enables the viewer to identify important urban design features such as sidewalks and bus stations which contribute to neighbourhood connectivity. Furthermore, specific developments analysed to
find out how land uses have changed on individual plots. Even though this methodology is imperfect, one could easily recognize if the land use changed from an industrial one to a residential one by looking at the parking lots. For example, industrial parking lots would have a large number of trucks, whereas residential parking lots would have a small number of cars. Similarly, Microsoft's www.bing.com could be used to provide an additional layer of information.

Figure 25: Example of Bird's Eye View Imagery

Bird's eye view imagery available through www.bing.com enables the viewer not only to identify specific land uses, but also to measure the scale of developments and buildings. While one can only measure the footprint of a building from an orthographic photo, buildings heights can be measured from the
bird’s eye view imagery. This enables the user to get a better sense of the
development density within a TOD neighbourhood and an in-depth knowledge of
how different urban elements relate to one another. Of course, even though the
data coverage is very good in North America, there are some limitations to using
this data because it is not readily available in all areas.

In addition to the two provided examples, academics could also use the
Google Streetscape imagery to analyse TOD neighbourhoods and identify
various features from the ground level view. Google Streetscape imagery is
recorded from a truck driving down a given street and provides the viewer with a
360 degree image. These images provide a good amount of detail that show the
urban environment from a viewpoint very close to the one of a typical pedestrian.
It is important to note that none of these methodologies are equal substitutes for
on-the-ground research, but can be valuable tools that enable researchers to
review a large number of TOD neighbourhoods and zero in on specific case
study areas that merit additional attention.
CHAPTER 5: CONCLUSIONS

The goal of the capstone project was to evaluate similarities and differences between the Expo and Millennium lines, and trace what changes were induced by the opening of the Millennium Line. A series of attributes and indicators describing TOD neighbourhoods identified in the Literature Review section are grouped based on Density, Diversity, Design and Demographics.

TOD neighbourhood density was analysed based on population densities calculated from available Census data. Population densities in neighbourhoods around the SkyTrain lines were higher than the Metro Vancouver average. However, densities along the Expo Line were four to five times higher than Metro Vancouver average. These densities are an indicator of mature TOD neighbourhoods developed around the Expo Line stations since it opened in 1986. An indicator of new development and densification around the Millennium Line stations is the increase of more than 40% in population density between 2001 and 2006.

TOD design was analysed by assessing the neighbourhood walkability through the Walk Score online tool. The walkability and the number of available amenities in neighbourhoods around the Expo Line were significantly higher than in neighbourhoods around the Millennium Line. This can be attributed to two factors. First, neighbourhoods around the Expo Line are well established communities in comparison to some of the new developments around the
Millennium Line. Therefore they have a larger number of businesses and services available to local residents. As previously mentioned, the Expo Line study areas also have more than double population densities compared to the Millennium Line. These higher densities demand more services, but also provide efficiencies of scale for many community services and amenities that can be located in closer proximity to a larger number of users. Lastly, as the diversity analysis will show, there is a correlation between land use and amenities.

TOD diversity was assessed through a GIS land use analysis. The 2001 GVRD Land Use data shows several significant differences between the Expo and Millennium Line. First of all, neighbourhoods around both lines are much denser than the Metro Region. Regionally, more than half of all land is undeveloped and dedicated to recreational purposes or placed in nature reserves. In neighbourhoods around the SkyTrain lines, this proportion varies between 10 and 20%. In particular, industrial and commercial lands take up a much larger proportion compared to the regional level. There are two significant differences between the Expo and Millennium lines. First, the Expo Line neighbourhoods have more residential land (especially higher density) than the Millennium Line areas. Second, the Millennium Line neighbourhoods have more commercial land and more than triple the amount of industrial land compared to the Expo Line areas. The large amount of industrial land along the Millennium Line is surely a factor that plays a role in decreasing the neighbourhood walkability score. Another significant fact is that areas within 400m from the SkyTrain lines have significantly higher residential densities than the wider
1,500m study areas. This particular data could be used in future studies to find out how the neighbourhoods changed over time.

Neighbourhood demographic data shows that the Expo Line neighbourhoods have the same characteristics as other TOD neighbourhoods around North America. These neighbourhoods are home to lower income residents with larger proportion of rental housing. Furthermore, these neighbourhoods have slightly smaller households with a lower proportion of children and teenagers. Lastly, the closer an area is to a transit station, the more pronounced these indicators are.

On the other hand, neighbourhoods around the Millennium Line have more similarities with the Metro Vancouver region. However, the 2006 data is indicating a shift in neighbourhood demographics towards formation of TODs. One uncharacteristic fact that stands out is that there is a rather high proportion of home owners in the 400m Millennium Line capture zone. New condominium developments around the transit line have attracted home buyers with higher incomes. Most importantly the car user data indicates that since the Millennium Line started operating there has been a shift from car commuters to public transit riders. Particularly strong increase in the proportion of public transit in the 400m Millennium Line capture zone shows that a large number of new residents in the area have chosen the area through “self-selection”. In other words, these residents have sought out to live in TOD neighbourhoods near good transit services.
Several important limitations of the study must be recalled. For example, while the US Census collects data on car ownership, the Canadian Census does not. This particular data would be useful for future analysis and comparison with transit ridership data. Furthermore, Canadian Census data has significantly changed over time both in terms of the collected data and the geographic boundaries. Most importantly, the most useful data for transportation and urban planning analysis should be provided at a smaller geographic scale. A larger number of available indicators on a Block level would enable the researchers to analyse in more detail how the TOD neighbourhoods change as we move further away from transit stations. It is important to note that in future studies, the scope could be increased to conduct an analysis on a station by station level. Such detailed analysis would reveal how specific development projects have impacted neighbourhood demographics and transit ridership rates in a given TOD.

In conclusion, the Millennium Line has had a very significant impact on improving transit options in the Metro Vancouver region and attracting new transit riders. A large amount of commercial and industrial lands around the Millennium Line holds a great deal of potential for future land redevelopment and planning of TODs around the stations. While true TOD neighbourhoods are just starting to develop around a few Millennium Line stations, many such neighbourhoods have been developed and refined over the last 23 years in areas around the Expo Line.
REFERENCE LIST


Hendricks, S.J., et al. (2005). *Impacts of Transit Oriented Development on Public Transportation Ridership.* University of South Florida, Tampa; National Center for Transit Research; Florida Department of Transportation; Research and Special Programs Administration

Hendricks, S.J., & Goodwill, J. (2002). *Building Transit Oriented Development in Established Communities.* National Center for Transit Research; Florida Department of Transportation; Research and Special Programs Administration.


Lund, H.M., Cervero, R., & Wilson, R.W. (2004). *Travel Characteristics of Transit-Oriented Development in California*. California State Polytechnic University, Pomona. Dept. of Urban and Regional Planning; University of California, Berkeley. Dept. of City and Regional Planning; California Department of Transportation.


Renne, J. et al. (2007). *Measuring the Performance of Transit-Oriented Developments in Western Australia.* Planning and Transport Research Centre, Institute for Sustainability and Technology Policy, Murdoch University and The University of New Orleans.


APPENDIX A

Figure 26: Excluded Enumeration Areas from the 1996 Census Data
Figure 27: Excluded Dissemination Areas from the 2001 Census Data
Figure 28: Excluded Dissemination Areas from the 2006 Census Data
Table 1: Census Geographies Excluded From Calculations

<table>
<thead>
<tr>
<th>1996 Enumeration Area</th>
<th>2001 Dissemination Area</th>
<th>2006 Dissemination Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>59020019</td>
<td>59151572</td>
<td>59151572</td>
</tr>
<tr>
<td>59023123</td>
<td>59151913</td>
<td>59151913</td>
</tr>
<tr>
<td>59014016</td>
<td>59152187</td>
<td>59152187</td>
</tr>
<tr>
<td>59014009</td>
<td>59152823</td>
<td>59152823</td>
</tr>
<tr>
<td>59014012</td>
<td>59152819</td>
<td>59152819</td>
</tr>
<tr>
<td>59014015</td>
<td>59152822</td>
<td>59152822</td>
</tr>
<tr>
<td>59005002</td>
<td>59152821</td>
<td>59152821</td>
</tr>
<tr>
<td>59005220</td>
<td>59152820</td>
<td>59152820</td>
</tr>
<tr>
<td>59026363</td>
<td>59152818</td>
<td>59153523</td>
</tr>
<tr>
<td></td>
<td>59152816</td>
<td>59153608</td>
</tr>
<tr>
<td></td>
<td>59152261</td>
<td>59153524</td>
</tr>
</tbody>
</table>