

**Transit Potential of Waterloo Region's
Central Transit Corridor**

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Abstract

The use of transit in our deconcentrated and dispersed city systems has decreased with the primacy of the automobile. In striving to not only build a transportation system to meet public demand, but manage the system to direct future urban growth patterns, land use must be consistently integrated with transportation planning. Urban form that incorporates transit relies on the existence of certain land use and demographic characteristics. These transit-supportive characteristics are examined in the literature on other cities, primarily in North America. Such factors are then applied to the local context of the Region of Waterloo in southern Ontario. The current transit usage pattern and a study of the factors currently defining local transit patrons reveals very low levels of ridership and few factors determining transit use, evidence of the automobile dominance and dispersed travel flows characteristic of mid-sized cities. The current Regional government proposal to introduce rapid transit along the Central Transit Corridor (CTC) is analyzed as to where the greatest potential to increase transit ridership exists, and based on the same demographic and land use factors that encourage transit use in other communities. While the highest levels of latent potential for transit patronage do exist along the CTC alignment (particularly in the northern half of the region), a question remains regarding the aggregate local transit potential compared to other cities. Additional research is needed to reveal whether the potential transit riders will actually be persuaded to shift modes given the current entrenchment of auto-based travel.

1.0 Introduction, Purpose, and Definitions

1.1 Background

The use of transit in our deconcentrated and dispersed city systems has decreased with the primacy of the automobile. Increasingly, the financial, social and environmental costs of the car are making it difficult for governments to maintain control of the modern transportation system. Issues such as pollution and who pays the costs of car-supporting infrastructure are now a part of societal debate. Attempts to increase the use of public transit, particularly for trips and for populations for which it may be a competitive option have become an important counter to the 'technological fix' for the car. In striving to not only build a transportation system that meets public demand, but to manage the system to direct future urban growth patterns, land use planning must be consistently integrated with transportation in today's Canadian city. Alternative visions for urban transportation that incorporate transit rely on the existence of certain land use characteristics (a higher density, a mix of uses, pedestrian-friendly streetscapes, as argued by Cervero, 1996a; Frank and Pivo, 1994; and Pucher, 1998) and certain demographic characteristics (the young, the old, the journey-to-work trip, etc., as suggested by Miller, 2000).

While there is already an existing population which uses transit by necessity in the Canadian city (the so-called "captive rider", representing a small minority of the population in the average mid-sized city according to Hutchinson [1991]), the real market for expanding the use of transit is the "choice" transit rider. In trying to lure current auto users into becoming (at least somewhat frequent) transit riders, several cities have employed the use of commuter rail and rapid transit (Raad & Kenworthy, 1998). For the

average mid-sized North American city since the 1970s, this has often taken the form of light rail transit (LRT), which can be supported by a base urban population of about 500,000. At approximately \$5 to \$25 million per kilometre, it is fairly cost effective in relation to other types of rapid transit infrastructure, such as subway (Henscher, 1999; TRB, 1998a). While an all-bus system is arguably more cost effective (e.g. DeJong, 2001; Henscher, 1999), since its only infrastructure costs can be the cost of the vehicle, it is often considered to be slower, uncomfortable and inconvenient, and therefore difficult to lure choice riders to a bus-only system (Gomez-Ibanez, 1985; Huang, 1996). Nevertheless, cities such as Ottawa have had success in attracting ridership as well as land use intensification with an all-bus system (Federal Transit Administration, 2003a).

1.2 The Study Area

The Regional Municipality of Waterloo is the upper-tier of local government for the cities of Cambridge, Kitchener and Waterloo, and the surrounding townships in southern Ontario (see Figure 1-1). Within this jurisdiction, Statistics Canada has defined a Census Metropolitan Area (CMA) called Kitchener.

The region's population in 2002 was 458,400 (Region of Waterloo, 2002a). The CMA population in the 2001 census was 414,284, making it the fifth largest urban area in Ontario, and the eleventh largest nationally (Statistics Canada, 2003). The region is a mid-sized Canadian urban area which has experienced rapid recent growth and is expected to reach the 700,000 mark in the next 25 to 35 years (Region of Waterloo, 2002c). With this rapid growth, have come increasing concerns among politicians, planners, and the general public about environmental protection, preservation of prime

agricultural lands and the old-order Mennonite heritage of nearby rural communities, and the public health and quality of life of the region's diverse communities. Some of this growth has been the result of overspill from the Greater Toronto Area, less than a one hour drive east of the region.

Much of this recent growth has been of a dispersed nature, leading to auto dependency, which is characteristic of most mid-sized cities (Filion, Bunting & Curtis, 1996; Bunting et al., 2000). The journey-to-work modal split for the region in 1996 (Table 1-1) shows the high degree of auto use and the correspondingly low levels of pedestrian, transit, biking, and other modes (collectively only 16 per cent). On this basis, the Regional Municipality and its transit provider, Grand River Transit, have begun the process of developing a light rail transit (LRT) line, with the hope of directing future growth in a more transit- and pedestrian-oriented fashion (Region of Waterloo, 2002b). Light rail transit systems have been used in a number of other communities as a higher-order transit strategy, particularly as they approach the 500,000 population threshold (e.g. Calgary, Portland), where it has been found to be a relatively effective mode at a reasonable cost. The linear orientation of the region's urban form (running north to south from Waterloo to Cambridge) is also consistent with the development of a linear transit corridor covering the core portions of the urban area. A combination of LRT and/or rapid busway (i.e. BRT) options are currently being investigated for different parts of the corridor (Region of Waterloo, forthcoming).

Table 1-1 Mode Share Summary (AM Peak Hour, Home-based Work) (adapted from Regional Municipality of Waterloo, 1998b, Exhibit 3.11)

Mode	Person Trips (1996)	Modal Split (1996)
Auto (driver + passenger)	64,920	84%
Transit	3,864	5%
Pedestrian	7,729	10%
Cycle	773	1%
Other (motorcycle, taxi)	370	0%
Total	77,286	100%

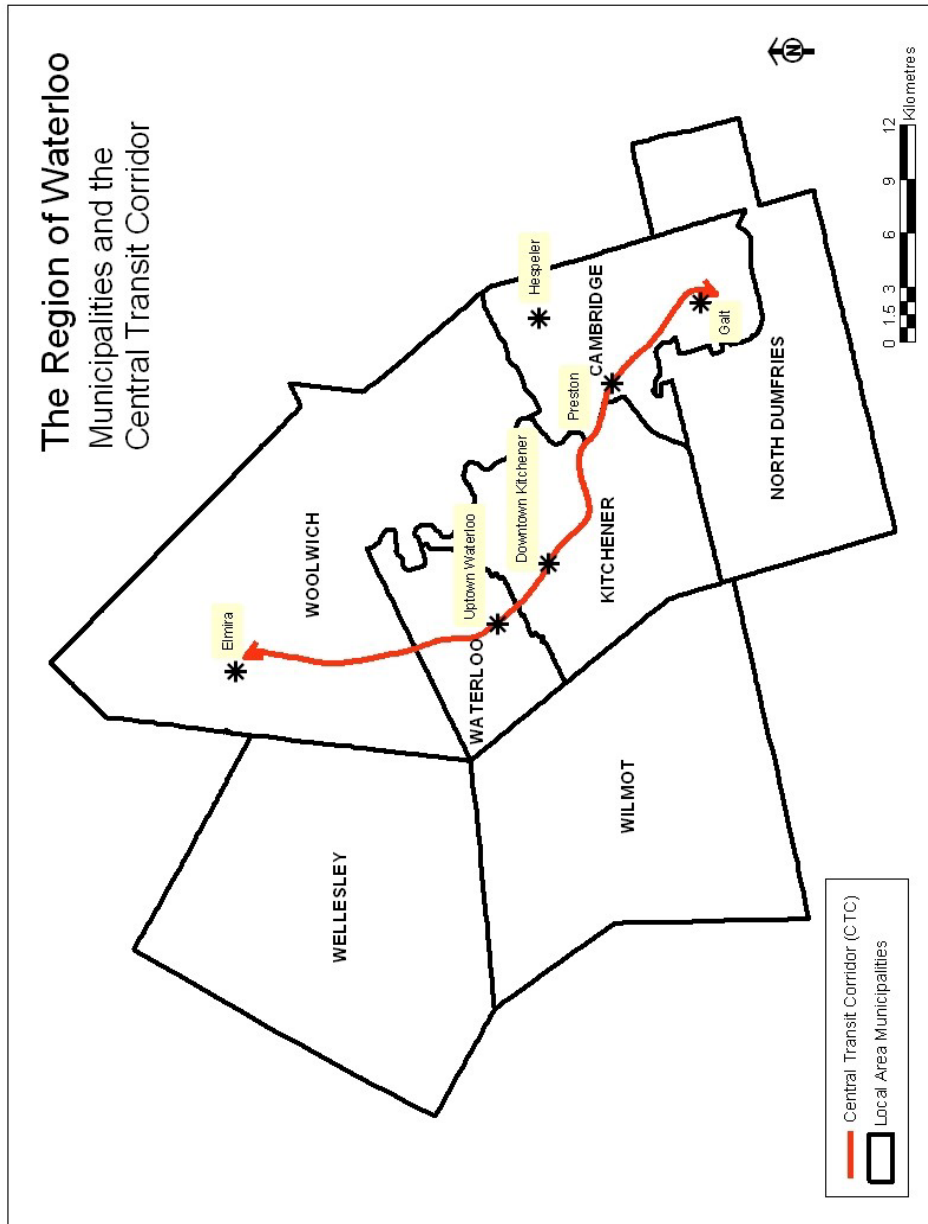


Figure 1-1 Waterloo Region’s Administrative Boundaries and the Central Transit Corridor (CTC) depiction from the Regional Official Policies Plan, 1998)

1.3 LRT in Waterloo Region

This paper is the product of research done in conjunction with the proposal for higher order transit (i.e. LRT, BRT) by the Region. While the idea of light rail or LRT in the Region began in the 1970s with the creation of the Regional government and the first of its Regional Official Policies Plans (ROPP) (Regional Municipality of Waterloo, 1976), the idea has been rejuvenated in recent years as a result of the dramatic growth in population and employment that is currently underway and expected to continue for the foreseeable future. A major concern is that the region's growth is now approaching the established urban boundaries, so there is the perceived need to redirect growth away from greenfield development sites, towards reurbanization and redevelopment of existing built-up areas. This is consistent with the principles of 'smart growth' (e.g. Avin & Holden, 2000; Froehlich, 1998; Gihring, 1999). Locally, it is hoped the Central Transit Corridor (CTC), identified in Map 8 of the 1998 ROPP Consolidation (Regional Municipality of Waterloo, 1998a) and being forwarded as a key part of the Region's Growth Management Strategy (Region of Waterloo 2002c; 2003), can serve as a focus of this reconcentration. While such transportation infrastructure can help espouse the ideals of 'smart growth', and this certainly must be kept in mind, it is not the purpose of this study to focus on such 'smart growth' principles or how the corridor fits with a vision for 'smart growth'.

With the increasing central city densities that the Region anticipates from redirecting growth to the cores and corridor, traffic congestion could become a problem. This is especially a concern in Waterloo Region, where a great majority of individuals attain mobility through the use of the private auto (refer to Table 1-1, above). It is hoped

that traffic problems that might be generated by reconcentration can be circumvented through higher public transit use, which could be achieved through the introduction of rapid transit connecting major activity centres along the CTC.

Geographically, the corridor cuts a north-south swath through the region's three urban centres, Waterloo, Kitchener, and Cambridge (refer to Figure 1-1). The Region of Waterloo, in its proposal to the federal government for infrastructure funding for the project (April 2002), has identified a five-stage approach to LRT in the corridor. The first stage, for which the funding is currently being sought, is to run from the St. Jacobs Farmers' Market area at the northern edge of the City of Waterloo to the eastern end of Downtown Kitchener (refer to Figure 1-2). Intermediary connections are to be provided at the University of Waterloo's Research and Technology Park, the University of Waterloo's South Campus, Uptown Waterloo, Union Street (including Grand River Hospital), and Victoria Street. The Victoria Station is designed to spark development in a largely decaying industrial/commercial district ("The Warehouse District") in the west-central part of Kitchener. This site involves an intermodal transportation facility (to replace the current train and bus stations in Kitchener), as well as a convention centre, and opportunities for complimentary private development (Region of Waterloo, 2002b). Given that advancing the proposal will cost the taxpayers hundreds of millions of dollars, and that it will impact on local urban transportation decision-making for 15 to 25 years or more, research into the transit potential for various geographic areas of the region is needed.

Several different research projects are underway to investigate the feasibility of LRT and the potential land use change that might be expected near stations. The

research presented here takes a slightly different approach. This paper details the general land use and socioeconomic characteristics of areas surrounding the planned corridor. Using measures of high transit (including light rail) use from other jurisdictions (mainly in Canada and the U.S.), an attempt has been made to determine which areas in the three-city area covered by the corridor have characteristics in population and land development that are currently most supportive of transit. Beyond exploring the geographical pattern of current transit use, this paper seeks to find the areas in the region where transit use might have the greatest potential increase, associated with improvements in transit service through LRT and/or BRT. This exercise is designed to point to potential corridor and station locations, as well as to identify strategic sites where connections and integration with the existing bus system are most needed or most likely to find higher levels of ridership. This research can ultimately assist the regional government in its efforts to increase the modal share of transit, one of the primary goals of the Regional Transportation Master Plan (Regional Municipality of Waterloo, 1998b).

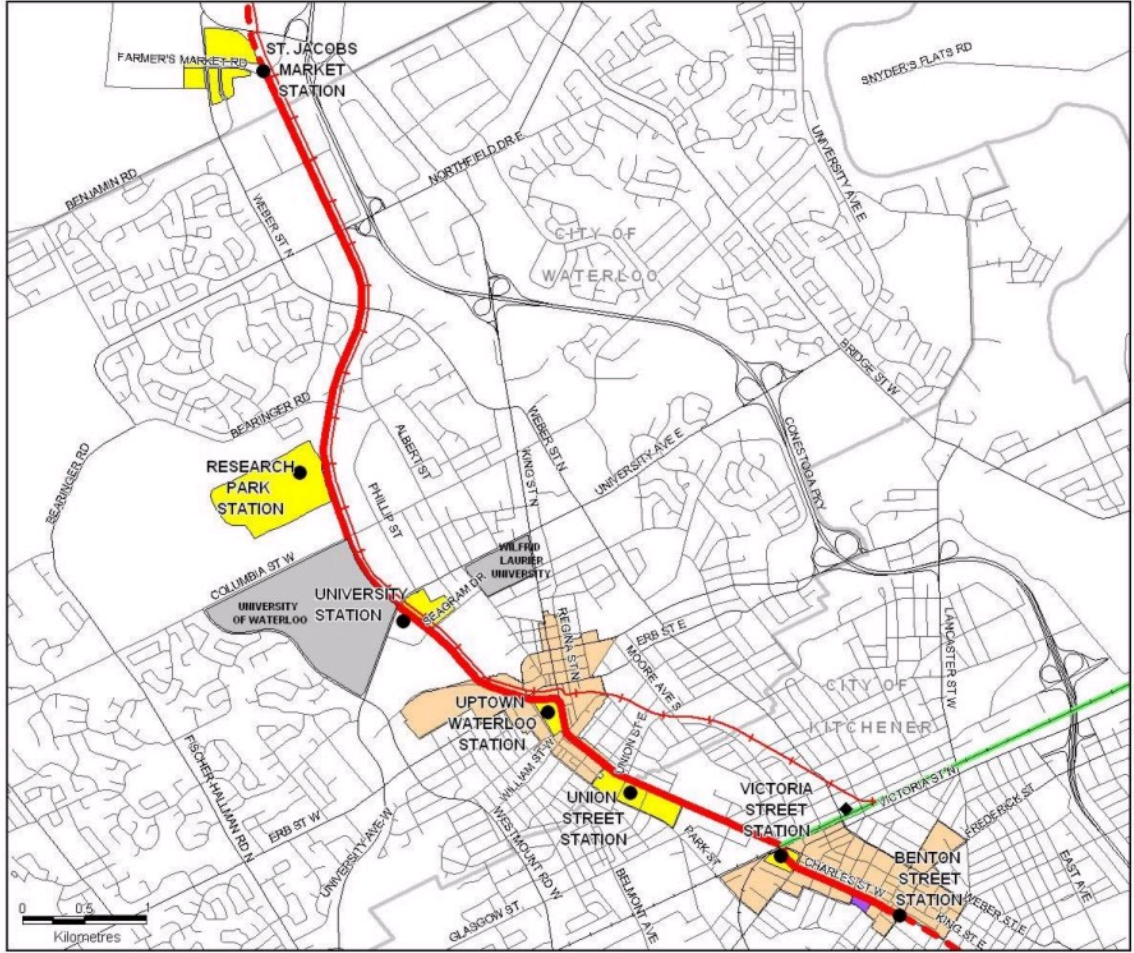


Figure 1-2 Light Rail Transit proposal: St. Jacobs to Downtown Kitchener (Region of Waterloo, 2002b)

1.4 An Overview of this Report

In addition to this introduction, designed to provide background information on the transit trends, introduce the study area, define the purpose of this study, and provide important definitions, this report comprises several sections.

In Section 2.0, the study is put into the context of other studies, reports, and the research literature completed on similar and related transit issues. An overview of the scope of urban transportation and transit research is provided, together with a more in-depth discussion of previous research on variables impacting on transit usage patterns.

Section 3.0 serves three purposes. The research rationality is discussed first; comments particularly concern the timeliness of this research, given the ongoing plans by the Regional government in the study area. This section also details the variables selected in determining current and potential transit ridership patterns. Descriptions of the two variable sets and their reasons for selection are provided. A summary table contains the definitions and calculation information for all variables. Finally, this section outlines the methodology used to calculate the two ‘Transit Potential Index’ measures and the analysis of current transit ridership patterns.

Section 4.0 provides results of the analyses, including maps showing the geographic distribution of current transit ridership patterns and the potential transit patterns, based on the indices. In addition to appropriate maps and tables, the subsequent discussion section provides some interpretation.

Section 5.0 includes conclusions on the future transit potential of the study area, including geographic areas that might expect the highest potential use and implications for the current proposal and future plans by the Regional government. Some specific

comments are also made as to the benefits of rapid transit for the study area. Potential limitations to this research and areas for further study are also provided.

1.5 Definitions

Several terms are used extensively in this research. Many of these have specific meanings to the urban geography, planning, or transportation research communities.

The term **modal split** is used to describe the relationship between the number of riders using each transportation mode, usually within a specified jurisdiction. It is often simplified to mean the relative number of auto users compared to transit riders in a given community (as in the transportation planning process, Hutchinson [1991]).

Among the different urban transit technologies available to mid-sized communities, the two most prominent in the research and in application are **light rail transit** (LRT, also referred to as “light rapid transit” or simply “light rail”) and **bus rapid transit** (BRT). *LRT* applies to a fixed rail technology, which operates in an urban or suburban area, on-street and/or on a separate right-of-way. LRT normally consists of one or more engine cars and a series of attached passenger cars. Vehicles can look quite similar to subway cars, which are usually a form of so-called “heavy rail” (Light Rail Central, 2000). In Canada, various forms of LRT are currently in use in Vancouver, Calgary, Edmonton, Toronto, and Ottawa (Light Rail Central, 2002; Translink, 2003).

In contrast, *BRT* uses regular and/or articulated (accordion-style) buses. These run on-street, with priority lanes and signals, or else in a separate right of way (Federal Transit Administration, 2003b). Similar to LRT or subway systems, they often stop only at scheduled “stations”, which can be similar in design to subway stations. The buses can

run at grade with the surrounding landscape or below it on forms of “bus expressways”, as found in parts of Ottawa (Federal Transit Administration, 2003a). Ottawa is, in fact, the only Canadian centre currently using a true form of BRT. Vancouver, Edmonton, Quebec and other centres have express bus services which operate together with regular street traffic, but stop only at designated “stations” (Federal Transit Administration [2003a] concerning Vancouver; ETS [2003] concerning Edmonton; RTC [2003] concerning Quebec). These services are also sometimes considered a form of BRT.

2.0 The Research in Context: A Review of the Literature

This review has been subdivided into several sections, each dealing with a different area of research that is related to the topic of this thesis, the potential for increased transit use based on socioeconomic and land use characteristics. The first section explores urban transportation research in general, with an emphasis on public transit. The second section addresses research on the variables that affect public transit use.

2.1 Urban Transportation Research

The area of land use and transportation integration in planning and urban geography has been a topic in the literature for several decades. Recent research papers have reiterated the need for an integrated perspective in understanding both aspects of the urban system (e.g. Newman & Kenworthy, 1996; Shinbein, 1997; Polzin, 1999). History demonstrates the importance of links between urban form and the prevailing transportation infrastructure and technology (Schaeffer & Sclar, 1980). Yet, to date planners and other policy makers have often not been very successful in integrating transportation with land use planning measures.

Another strain of research emphasizes pedestrianizing the city (e.g. Robertson, 1990 & 1993; Isaacs, 2000; Laville, 2000; Zacharias, 2001) by maintaining a pedestrian-auto balance in city core areas to promote downtown vitality. A central element in a pedestrian-focused, revitalized downtown can be the efficient provision of public transit to bring people into the core. The presence of pedestrians and transit-oriented land use

development can effectively support the sort of street life and cosmopolitan atmosphere that is desired in downtown revitalization plans (Robertson, 1993).

Literature on transportation demand and planning is also extensive (Hutchinson, 1974; Meyer & Miller, 2001). Brown et al. (1972) and Miller (2000), among others, outline the traditional four-stage process and discuss emerging trends in transportation planning, which include land use interrelationships. Urban transportation geography texts outline the planning processes, how urban transportation can be modelled using scientific approaches, and some of the social and environmental impacts of policy (Hanson, 1986; Tolley & Turton, 1995) (see Table 2-1 for example, on environmental, economic, and social implications of auto dependency). Research on current trends has looked at how the shift toward polynucleated urban form has affected commuting patterns, where increased affluence, car ownership and the convenience of private commuting (together with multi-nucleated form) leads to dispersed work locations and congestion (Clark & Kuijpers-Linde, 1994). In addition, there has been a resurgence in research on the transportation-land use relationship as it relates to specific geographic areas and transportation sectors (e.g. Andrey, 1995).

In the design and implementation of transit improvements, Shinbein (1997) offers specific design requirements for developing pedestrian pockets or transit-oriented developments (TODs). These requirements imply a mixed land use, and high-density development, which can be associated with a centralized transit station in a light rail system. Pushkarev and Zupan (1977) focus on the supply and demand balance of urban transit, including a detailed analysis of which transit technologies (local and express bus, light rail transit, etc.) are compatible with which densities of land use. In general, the

higher the density and the more concentrated the urban system, the higher the level of transit technology that can be supported.

‘Before and after’ research has examined the change in auto use, accidents, transit travel times and vehicle flows after the introduction of transportation improvements, such as a bus priority corridor. Travel times on transit were reduced, and in particular, much more consistent after the implementation of urban design and traffic improvements (Wood & Smith, 1992). Lawless (1999) outlines the 'before and after' effects of light rail infrastructure investment on urban regeneration in Sheffield, England. Due to the lack of co-ordination between regeneration and transportation policies, the small degree of urban regeneration gained from transportation infrastructure was from new roads rather than the LRT. Similarly, Dewees (1976) looks at Toronto's transit system before and after the conversion from streetcars to subways. He finds some evidence for increased ridership after the switch to subways, along with substantial time savings for station-to-station and longer transit trips; the impacts on modal split, however, were inconclusive due to the introduction of competing highway infrastructure. Gomez-Ibanez (1985) examines the impacts of LRT introduction in San Diego, Calgary and Edmonton. He finds little improvement in ridership in San Diego, and some evidence for increased ridership in Calgary and Edmonton (although in Edmonton, this might have been partially the result of a restructuring of the bus-based system). In Calgary in particular, LRT's introduction led to more concentrated travel flows and one-way commuter traffic than the bus-only system. In Edmonton, there have been questions about the system being underused across the day and across the line.

Regarding the state of transit in Canadian cities, Levy (1976) discusses the general and regional trends in Canadian transit, including the overall declines in ridership and cuts in service of the 1960s, the move towards municipal ownership in the late 1960s and 1970s, and the impacts of emerging technological innovations (such as cleaner bus vehicles, LRT and busways). He provides a detailed analysis for 12 mid-sized Canadian cities (100,000 to 250,000), including Kitchener, for the mid-1970s. Levy finds that the cities have used various service improvements (more routes and frequency, new transit terminals for better connections, dial-a-bus in low-density areas, etc.) and promotional techniques. Service provision was found to be similar across most of the cities. Many were considering busways or light rail technologies, which were just emerging as a transit option in the early 1970s. However, the small size of the cities tended to restrict the ability to heavily market the service or have the personnel for comprehensive transit-land use planning. This was suggested as part of the reason why their systems tended to have lower ridership numbers, in addition to local factors (employment, urban form, transit strikes). In a similar vein, Cervero (1986) discusses innovations of transit systems in larger Canadian cities, including light rail projects in Toronto, Vancouver, Calgary and Edmonton, arguing that Canadian transit systems have been more innovative than their U.S. counterparts in launching new technologies (such as LRT), timed-transfer networks (Edmonton) and bus-only systems (Ottawa). Another major innovation early in the 1980s was the attempt to plan land use in advance of transit, helping drive future development that is supportive of transit; this was especially successful in Vancouver and Ottawa.

Miller and Shalaby (2000) offer a detailed analysis of current and changing trends in household travel patterns in the Greater Toronto Area, compiled from the 1996 and previous Transportation Tomorrow Surveys (TTS) of the University of Toronto. This statistical compilation, some of which includes the Kitchener CMA, closely relates to the research completed here, describing the general patterns of transportation and travel flows in the local area. Of note in the Kitchener area, is the place of walking trips after auto travel's modal split. However, since the TTS gathers little by way of demographic or socio-economic attributes of trip-makers, the data do not provide for a detailed analysis of transit rider attributes.

Research similar to that contained in this thesis is ongoing (Filion, Bunting & McSpurren, forthcoming). Socio-economic and land use factors are being examined in selected suburban census tracts of Toronto, Calgary and Kitchener that have higher than average transit use. Furthermore, the research completed for this thesis shares much in common with feasibility and impact studies produced by individual municipalities, such as the Regional Municipality of Ottawa-Carleton (1998), Vancouver Regional Transit System (1998), City of Calgary (2002), and Region of Waterloo (forthcoming).

Table 2. Problems of automobile dependence.

Environmental	Economic	Social
Oil vulnerability	External costs from accidents, pollution, health impacts . . .	Loss of street life
Photochemical smog	Congestion costs, despite endless road building	Loss of community
Lead, benzene . . .	High infrastructure costs in new sprawling suburbs	Loss of public safety
High greenhouse gas contributions	Loss of productive rural land	Isolation in remote suburbs
Urban sprawl	Loss of urban land to bitumen	Access problems for the carless and those with disabilities
Greater stormwater problems from extra hard surface	Loss of time due to sprawl, increasing distances	
Traffic problems – noise, severance		

Table 2-1 Environmental, economic and social implications of auto dependence (from Newman & Kenworthy, 1996, Table 2)

2.2 Variables Affecting Transit Use

Much of the literature on modal choice (the decision between transportation modes) has focussed on the factors involved in individual decision-making. Ben-Akiva and Lerman's (1985) classic research pioneered the use of the logistic regression technique (the logit model) in formulating a model of an individual's choice of transportation (car versus transit). Other researchers have used the logit model technique for specific cities (e.g. Chartier [1992] in Toronto). Another related research area has been that of individual choice factors in transportation (Michaels, 1980; Mierzejewski & Ball, 1990). This research tends to focus on psychological and behavioural/motivation factors involved in the decision to use transit, normally in comparison to the private automobile.

While this area of the literature does examine decision-making, it is heavily focussed on individuals and tends to lack the view of wider patterns operating over geographic space. Since this thesis research takes a future perspective on attributes of transit riders, with a view to the location of future transit infrastructure, research which focuses on patterns at work in the aggregate and in geographic areas rather than the individual was also investigated.

The literature of several different disciplines and alternative perspectives examines the variables considered characteristic of transit riders. Some of this research is more theoretical in nature, arguing that certain attributes of the environment or the population should encourage higher transit use relative to the average (e.g. Shinbein, 1997). Other research takes an empirical approach to examine the variables that can be used to distinguish transit riders from non-transit riders (e.g. Mohamed, 1991; TRB, 1996; 1998;

2000; Filion, forthcoming; etc. Also see Badoe & Miller [2000] for a comprehensive review of empirical studies on urban form and travel behaviour). Additional literature gets at the transit rider issue from the opposite perspective: a number of papers have dealt with the variables that determine auto ownership and auto use (e.g. Kain, 2001; Southworth, 2001). From this, the characteristics of the people who do not use automobiles, but opt for transit, biking and walking can be gleaned. Among the characteristics examined in this type of research, two major themes emerge: socioeconomic or demographic-type attributes, and land use and urban form-related attributes.

Several research papers and reports address both demographic and land use aspects of the transit rider market (Dunphy & Fisher, 1996). For example, Kain (2001) stresses that urban development change and socioeconomic factors both need to be considered in policies of transit and auto modal split. Dielemen, Dijst and Burghouwt (2000) argue that socioeconomic and residential environment factors “are of about equal importance for modal choice” (p. 524). As Badoe and Miller (2000) point out, “it is the interaction between socioeconomics and urban form which is central to the understanding and modeling of locational and activity/travel decision making” (p. 254). Other researchers have taken a side as to which one of these two sets is more important in determining transit ridership. For example, Newman and Kenworthy (1991) argue that urban development policy, such as for increasing population and job densities, can have greater impacts than economic factors like income. Similarly, Ewing (1995, as cited in Badoe & Miller, 2000) found that development patterns had impacts on travel beyond those created by socioeconomic status.

2.2.1 Socioeconomic and Demographic Variables

A large group of factors, including gender, income, age, education, immigrant and ethnic status, vehicle ownership, and work/mobility limitations, have been found to be important in defining a transit “market niche”. In a comprehensive report on current and future transit markets by the Transportation Research Board (TRB, 1998b), these factors were provided with weights relative to average metropolitan use across the U.S. (refer to Table 2-2). In this research, individuals’ demographic and socioeconomic attributes took precedence over consideration of urban form influences. Badoe and Miller’s (2000) review of the empirical literature lends support to the fact that many such socioeconomic variables (income, age, gender, and occupation) are important in determining travel behaviour. Another TRB study (2000) investigated the transit rider variables across Canada. The existing markets for transit were among 18 to 24 year olds, those with household incomes less than \$20,000, students, single parents, the unemployed, single people without children, and people considered “influential” in their communities (i.e. they took an active role in public and community life).

Although other socioeconomic variables were considered, Messenger and Ewing (1996, as reported by Badoe & Miller, 2000), found income to be the major socioeconomic factor involved in the transit modal share, through helping to determine auto ownership patterns. Household income, along with urban development factors, was found by Kain (2001) to be important in determining patterns of car ownership, trip making and modal choice; in particular, increasing household income was linked with increasing auto ownership. In contrast, higher incomes have been associated with higher

transit use in the inner city and inner suburb, particularly in areas proximate to subway stations (Filion, forthcoming). On the opposite end of the scale, Schimek (1996b) found a higher proportion of lower incomes to partially account for the higher transit use in the inner city and inner suburbs of Toronto, as compared to Boston. Thus, it appears transit ridership involves segments of the population at both extremes of the income grid. In another study, however, the income variable was not found have a statistically significant relationship at all for LRT (although it did for commuter rail) (TRB, 1996).

In addition to income, family status has been found to influence mode choice, as well as distance travelled (Dieleman, Dijst & Burghouwt, 2000). The presence of children in a family was found to be an important factor in increasing auto use. In Seattle, Yee and Niemeier (1998) found a decline in transit use for work trips for certain households with more than one adult in the 35 to 64 age range. Additionally, in contrast to some other research, in households with only one adult and under 35 years of age (what some might refer to as the “young, single professional” profile), there was actually an increasing trend toward *fewer* non-auto based work trips. Yet, in Dallas and Phoenix, it was assessed to be the demographic trend towards increasing numbers of young professionals locating in downtown that was driving the demand for alternative commuting choices, including LRT (Holz Kay, 2000). Still other research, investigating household size specifically, have not found an effect based on the size of the household alone (Mohamed, 1991). Thus, the *specific context* (i.e. the city in question and location within the city) is very important in determining many of the potential effects of family status and other demographic factors on transit versus auto travel.

Garrett and Taylor (1999) define “transit dependents” as a major market for transit. These are people who are too young, old, or low in income to drive, and those who have mobility limitations (i.e. physical disabilities). Specific markets of transit by gender, age, and income status (lower-income) have been found among transit riders in Ottawa (Regional Municipality of Ottawa-Carleton, 1996), Montreal (Chapleau & Girard, 1986), and Winnipeg (Cleroux, Florian, & Galarneau, 1979). In Toronto, overall the use of transit decreases with increasing age (Mohamed, 1991).

Transit use also tends to be much lower than average among the ‘blue collar’, middle class workforce, a lifestyle which often also relates to location choice (i.e. the middle class suburbs). Even suggestions of transit improvements often cannot convince this market segment to use transit (Kingham, Dickinson, and Copsey, 2001).

Gender has also been found to impact transit use. In one study, it was found that particularly among men, it is difficult to encourage use of public transit and foster positive attitudes concerning transit service (Pooley & Turnbull, 2000). Mohamed (1991) echoes this finding, with females in Toronto showing more preference for transit use compared to males over most age categories (although the reverse was true over 45 years of age).

Various other specific demographic variables and personal attributes have been implicated in the level of transit usage. For example, the availability of a driver’s license influences modal choice, as might be expected. Increasing numbers of vehicles is also associated with an increase in auto-based trip making. The probability of using an automobile also increases with a trip maker’s residence in a house versus apartment (Mohamed, 1991).

In summary, while a number of socioeconomic variables appear to be important, the exact importance of one relative to others in the literature remains inconclusive. In large part, the significant variables seem to be dependent on the method of study (individual versus aggregate), the time period, the available data sources, and certainly the geographic region under study. Concerning geography in particular, transit travel trends tend to differ for demographic segments based on the size of the city (generally higher numbers in larger cities, and with the presence of a different demographic mix of population) (e.g. TRB, 1998b; 2000). In addition, patterns of demographics and transit travel differ with the location within the city (inner city versus inner suburb versus outer suburb) (as found by Filion [forthcoming], for example). Nevertheless, several basic factors, such as income, age, gender, and ethnicity appear to be important factors in defining a potential transit sub-market across many different locations and types of research.

TABLE 1 Transit use by various market niches indexed to average metropolitan transit use

Market Niches	MSA Transit Index	Market Niches	MSA Transit Index
Sex		Household Income	
Men	.85	< \$5k	1.23
Women	1.18	\$5 - 10k	1.24
Race and Ethnicity		\$10 - 15k	1.08
White	.68	\$15 - 20k	1.04
Black	2.72	\$20 - 25k	.97
Hispanic (all races)	1.73	\$25 - 30k	.90
Asian	1.74	\$30 - 40k	.78
Vehicle Ownership		\$40 - 50k	.77
No Car	5.76	\$50 - 60k	.84
One or More	.68	\$60 - 70k	.91
Age of Worker		\$70 plus	.95
17-29	1.14	Immigration Status	
30-39	.96	Non-immigrant	.84
40-49	.87	Immigrant	2.08
50-59	.92	Years in US	
60-64	1.07	< 5	3.01
65-69	1.10	5 - 10	2.25
Education		10 - 15	1.74
No School	2.59	15 - 20	1.89
Elementary	2.08	20 - 25	1.88
Junior High	1.69	25 - 30	1.49
Some High School	1.25	30 - 40	1.48
High School	.91	40+	1.80
Some College	.82	Limitations	
College	1.05	Work Limitation	1.25
Graduate School	1.06	Mobility Limitation	2.41

Source: Unpublished tape readable data from the 1990 US Census, 5% PUMS

Table 2-2 Weighting Factors for Transit Users (from TRB, 1998b, Table 1)

2.2.2 Land Use and Development Intensity Variables

During historically higher periods of transit use, the nature of development in cities was one of much higher densities and a greater mix of land uses (Newman & Kenworthy, 1996). There is an increasing push, together with trying to increase the use of transit in cities by various levels of government (particularly in North America), to also advocate land use planning principles to better support the return to higher transit use and service provision. A higher level of transit service, in frequency or in advanced technologies such as BRT and especially LRT and subways, requires a shift away from the predominant urban development forms of the past several decades – monofunctional zones of the city, separation of work and residential spaces, and a predominantly dispersed nature of development, in the form of low-density suburban housing tracts and industrial and business parks. Attempts to shift towards higher densities, mixed use residential and employment nodes and corridors, together with more sustainable forms of transportation, are often presented under the titles of ‘growth management’ or ‘smart growth’ (e.g. Avin & Holden, 2000; Froehlich, 1998; Gihring, 1999). It has been recognized that higher-order transit (such as LRT) requires a coalescence of higher density and mixed use development, together with a move to centralize cities toward a core, or several cores (nodes) along a linear corridor, which can then be served by fixed line transit service (Boarnet & Crane, 1997). The role of density and styles of urban development required for increasingly sophisticated transit service has been recognized since at least the 1970s (e.g. Pushkarev & Zupan, 1977). While city size is generally correlated with the increased ability to cost-effectively provide transit service, exceptions

exist in which highly concentrated and centralized cities of small or mid-size can sustain high levels of transit service provision because of built form.

From the specific literature on the roles of land use, development, and urban form on encouraging transit ridership, a set of specific land use variables has emerged. In some cases the role of land use has been studied separately from socioeconomic status, but in many cases, the two are integrated, together with other factors of influence, such as transit service provision, or individual motivations. For instance, Kain (2001) suggests the density of urban development, in addition to household income, contributes to car ownership, trip-making and modal choice (in particular, higher densities are associated with lower levels of car ownership).

Concerning land use and intensity, suburbanized residential environments, where uses are segregated, have been linked to increased auto use (Dieleman, Dijkstra & Burghouwt, 2000), which implies less transit ridership. Kingham, Dickinson and Copsey (2001) indirectly show the low transit ridership (less than three per cent in their study) found in typical business park and industrial areas, which generally have monofunctional land use and low employment densities. Frank and Pivo (1994) found a dramatic increase in the proportion of transit trips occurring as employment density increased above 75 employees per acre, however, there was only a very weak relationship between land use mix and mode choice. Cervero (1996a) found that a person is more likely to take mass transit, bike or walk when living in a mid- or high-rise community, echoing Frank and Pivo's (1994) similar finding with employment density. However, he also found that one's proximity to mixed-use areas does encourage non-auto commuting, given trip distance and vehicle ownership are held constant.

In general, changing employment and population density are considered important trends that will impact on future transit markets (TRB, 1998b). Factors such as CBD job density and population (residential) density within two miles of transit stations have been found to be statistically significant in influencing LRT ridership and fostering an exponential growth in such ridership as they increase (TRB, 1996). High residential density has been positively related to the number of non-motorized trips. As such, developing at greater densities near transit stops increases the number of riders and the per cent of the population using transit (Shriver, 1997).

As reported by Badoe and Miller (2000), some studies have shown little impact of residential density and urban design on transit usage (e.g. Peat, Marwick & Mitchell, 1975; Levinson & Kumar, 1993; Burby, 1974). However, others have supported the view that transit usage is heavily influenced by the density of development (e.g. Smith, 1984). Dunphy and Fisher (1996) found there was a tendency for lower auto use in higher density environments. However, Schimek (1996a) found the impact of density to be only a minor one. The seemingly contradictory results suggest the need for a ‘constellation’ of factors, including but not limited to density – in addition, rapid transit service, concentrated workplaces, and white collar work forces are important factors in increasing transit use.

Concerning density, but also urban design features, Filion (forthcoming) found grid pattern and pedestrian streets to be an important factor in higher transit use in the inner city. Higher residential densities and the presence of high-rise apartments were important in contributing to higher than average transit use within the inner city, inner suburb and outer suburb. Cervero and Kockelman (1997) also found that increasing

densities, mix of land use, and the presence of pedestrian streetscapes had significant (though small) impacts in encouraging non-auto-based travel. Transit trip rates are higher in transit-oriented relative to auto-oriented development (Cervero, 1996b). This is particularly the case for development containing higher residential densities.

Other attributes measure the ratio between land use variables. Nowlan and Stewart (1991) suggest the relationship between employment and housing (essentially a measure of the jobs-housing balance) impacts commuting choice (from Badoe & Miller, 2000). The area of land covered by buildings (i.e. coverage) near transit stations and measures such as Floor Area Ratio (FAR) have been used in past research on transit-supportive land use (Andreas & Klaptocz, unpublished).

As Badoe and Miller (2000) conclude, the findings in the literature on urban form's impact on transit travel behaviour have been mixed at best. Some studies confirm the role of higher density and mixed land uses in reducing auto travel and increasing transit and walking, but others find only weak relationships. Nevertheless, collectively the literature does suggest at least some role for land use variables in helping to foster transit ridership. The land use variables work together with a set of inter-related factors: demographics and socioeconomics, as discussed earlier, but also the type of transit service, and the general style of urban form. Additionally, of major importance is the context of a place (city size, location within the city and country, etc.).

3.0 Rationale and Methodology

3.1 Research Rationale

As evident from the review of the literature, the *transit potential* of urban areas, particularly from an empirical basis and for specific urban areas, has been a neglected part of the body of knowledge within urban geography and transportation studies. Although several research papers have discussed U.S. or Canadian urban areas with regards to current or past demographic and land use variables related to transit, little attempt has been made to suggest the implications of current patterns on future transit use, in the event of a major transit infrastructure improvement. Among the transit research that has been done in Canada, most of it focuses on larger urban centres. The public transit system of Waterloo Region has never been investigated in this manner from an academic, empirical perspective.

An additional rationale for the timeliness of this research is the fact that the Waterloo transit proposal is still in its developmental stages. As such, no secure plans have been made for the corridor's eventual location beyond a preliminary proposal for funding for part of the corridor (Region of Waterloo, 2002b). Therefore, the results of this research can affect upcoming decisions. Together, the LRT proposal, the ongoing growth management strategy development, the CTC Feasibility Study (which is investigating different alignments and technologies), and the supportive land use study completed with the University of Waterloo, integrate clearly with the research results which this report provides.

3.2 Defining the Areas of Study

The corridor selected for investigation was based on several converging sources. An approximated depiction of the corridor is included in the Region of Waterloo's Official Policies Plan (as provided in the introduction, Figure 1-1). More detailed plans for the St. Jacobs to Kitchener section of the corridor, including sections of railway lines under consideration, were available from the Region's LRT funding proposal to the federal government (Figure 1-2). This proposal also conceptualizes future phases and alignments throughout the region (refer to Figure 3-1). Candidate nodes used in the CTC Feasibility Study and the CTC Supportive Land Use Study (refer to Figure 3-2) have also been incorporated in order to more clearly define sections of the corridor through Kitchener and Cambridge. In addition, the options map of the region's growth management strategy depicts the proposed higher-order transit and reurbanization corridor (Region of Waterloo, 2002c).

For the calculation of the variables of interest, geographic areas of study around the corridor had to be defined. In larger urban areas, Statistics Canada data is provided according to Census Metropolitan Areas (CMAs) in which there is an urban core and adjoining urban and rural areas with significant relationship to the core (refer to Statistics Canada [2002] for more detail on the definition of CMAs). In Waterloo Region, Statistics Canada has defined the Kitchener CMA to include the Cities of Cambridge, Kitchener and Waterloo, and the Townships of Woolwich and North Dumfries. As such, the Townships of Wilmot and Wellesley, while part of Waterloo Region's administrative boundaries, are not included in the statistical definition. Accordingly, these areas are

excluded from the results presented here; this can be justified in that the proposed CTC does not pass close to either of these two jurisdictions (refer back to Figure 1-1). In 1996, the year for which most data used in this research were obtained, there were 82 census tracts (CTs) in the Kitchener CMA. However, due to the very low population in one of these (106.03) and the resultant suppression of data, most of the Statistics Canada-based data is available for only the remaining 81 tracts.

The transportation data, obtained through the regional government from a University of Toronto study called the Transportation Tomorrow Survey (TTS), is usually aggregated into geographic boundaries called traffic zones. These zones are normally smaller than census tracts. For the 1996 survey, used in this research, the Region (including all three cities and four townships) was divided into approximately 300 traffic zones.

The initial intention of this research was to use census data at the census tract level to match up with the smaller traffic zones of the transportation data (from the TTS). However, several problems were encountered with this objective, the main one being the lack of coincident boundaries between the two systems. Since the transportation data were also available in a non-aggregated format (using UTM co-ordinates of the origin and destination points for trips), and could be joined to the census tract boundaries using GIS, analysis proceeded using census tracts for both the census and transportation data sets.

In addition, while the initial plan was to use the relevant census tracts within 1000 metres of the proposed Central Transit Corridor, some past research has suggested the value of including areas outside of a 1000-metre buffer zone. Connector bus service, for

example, has been used in other jurisdictions to improve the connectivity of people living outside the reach of rapid transit by walking alone (see Loetterle, 2001 on Portland, Oregon for example). Since the addition of the remaining census tracts in the Kitchener CMA did not constitute a major addition to the number of tracts under review, all 81 tracts with available data were included in subsequent analyses, as shown in Figure 3-3.

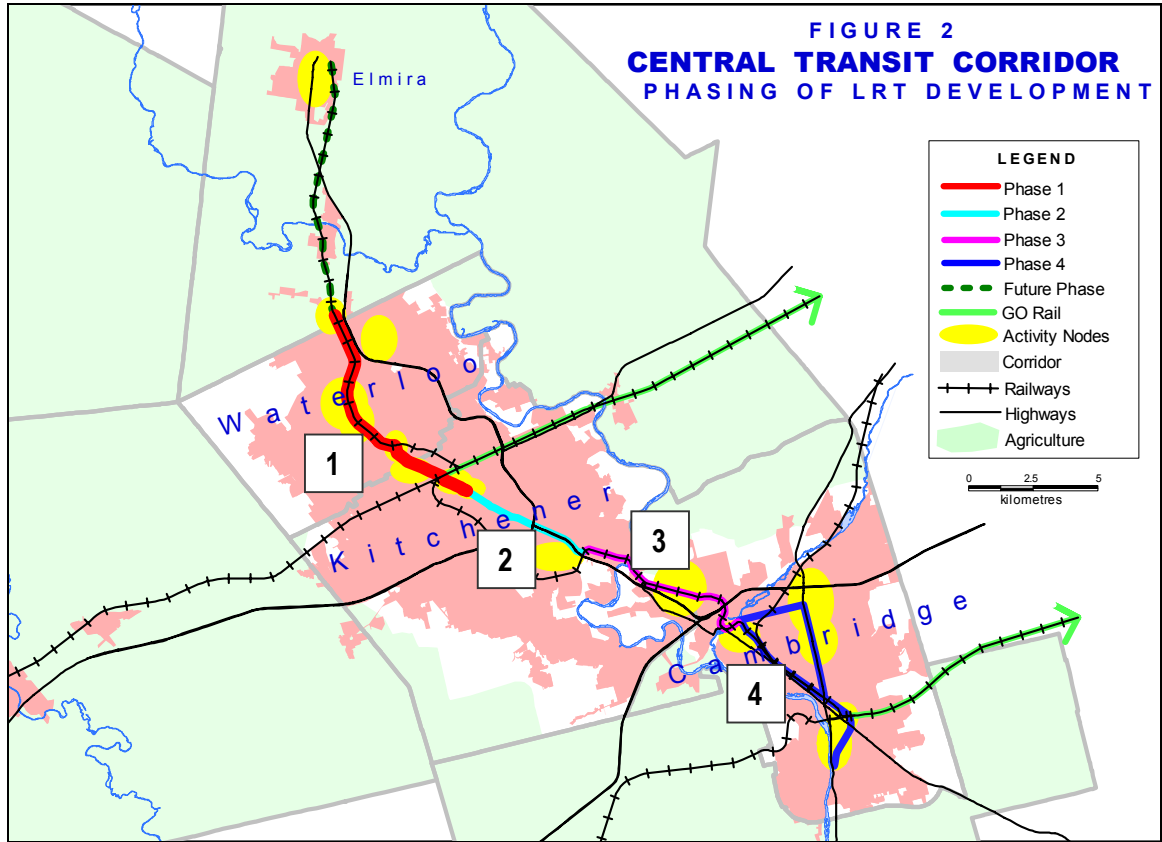


Figure 3-1 Potential phases of light rail transit development (Region of Waterloo, 2002b)

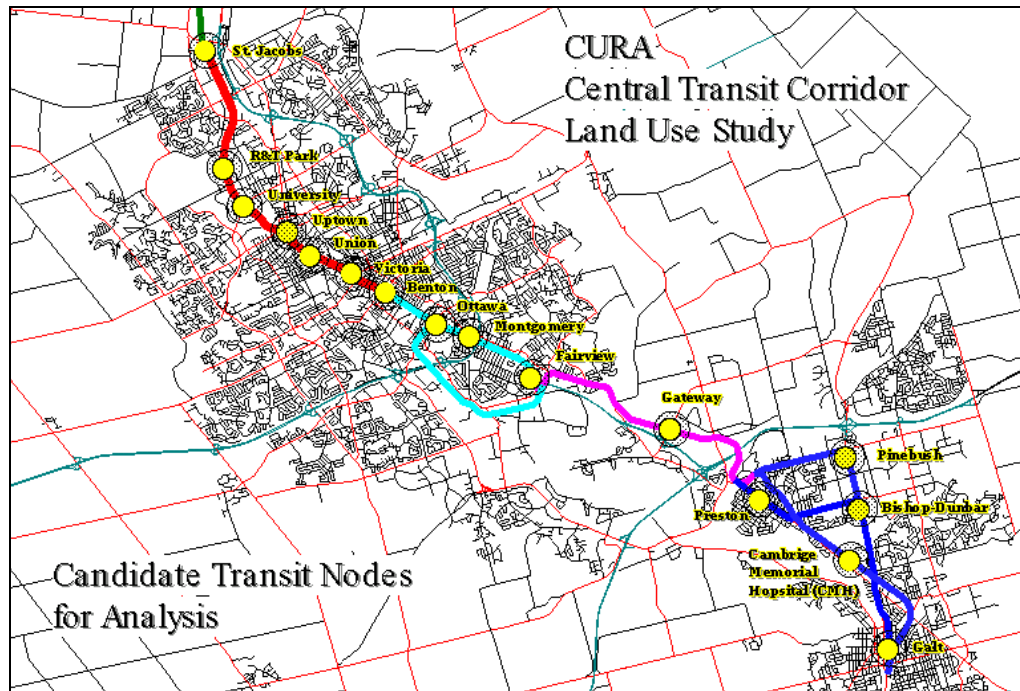
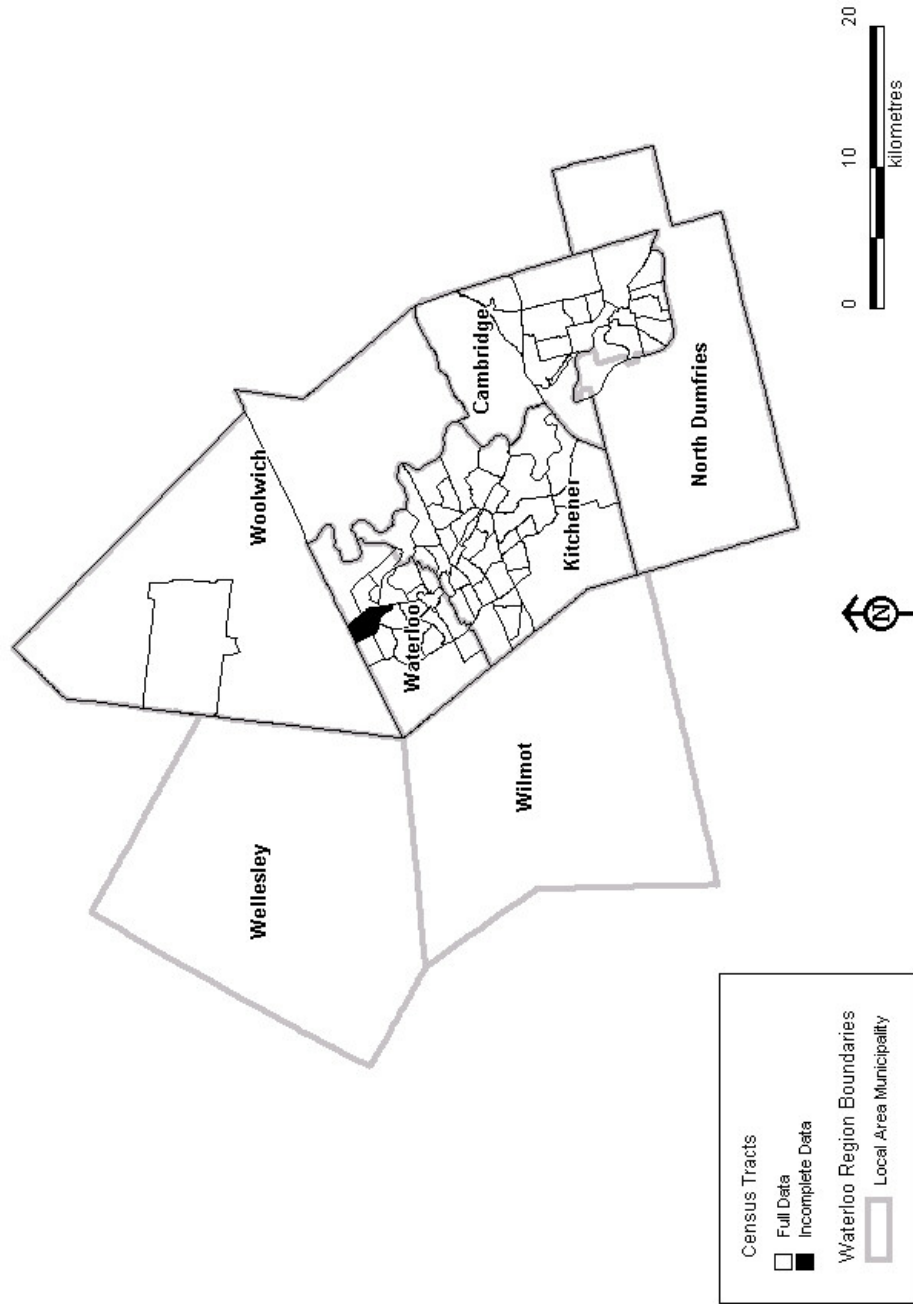


Figure 3-2 Candidate transit stations for the CTC Supportive Land Use Study (Andreas & Klaptocz, unpublished)

Figure 3-3
Waterloo Region and Kitchener Census Metropolitan Area - Census Tracts



3.3 Descriptions of Data Sources for the Index

Several different sources of data were used to interpolate variables based on the factors outlined in the literature. These data included socioeconomic and demographic statistics from the 1996 census from Statistics Canada, available through online data request. Various digital GIS layers from the Region of Waterloo and University of Waterloo were used to calculate most of the land use variables. For the multiple regression of current transit usage patterns, the *trips* table from the 1996 Transportation Tomorrow Survey database was used.

3.3.1 Statistics Canada Demographic Information

All of the socioeconomic and demographic information for the calculation of associated variables was obtained from the census tract profiles, available in digital, raw format on the Internet. These data are provided for research purposes by servers connected with Statistics Canada. All of the data used were from the 1996 Census, since the results from the 2001 Census were not yet available for all data sets and variables.

Some land use variables were also calculated based on the 1996 Census. Statistics Canada collects data on dwelling types, which were used to determine the relationships between high and low density housing (such as single family) in the census tracts.

3.3.2 Spatial Data Sets

Several spatial data resources were available through the planning department of the Region of Waterloo. The majority of the land use variables were calculated based on these data sets.

Spatial data on the location and number of small buildings, along with the square footage of the footprint of large buildings proved useful in calculating the building ground cover for each census tract.

A special data set containing institutional, commercial, and industrial land uses (referred to commonly as the ICI data set) was used to provide a rough measure of non-residential floor area. This ICI data set also provided the number of employees for each census tract, which was subsequently used to define employment density.

Population density was measured using the census population data of Statistics Canada together with census tract spatial attributes (surface area).

3.3.3 Transportation for Tomorrow Survey

In order to obtain the current pattern of transit use in the region, the Transportation Tomorrow Survey was used. This data collection exercise on trip-making in the Greater Toronto Area (including the Region of Waterloo) is completed every five years by the University of Toronto (Joint Program in Transportation, 2002). Again, because the 2001 data set is still being calibrated and awaiting final release, the latest version of the 1996 survey, obtained through the planning department of the Region, was used here. The trip data set was available with spatial coding for both individual, point

locations (based on UTM grid co-ordinates for each trip's origin and destination point) and aggregated into "traffic zones".

Because of the problem with inconsistent boundaries between census tracts and traffic zones discussed earlier (Section 3.2), a spatial join (a form of query) was used in GIS to assign a census tract identifier to each trip origin and destination, using its UTM grid co-ordinates. As such, the use of traffic zones could be entirely eliminated as an issue.

3.4 Selection and Calculation of Variables

Since this research focuses on two sets of empirical data variables that foster transit ridership, it is a useful exercise to outline what constitutes these sets of socioeconomic and land use/intensity attributes.

The socioeconomic and demographic variable set was selected based on the factors suggested in the literature to be supportive of transit and/or those consistent with the transit-rider market segment. A wide spectrum of factors was suggested. This included variables associated with age, gender, immigrant status, visible minority population, workforce type, education, household income, and automobile ownership and use. A full description of all variables and their definitions is provided in Table 3-1.

Once again, the literature provided several suggestions for factors related to land use and land use intensity that would be supportive of transit. It is often argued that such land use characteristics serve to encourage the local population to use transit more or less, relative to nearby areas with differing land use types or intensities. Unlike the TRB report (1998b, as in Table 2-2), which suggested specific demographic variables, the

research on land use factors tends to be more general. Features such as a land use mix, higher density of uses, and more employment and/or population densities are among those suggested. Since most of the literature was indefinite on specifics, the variables were determined by considering the available land use data (as outlined in Section 3.3.2), using basic factors such as employment and population density that are explicitly suggested in the literature, and by creating new variables (such as employment-population ratio and dwelling ratio). Together, the land use variable set is consistent with common land use planning measures, but is also in keeping with the available data and the general factors suggested in the literature. A full description of each of the land use variables is provided in Table 3-1.

In most cases, the measures calculated for both socioeconomic status and land use were based on the proportion of the total population counted on a particular factor (e.g. the population for sex and age characteristics, income characteristics, etc.) that had a particular characteristic. As a result, most of the data occur in the range of zero to one, one (1.000) representing 100 per cent of the population having that characteristic. Exceptions are density, FAR and ratio measures, which are open-ended by definition.

For the purposes of comparing the variables outlined above with current transit usage patterns, current transit patronage by census tract had to be calculated (the multiple regression process is detailed in 3.6, below). The trips by transit were calculated by first eliminating all trips (transit or otherwise) that did not begin and end within the Kitchener CMA. Thus, after assigning census tract identifiers to the trips, those trips without an identifier for the origin and/or destination were deleted. These trips could not potentially be made by current or future transit associated with the CTC.

Next, using database queries, the trips made having an origin and/or destination point within a given census tract were identified and counted. A similar process was completed after querying only the transit trips, to gain the number of transit trips with an origin and/or destination in each census tract. A simple division process provided the transit trips as a percentage of all trips in each tract. Following Frank and Pivo (1994), a trip was defined to have involved a particular tract if either its origin, its destination, or both occurred there. The number of trips with their origin *and* destination both within the tract were then subtracted from the total so as to not double-count these trips. Please refer to Appendix B for the procedure detailed diagrammatically.

Table 3-1 (1st page)

Table 3-1 (2nd page)

Table 3-1 (3rd page)

Table 3-1 (4th page)

Table 3-1 (5th page)

3.5 Calculating Indices

3.5.1 “Unweighted” Index – Socioeconomic and Land Use Factors

The first of the three major components involved in the analysis portion of this research was the creation of a generalized, “unweighted” index of all the land use and demographic factors suggested in the literature on transit-supportive characteristics. This index was achieved by summing the calculated values for all relevant variables; to account for differences in the measurement of different variables (e.g. density and FAR measures as compared to proportions of the population), all variables were first standardized to z-scores. The variables suggested in the literature to encourage transit use were assigned a positive sign; conversely, those said to detract from transit use were assigned a negative sign. All of the resulting variables were summed for the 81 census tracts. Refer to Table 3-1 for the identification of variables used in this unweighted index, together with their direction of contribution (positive or negative).

The resulting summed index values were then mapped using absolute values and standard deviations around the mean of the index (see Section 4). From this map, the geographical distribution of census tracts with high potential for transit use could be visualized and assessed relative to the position of the Central Transit Corridor.

3.5.2 “Weighted” Index – Socioeconomic Factors

The second of the major analysis components was the calculation of a weighted index. The weighting represents an attempt to more accurately represent the importance of factors in relation to one another. While several research papers and technical reports exist concerning these types of variables, most of them do not suggest the relative importance of specific variables. Much of the research on demographic variables argues their importance relative to land use variables, but is unclear on the importance of specific demographic or socio-economic variables relative to one another. For example, is age more important than income or education, in determining a potential transit rider? These questions are seldom addressed. One of the only exceptions, that takes a wider view than examining a specific time and urban area, is the 1998 report by the Transportation Research Board (TRB), which specifically examines transit markets now and in the future for the entire U.S.

Since the TRB report provides an aggregated picture of both larger and smaller U.S. transit systems, the weighting system for current transit riders, based on socioeconomic variables, was deemed appropriate to use as the potential for Waterloo Region. While it has been shown that U.S. transit use is lower than that of Canada (e.g. Raad & Kenworthy, 1998), the presence of the data from the larger cities should inflate the numbers enough to provide an estimate of the weights potentially found in a mid-sized Canadian urban area, such as Waterloo Region. (Refer to Appendix C for more discussion on this issue).

Table 3-1 shows the variables that were included in the weighted index. In a few cases, the variables are somewhat different between those in TRB (1998b) and those available for Kitchener, mainly due to the differences in the census questions between Canada and the U.S. Nevertheless, most of the variables identified in the TRB report were approximated using data for Kitchener. Since some of the variables calculated for Kitchener were not considered in the TRB report or vice versa, the geographical pattern of high potential transit use from the weighted index must still be considered in relation to the “unweighted” index which considers all socioeconomic and land use elements.

In terms of calculating the weighted index, the values from the census tracts were multiplied by the weighting factor from Table 1 of TRB (1998), provided here in Table 2-2. Then, for each subtype of variable (e.g. age, gender, immigration, household income, etc.), the weighted values for its constituent variables (e.g. males and females for gender, the different age groups for age, etc.) were added together and divided by the number of constituent variables. Thus, the result was a single value for each variable subtype (e.g. one value for age, one for gender, one for income, etc. – see the data tables in Appendix E). Finally, these resultant values were all summed for each census tract. The outcome is a weighted “transit potential index” value. Again, the data were presented visually in map form using absolute numbers and standard deviations around the mean. As such, the geographical pattern of high potential transit use could once again be described. Resulting maps and discussion are provided in Section 4.

3.6 *Multiple Regression with Current Transit Use*

A final component of the analysis was to determine which (if any) of the socioeconomic and land use factors used to define the indices actually help to define who uses transit in the Kitchener, Waterloo and Cambridge areas based on current (1996) transit trip patterns. A multiple regression procedure was used to determine the relationship between 36 different variables and the dependent variable, the proportion of all trips by transit for each census tract. A stepwise regression procedure was followed, using SPSS statistical analysis software. The results of the regression are summarized in Section 4. The independent variables used in the regression are indicated in Table 3-1.

4.0 The Transit Potential and Current Transit Use

4.1 Current Transit Use

The current level of transit modal split for all trips (origins and destinations) is depicted in Figure 4-1. As evident from the map, the census tract (017.00) containing the Kitchener Transportation Centre (bus terminal) at 14 per cent, as well as the tract (009.03) containing Resurrection High School on the west side of Kitchener-Waterloo (at 12 per cent) have the highest percentage of current transit patronage, by a large margin. The pattern indicates the downtown focus of the bus system in Kitchener in 1996, together with bus traffic to and from the commercial core, a traditional market for transit. The large apparent role of high school students in the transit market in Kitchener is also suggested, given that the Resurrection tract has little else within it that could be leading to such a high modal split for transit. Other areas with moderately high modal splits for transit in Kitchener (five to nine per cent) are:

- most of inner-city Kitchener (except for the Strange Street/Gage Avenue area), where there are mixed use, higher density employment and residential areas, a major hospital, and in close proximity to many bus routes and frequency of service (census tracts 010.00, 011.00, 012.00, 013.00, and 020.00)
- the Queen South and Victoria South corridors (west of the core area), where there are mixed use corridors, including large sections of high-rise apartments (009.02)
- the Margaret Avenue/Union Street/Guelph Street area of Kitchener, where there are high-rise apartments, a community centre, and a grocery store proximate to inner-city neighbourhoods (the grocery store in that area has since closed) (023.00)

- The Fairview Mall area (in south-end Kitchener), which is a major transit transfer point going to Conestoga College (005.00). Also, the shopping centre and nearby mid- and high-rise apartments are likely transit draws. Thus, this area has a mix of residential, employment, and shopping-based transit usage.
- pockets of Southwest Kitchener (including Block Line near Strasburg and Westmount Roads, which is the area around Forest Glen Plaza) (002.02, 002.04, and 002.06)

In Cambridge, the areas with the highest transit use (only about four per cent) are in the Galt core area (124.00), and south of the St. Andrews Street corridor in the southwest corner of the city (West Galt) (122.02).

In the City of Waterloo, the highest transit use is along the King Street area in the uptown core (102.00), and the University Avenue corridor (including the student housing areas between University and Columbia Street) (101.02, 101.03, 101.04, 105.00, 106.01, 106.02, 107.01, and 109.02). All of these areas of Waterloo have only about a four to five per cent transit modal split.

Again, these areas of Cambridge and Waterloo demonstrate the current role of students and the higher density, mixed-use urban cores in the Kitchener CMA's transit patterns. Also, the fact that the areas with highest transit use in Cambridge and Waterloo are at or below the regional average (i.e. less than about 4 to 5 per cent) demonstrates the very low transit patronage in these two cities, even relative to the City of Kitchener.

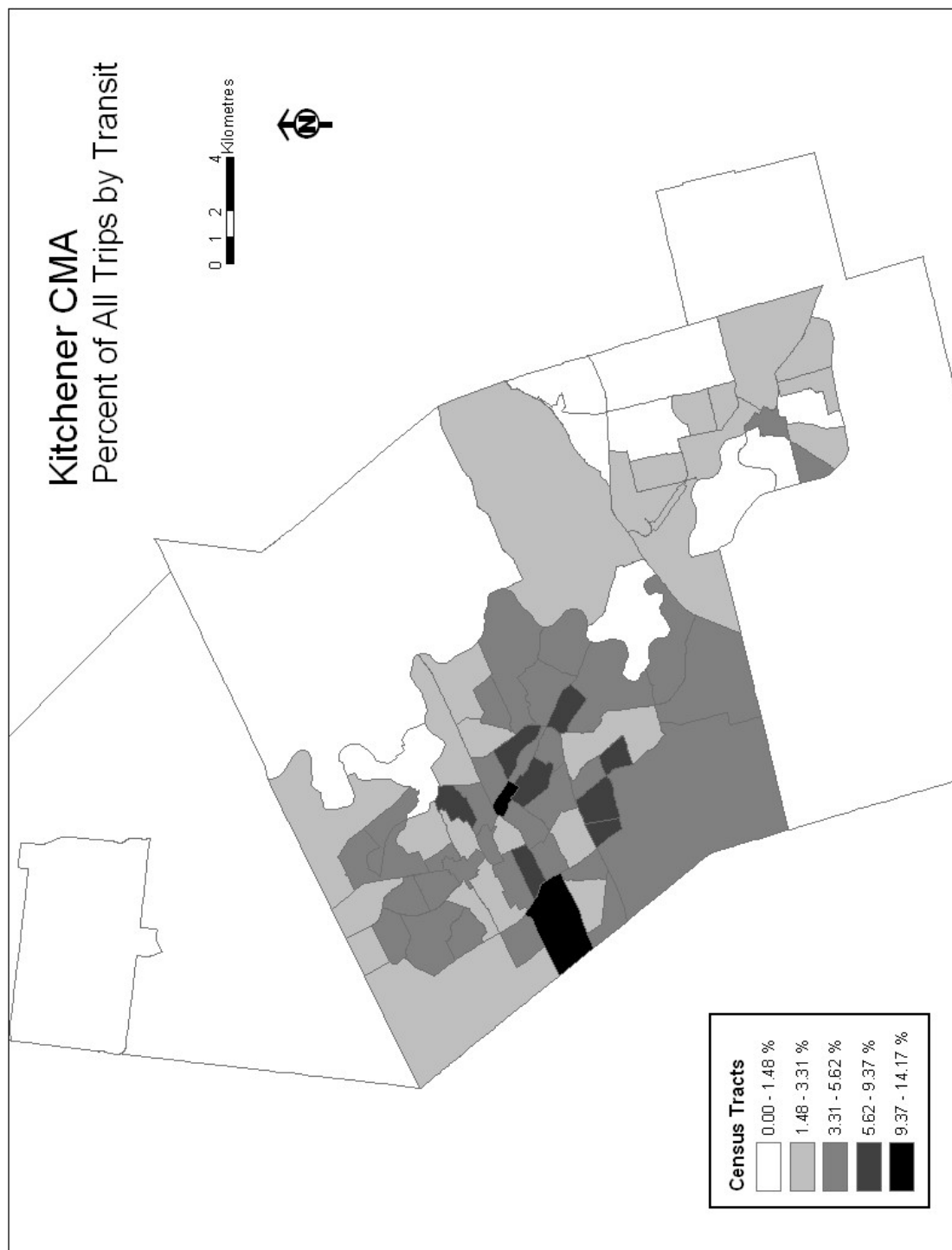


Figure 4-1 Modal split for transit in Kitchener CMA census tracts (1996).
(based on Transportation Tomorrow Survey data, University of Toronto).

4.2 Factors Currently Determining Transit Patterns in Waterloo Region

A multiple regression analysis of the socioeconomic and land use variables suggested in the literature to be important in determining transit-riders revealed very few factors associated with the Kitchener CMA's transit ridership numbers for 1996. In the stepwise regression procedure adopted, a total of four model solutions resulted. The first variable entered was the dwelling ratio (ratio of high density to single family dwellings) (DWEL_R). This had a significant and positive relationship to transit use. In subsequent model solutions, three other variables emerged as significant. With a positive relationship to increasing transit patronage was population density (POP_DENS). This echoed much of the literature on density, although employment density was *not* found to be significant, as was suggested by other research. With a negative relationship to transit modal split, in line with the literature, was the proportion of the population that was non-immigrant (PC_X_IMM) in a census tract (thus demonstrating a positive relationship between transit modal split and the percentage of the census tract population classified as "immigrants"). Somewhat curiously, though, there was also a negative relationship between transit patronage levels and the proportion with an elementary school education (EDU_ELEM). This seems to suggest that census tracts with higher numbers of people with only an elementary education will, in the Kitchener CMA at least, *not* have a greater propensity to use transit; in fact the opposite is true in these areas, with a greater propensity to be a lower transit-using census tract. This seems not only counter-intuitive, but it is also inconsistent with the research. Although, this was, of the four significant

variables, the one with the least significance. For further details on the model solutions and coefficients, please refer to Tables 4-1 and 4-2 below.

Table 4-2 shows the results of forcing all of the variables into the regression process. Although most are not statistically significant to the model developed (i.e. they are well above the 0.05 level of significance), it is useful to look at how the variables related (positively or negatively) to transit use. Most are consistent with the literature, but there are a few anomalies, such as:

- the negative relationship to transit use for the 0-14, 15-29, and over 60 age groups (PC0_14, PC15_29, PC60_);
- the negative relationship for 'white collar' occupations (WHITE_C);
- the negative relationship for the various visible minority groups suggested to have higher than average transit use by TRB (1998b) (VM_BLACK, VM_HISPA, VM_ASIAN);
- the negative relationship to increasing transit use for households with incomes over \$50,000 (HHIGT50K); and
- the negative relationship suggested by the coefficients for employment density (EMP_DENS) and industrial/commercial/institutional coverage levels (ICICOVER).

In all of these cases, the research had suggested these variables should have a positive relationship to increasing transit modal split.

Two additional anomalies were present. The first was the positive relationship between transit and education less than high school (EDU_LTHS). As mentioned previously, this was suggested in the literature, but not found in a similar variable relationship (those with elementary education at best) in the stepwise procedure (Table 4-

1). Nevertheless, the negative relationship for the exact same variable (EDU_ELEM) *was consistent* between the two regression methods. Second, in a complete contrast between the two regression methods, was the variable measuring the ratio of high-density to single family dwellings (DWEL_R), which was found in the stepwise procedure as the most significant variable associated to transit use – it was positively related to increasing transit modal split, consistent with the literature. Unexpectedly, this variable was *negatively* related to transit modal split in the forced variable regression procedure. However, since in the forced variable method, none of the anomalous variables discussed here registered as statistically significant, attributing any actual meaning to these inconsistent results may not be necessary, other than to suggest that the accurate coefficient values and the positive and negative relationships to transit modal split levels are not reflected here because of the lack of significance for the coefficient estimates. The complete output for both the ‘stepwise’ and ‘forced variables’ regression methods is contained in Appendix D.

On the whole, the fact that so few factors actually appear to be associated with current transit usage in the Kitchener CMA may be reflective of the overwhelming predominance of the auto mode. Nearly everyone, regardless of characteristics, uses the car, or else the pedestrian mode as a distant second choice (refer back to the Waterloo Region modal split, Table 1-1). More on this issue is contained in the discussion below (Section 4.5).

Table 4-1 Model Summary and Coefficients from the Stepwise Multiple Regression

Model Summary(e)					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.502(a)	.252	.242	.8703980	
2	.605(b)	.366	.350	.8061159	
3	.642(c)	.413	.390	.7812367	
4	.669(d)	.448	.419	.7623864	1.849
a Predictors: (Constant), DWEL_R					
b Predictors: (Constant), DWEL_R, POP_DENS					
c Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM					
d Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM, EDU_ELEM					
e Dependent Variable: T_TRIPS					

Coefficients(a)								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.971E-17	.097		.000	1.000	-.192	.192
	DWEL_R	.502	.097	.502	5.157	.000	.308	.696
2	(Constant)	8.637E-18	.090		.000	1.000	-.178	.178
	DWEL_R	.442	.092	.442	4.828	.000	.260	.624
	POP_DENS	.344	.092	.344	3.755	.000	.161	.526
3	(Constant)	-2.072E-17	.087		.000	1.000	-.173	.173
	DWEL_R	.404	.090	.404	4.489	.000	.225	.583
	POP_DENS	.266	.094	.266	2.828	.006	.079	.454
	PC_X_IMM	-.234	.095	-.234	-2.459	.016	-.423	-.044
4	(Constant)	3.739E-17	.085		.000	1.000	-.169	.169
	DWEL_R	.429	.089	.429	4.843	.000	.253	.605
	POP_DENS	.266	.092	.266	2.892	.005	.083	.449
	PC_X_IMM	-.239	.093	-.239	-2.577	.012	-.424	-.054
	EDU_ELEM	-.190	.086	-.190	-2.203	.031	-.361	-.018
a Dependent Variable: T_TRIPS								

Table 4-2 Model Summary and Coefficients from the Multiple Regression (forcing of all variables into model)

Model Summary(b)					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.829(a)	.688	.419	.7623832	1.998
a Predictors: (Constant), DWEL_SF, WHITE_C, PC30_39, EPR, PC_X_IMM, VM_HISPA, EDU_HS, PERC_M, POP_DENS, COVERAGE, PC40_49, VM_BLACK, W_CHILD, EDU_ELEM, EDU_SCOL, VM_ASIAN, S_PARENT, PC50_59, DWEL_R, PC15_29, EDU_9_13, CARDRIVR, HHILT20K, SINGLE, ICICOVER, DWEL_HI, EDU_UNIV, EMP_DENS, HHIGT50K, PC0_14, VM_WHITE, PERC_F, EDU_COLL, PC60_, BLUE_C, DWEL_LO, EDU_LTHS					
b Dependent Variable: T_TRIPS					

Coefficients(a)								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.733E-14	.085		.000	1.000	-.171	.171
	PC0_14	-.149	1.976	-.149	-.076	.940	-4.134	3.835
	PC15_29	-.269	1.494	-.269	-.180	.858	-3.281	2.743
	PC30_39	-.303	.966	-.303	-.314	.755	-2.252	1.645
	PC40_49	9.721E-03	.887	.010	.011	.991	-1.779	1.799
	PC50_59	-.411	.834	-.411	-.492	.625	-2.093	1.271
	PC60_	-.997	2.417	-.997	-.413	.682	-5.872	3.877
	PERC_M	.569	1.657	.569	.344	.733	-2.773	3.911
	PERC_F	.946	1.695	.946	.558	.580	-2.473	4.364
	PC_X_IMM	-.410	.192	-.410	-2.137	.038	-.796	-.023
	BLUE_C	-1.061	2.297	-1.061	-.462	.646	-5.693	3.571
	WHITE_C	-.790	2.278	-.790	-.347	.731	-5.385	3.805
	VM_WHITE	-.887	1.345	-.887	-.659	.513	-3.600	1.826
	VM_BLACK	-3.086E-02	.328	-.031	-.094	.925	-.691	.630
	VM_HISPA	-.554	.363	-.554	-1.528	.134	-1.286	.177
	VM_ASIAN	-.983	1.130	-.983	-.870	.389	-3.262	1.295
	CARDRIVR	-.137	.422	-.137	-.325	.747	-.988	.713
	EDU_LTHS	9.506	7.498	9.506	1.268	.212	-5.615	24.628
	EDU_UNIV	-.459	.507	-.459	-.905	.370	-1.482	.564
	EDU_ELEM	-4.753	4.213	-4.753	-1.128	.266	-13.249	3.744
	EDU_9_13	-6.153	5.546	-6.153	-1.109	.273	-17.337	5.032
	EDU_HS	2.451	1.985	2.451	1.234	.224	-1.553	6.455
	EDU_SCOL	.525	.594	.525	.884	.382	-.673	1.723
	EDU_COLL	1.257	1.390	1.257	.905	.371	-1.546	4.060
	HHILT20K	.310	.503	.310	.617	.540	-.704	1.324
	HHIGT50K	-6.818E-02	.676	-.068	-.101	.920	-1.431	1.294
	W_CHILD	-.627	.871	-.627	-.720	.476	-2.383	1.130

S_PARENT	.250	.331	.250	.757	.453	-.417	.918
SINGLE	2.765E-02	.600	.028	.046	.963	-1.181	1.237
EMP_DENS	-.798	.570	-.798	-1.400	.169	-1.948	.352
POP_DENS	.430	.242	.430	1.774	.083	-.059	.919
COVERAGE	1.590	.821	1.590	1.937	.059	-.066	3.246
ICICOVER	-.482	.348	-.482	-1.386	.173	-1.183	.219
EPR	8.044E-02	.239	.080	.336	.739	-.402	.563
DWEL_R	-.345	.410	-.345	-.841	.405	-1.172	.482
DWEL_HI	6.633	4.070	6.633	1.630	.110	-1.575	14.841
DWEL_LO	6.706	4.086	6.706	1.641	.108	-1.534	14.945
DWEL_SF	.281	.357	.281	.787	.436	-.439	1.001
a Dependent Variable: T_TRIPS							

4.3 The Index of Transit Potential (unweighted)

A geographic depiction of the index of transit potential for Waterloo Region census tracts, developed using an equal weighting for various socioeconomic and land use factors (see Table 3-1) is presented in Figures 4-2 and 4-3. Figure 4-2 maps the unweighted transit potential index based on absolute values, while Figure 4-3 presents the standardized index (based on standard deviations around the mean of the index for all 81 census tracts with data). Based on Figure 4-3, which gives the picture of census tracts relative to one another, census tracts in the Waterloo and Kitchener cores have (relatively speaking) the most transit potential based on their current socioeconomic and land use attributes. Most of these census tracts, and especially the highest ones, fall along the King Street corridor through the two cities, from the university student neighbourhoods of Waterloo through to the area east of Downtown Kitchener. In Cambridge, only two tracts are currently above the average level of transit potential for the region: the Preston Village core area (128.00), and the Galt City Centre core area (128.00).

The older (and, in some cases, newer) built up and suburban areas of Kitchener and Waterloo and some built up parts of Cambridge (the central industrial areas, the Hespeler core area [131.01], and some of the southern Galt residential tracts) are around the regional average for transit potential on the unweighted index. The outermost areas of Kitchener (the extreme southwest, the northeast near the Grand River, and the tract nearest Highway 401 [025.00]) are below the regional average for transit potential. Similarly, two of the outermost census tracts (away from the core) in Waterloo (109.01, 109.02), are also below the regional average. In Cambridge, most of the northern part of

the city (outside of the Preston and Hespeler core areas), along with the western Galt area and the southeast corner of the city are below the regional average for transit potential. As might be expected, both of the townships in the study area (Woolwich and North Dumfries) are also below the average transit potential index level.

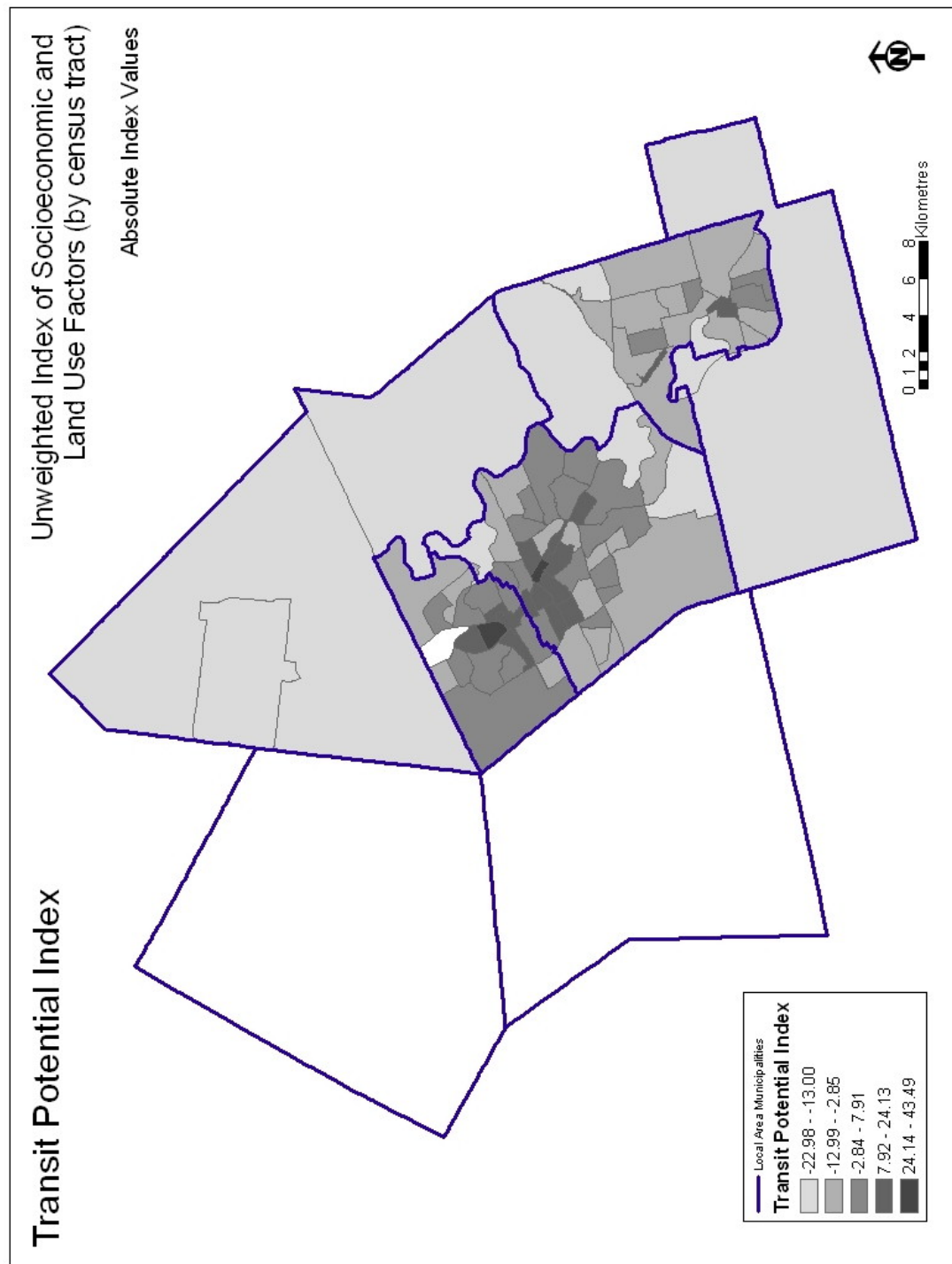


Figure 4-2

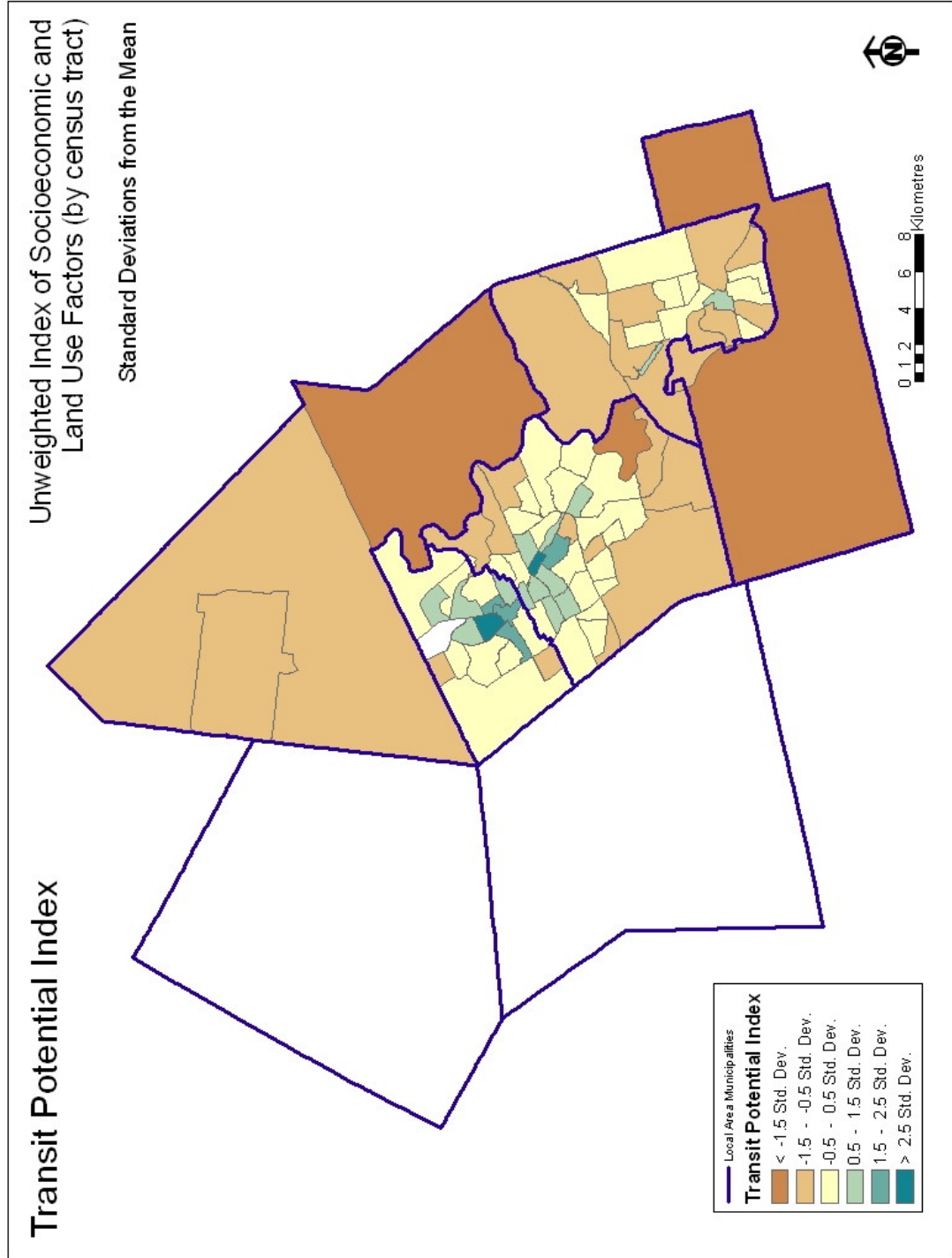


Figure 4-3

4.4 The Index of Transit Potential (weighted)

The maps depicting the absolute values (Figure 4-4) and relative levels (Figure 4-5) by census tract for the transit potential index based on socioeconomic variables alone are provided below. These values, based on weights from TRB (1998b) provide a similar picture to the ‘unweighted’ index values (presented above), although there are some important differences. Again, based on socioeconomic factors only, the townships (Woolwich and North Dumfries), as well as much of southwest and northeast Kitchener and northern Cambridge are below the regional average of the weighted index. The pattern becomes more complex for the inner suburbs and cores of the three cities, however.

In Waterloo, whereas the core census tracts and those toward the university were all above the regional average on the ‘unweighted’ index, based on only socioeconomic factors, several inner tracts are now at or below the regional average for the ‘weighted’ index (e.g. 102.00). This is likely attributable to the fact that the high densities for population and employment are no longer influencing their scores. Immediately east of the Waterloo core, most of the tracts are at the regional average. The University of Waterloo tract (101.02) and the tract southwest of the core (100.00) are below the regional average index value. The same is true for most of the east end of Waterloo. For the Waterloo core and the university area, the lack of permanent resident population in these areas probably means that the socioeconomic characteristics supportive of transit use are lacking in these tracts. The land use (especially employment) characteristics of these areas probably increased their values on the ‘unweighted’ index, since it also includes land use factors.

In Kitchener, the census tracts above the regional average on transit potential become more geographically dispersed when looking only at socioeconomics. The strength of the core's employment and population density, and the intensity of land use are eliminated as factors. This enables several of the inner suburbs to emerge as having a higher than average transit potential. This is especially the case for many of the census tracts west of the downtown, and towards the northwest corner of the city. Some areas of the core drop from above average to only average transit potential, with the elimination of density factors. The elimination of density and other land use factors also leads to an enlargement of the northeast Kitchener area of below average transit potential. Despite these differences in Kitchener, the general pattern of transit potential based on socioeconomic factors alone is still generally consistent with the 'unweighted' index; that is, the highest transit potential is along the King Street area through the downtown, and along the Queen Street and Victoria Street corridors, especially west/south of downtown.

In Cambridge, the elimination of land use factors lowers the transit potential for all three urban cores: Preston and Galt drop to the regional average, and Hespeler drops to below the regional average. The remainder of northern Cambridge stays consistently below the regional average transit potential, while the industrial areas of the central and east end rise, with a transit potential above the regional average. A similar result is true for the census tracts in the south and southeast areas of the city, which rise to above average and to the regional average, respectively. Some of the tracts in the central-west part of the city (between the Preston and Galt cores) also increase their relative potential to the regional average.

As suggested, these differences in transit potential based on socioeconomics alone are localized to specific tracts, and are probably largely attributable to the removal of land use variables (such as density) as factors influencing the 'weighted' index values.

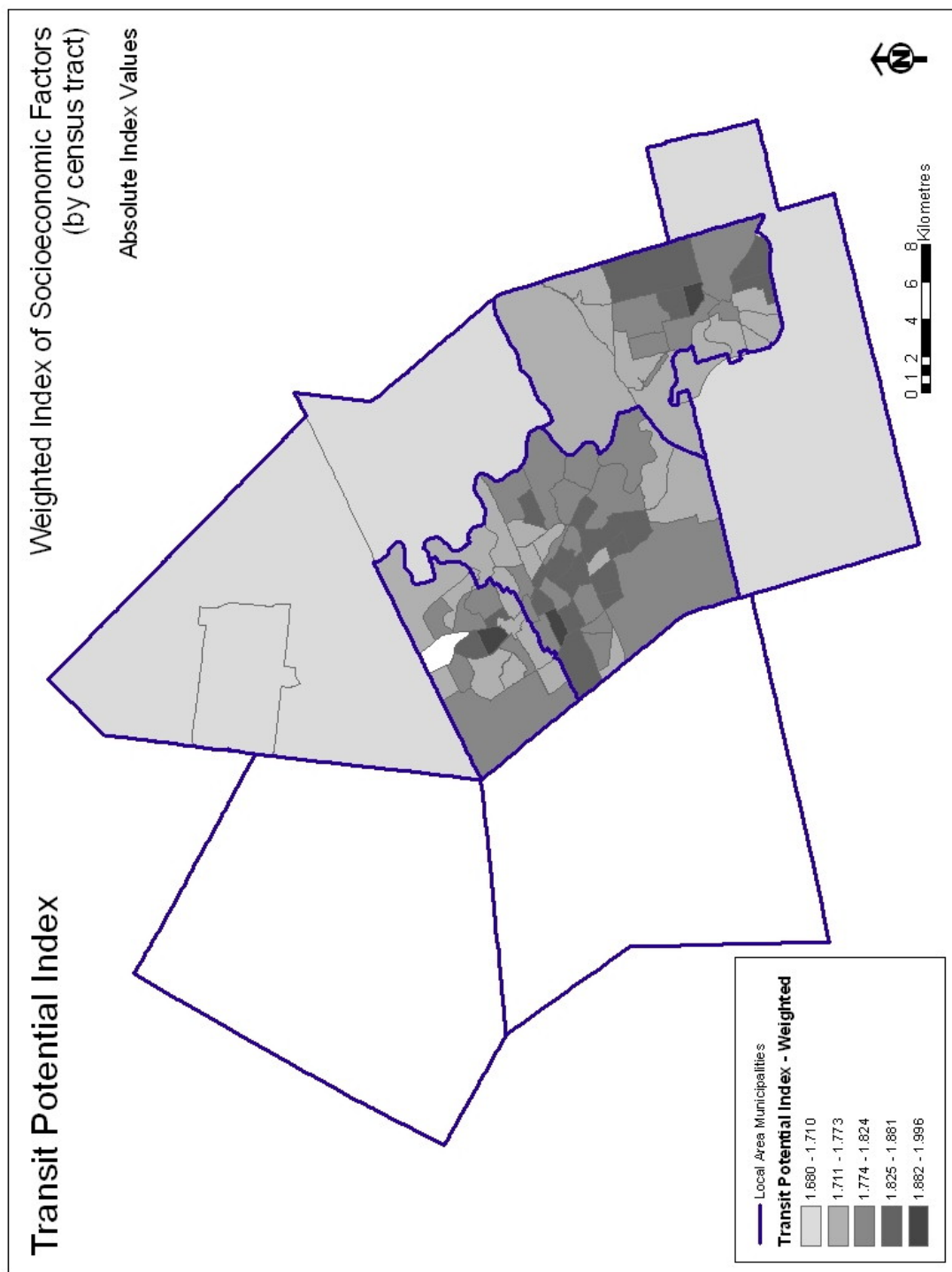


Figure 4-4

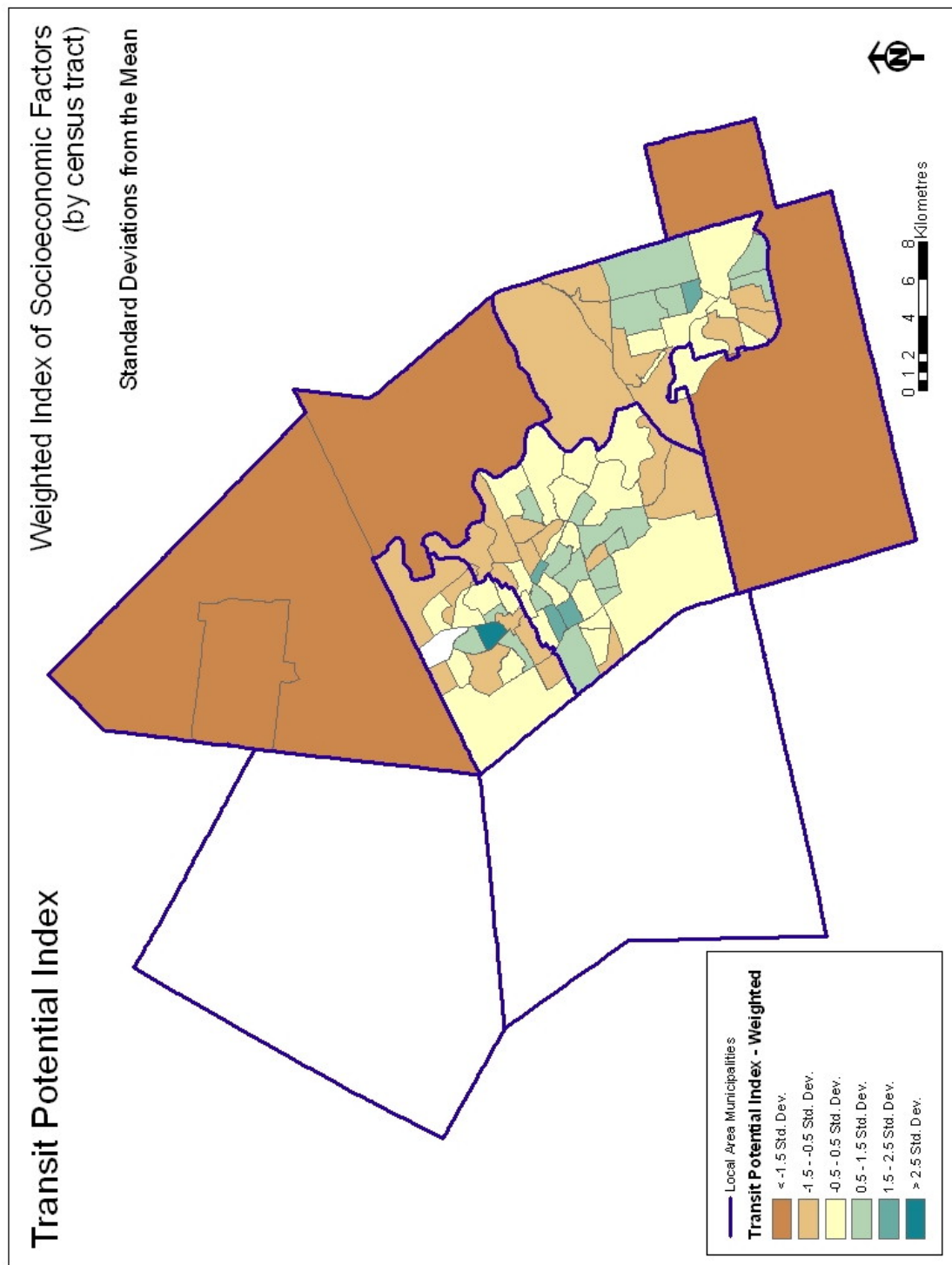


Figure 4-5

4.5 Discussion of Results

As evident in the results above, very little by way of socioeconomic or land use factors influence people to use transit, relative to other modes, in Waterloo Region. The current transit usage pattern (in terms of modal split) is also very low and characteristic of many mid-sized cities in Canada (see, for example, Miller, 2000, Figure 8.3 for a comparison of auto dominance for travel by city). Several reasons exist for this low transit use: some of them are general factors experienced in most mid-sized cities, and some are due to local patterns. In mid-sized cities in general, there tend to very dispersed travel patterns, a deconcentrated or dispersed urban form, and a city centre that is not the primate location for office or retail uses, and consequently a relatively limited transit system, in terms of service frequency and, as a result, ridership (Filion, Bunting & Curtis, 1996 on ‘the dispersed city’; Bunting et al., 2000). The fact that Waterloo Region and the Kitchener CMA are also very multi-nodal (that is, there are several major employment and retail nodes, both traditional urban cores and suburban employment and retail centres) means that this local factor – the intervening opportunities in Cambridge and Waterloo relative to the Kitchener downtown – make for an even more decentralized travel pattern and an absence of focus for good transit service provision (as would be the case in Toronto’s downtown, for example) (Bunting et al., 2000).

Because the current transit service is so limited, infrequent, and (at least in perception) difficult and costly to use in terms of time, the large majority of trip-makers in the Kitchener CMA (as in most mid-sized cities) opt to use auto travel, presumably at all cost. As a ‘last resort’ second choice, pedestrian travel is the option. As a result, even the number of so-called ‘captive’ riders in Waterloo Region is relatively low (only

about 5 per cent of people use transit for journey-to-work trips – refer back to Table 1-1 for the region's modal split in 1996). Because the number who opt for transit use is so low, nearly all demographic subgroups and people living and working in all types of land use environments appear to opt for another mode than transit. This might account for why so few variables currently define transit ridership in Waterloo Region. It may simply be that the virtually no one, not even those falling in the 'captive' transit market or other traditional transit market segments, choose the transit mode given the existing service options and the current competitiveness of transit relative to the car locally.

Keeping this in mind, it was the purpose of this study to suggest that the introduction of a rapid transit line (together with other local planning policies that will encourage urban intensification) could increase the transit potential. This is possibly the case both in areas adjacent to the LRT or BRT line, via direct improvements in accessibility and connectivity and increasing competitiveness of rapid transit to car travel, and in other locations, through people accessing the rapid transit spine using connecting local bus service to the LRT or BRT (as suggested in Loetterle, 2001). Through two different indices, presented in 4.3 and 4.4 above, the transit potential of various parts of the region has been determined spatially.

There are some minor differences in the results of the two indices. The weighted index of socioeconomic factors provides for a more dispersed pattern of transit potential because of its ignorance of density factors in cores. The unweighted index more clearly demonstrates the extremes in transit potential between urban cores, and suburban nodes and peripheral areas. Despite these differences, the two indices do correlate at a moderate to high level for the census tracts in the CMA (correlation coefficient, r , of

0.67). Both indices provide similar spatial results: the greatest transit potential lies toward the core areas (Downtown Kitchener, Uptown Waterloo, Preston and Galt) and along corridors, such as Queen Street and Victoria Street (in Kitchener), University Avenue (in Waterloo), and certainly the traditional main street of the region, King Street/Coronation Boulevard/Highway 8 running from the universities in the north to Galt in the south.

The pattern of transit potential is generally consistent with the current transit usage pattern (Figure 4-1), perhaps suggesting a latent potential in some of the highest areas of current patronage, and is consistent with the proposed alignment of the Central Transit Corridor (CTC) by the Region of Waterloo (Figures 1-1 and 3-1). In addition, the geographical areas of *highest* transit potential (relative to other areas in the region) are broadly coincident with the proposed first phase of LRT development (Figure 1-2), supporting this area of the Region as the place to first consider rapid transit service that can draw out some of that latent potential.

5.0 Conclusions, Limitations, and Applications

This paper has added to the literature and studies underway determining the feasibility and potential of Waterloo Region's Central Transit Corridor proposal for rapid transit introduction. The *current* spatial pattern of transit use revealed the highest levels in the Kitchener core, followed by selected suburban areas of Kitchener and parts of Waterloo and Cambridge (mainly the inner city). The lowest levels were found in the newer suburbs, the two townships under study, and across much of Cambridge.

A number of socioeconomic and land use factors which are characteristic of transit riders in other communities have been identified. Applying them to the current transit patronage levels revealed that only a select few of these, namely the density ratio and population density (among land use variables) and immigrant status and elementary education (among socioeconomic factors), currently help to define Waterloo Region's transit passengers.

Working on the assumption that a *latent potential* exists for transit patronage among residents beyond that which already occurs on the current bus system and based on the factors that appear to drive transit ridership in other communities, two indices of relative transit potential were calculated. Together these indices, with a moderate correlation, indicated the census tracts in the region with the highest transit potential. These areas are found in the city core areas and selected major arterial corridors such as University Avenue, the King Street/Highway 8 corridor, and Queen Street South and Victoria Street South. In Cambridge, the greatest transit potential was found in the Galt core and to a lesser degree, the Preston core and parts of West and North Galt.

5.1 Areas of Highest Transit Potential

The exercise has, by defining the transit potential geographically, indicated that the linear corridor currently under consideration by the Regional government is indeed the most beneficial place for transit improvements attempting to attract more transit riders. This is particularly the case for the Waterloo to Kitchener section, where a majority of the tracts with highest transit potential are located.

Regarding the potential placement of rapid transit nodes, two locations proximate to the CTC clearly stand out: the downtown tract in Kitchener (017.00) and the tract between the two university campuses in Waterloo (106.01), centred on University Avenue and Albert Street (within walking distance of the proposed University LRT station). Based on the areas with the next highest levels of transit potential, additional stations could be placed in the Uptown Waterloo core (102.00 and 105.00) and in the Cedar Hills area immediately southeast of Downtown Kitchener (011.00) (consistent with the LRT station proposed for Benton or Eby Streets). There is also relatively high transit potential for the tract immediately northwest of Fairview Mall in southcentral Kitchener (005.00), which lies along the CTC corridor. As such, and given its relatively close proximity to the Cedar Hills area, Fairview could also be considered for an early stage in the development of rapid transit service. This might necessitate the extension of the CTC section currently under consideration for the first phase of service (Figure 1-2) as far southeast as Fairview Mall.

Concerning bus service that can integrate with the rapid transit corridor and provide rapid transit access to more potential riders, a number of sites outside of the

corridor demonstrate a high latent potential (relatively speaking) that might be captured.

Candidate areas include:

- Several of the census tracts in the west part of Kitchener, particularly the Queen Street South/Queen's Boulevard, Victoria Street South and Highland Road West areas (009.01, 009.02, 010.00, and 018.00); perhaps ending at the nodes of Highland Hills Mall (in tract 008.02) and Resurrection High School (in tract 009.03), which are already major bus service points
- The census tracts around the Forest Glen Plaza node in southwest Kitchener, including the Laurentian Hills (002.02), Laurentian West (002.06) and Country Hills (002.04) neighbourhoods
- The Central Frederick inner city neighbourhood, northeast of Downtown Kitchener (016.00), and the residential census tract north of Stanley Park Mall in east-end Kitchener (014.02)
- The tract containing Conestoga Mall and most of the Colonial Acres neighbourhood in north Waterloo, together with the employment and retail area immediately south of the mall and expressway (where Manulife insurance and a power centre are located) (107.02)
- The Galt (124.00) and Preston (128.00) core areas, and the census tract in West Galt between St. Andrews and Cedar Streets (122.02)
- And finally, from a socioeconomic perspective only, the neighbourhoods around Avenue Road and Franklin Boulevard in North Galt (126.02, 126.03, and 126.04), and two of the tracts in southern Galt (120.01 and 120.02)

(A conceptual map of nodes and potential bus route connections with the first phase of the CTC and the suggested Fairview Mall extension is presented in Figure 5-1).

Assuming the Central Transit Corridor is implemented along the planned alignment, the potential for increased transit use exists in many areas adjacent to the corridor, including several nodes already planned as rapid transit stations (University of Waterloo, Uptown Waterloo, Victoria Street, and Benton Street from Figure 1-2). From the perspective of its placement in areas with the highest *potential* for enhanced transit use and where riders *could* be drawn onto a technology such as LRT, the present CTC proposal is the most feasible one. This being said, the question still remains whether the potential for increased transit patronage will indeed be unlocked by introducing rapid transit service. This is especially a question when the fact that most of the areas with highest potential already receive the greatest levels of relative transit service in the region by the existing bus-only system. This issue can be answered to some extent by the literature that suggests that transit patronage by those not formerly using transit can be achieved by introducing a radical change in service, which a light rail system or an exclusive bus right-of-way (BRT) would provide (e.g. Gomez-Ibanez, 1985; Henscher, 1999; TRB, 2000). Several conditions (outlined, for example, in Huang, 1996) for the successful introduction of rapid transit also exist in Waterloo Region, which bode well for the CTC's success against examples of less successful rapid transit implementation (e.g. Banerjee & Loukaitou-Sideris, 2000 on the Los Angeles' Blue Line; Gomez-Ibanez, 1985 on St. Louis and Buffalo). The region is rapidly growing, both in population and economically. Regional control of the system and the plans to introduce incentives to encourage land use change are beneficial (e.g. tax increment financing to encourage

brownfield development is currently under consideration by the City of Kitchener). The proposed line will also carry passengers between a mixture of activity centres throughout the day, and not face a predominance of journey-to-work traffic in one direction and the inefficient use of infrastructure (as suggested in Boarnet and Crane, 1997). Many of these same factors also work in the region's favour with regards to encouraging additional development to further support the transit infrastructure, and to make other parts of the CTC which currently have less potential more supportive. So, while some stations initially may have lower ridership, the physical infrastructure on the ground will tend to encourage development and population relocation in ways that will make the system increasingly supportive as time passes. However, this is predicated on the increasing need for regional-municipal co-operation in the area of land use controls and incentives to developers.

Still, other geographical, developmental and political trends, as they are now, limit the potential for success. Large parts of the built suburbs cannot easily be made effective or attractive for transit use. Efforts must, rather than focussing on a complete equity of transit service across the region, be targeted to specific suburban mixed use centres and core areas, and towards building new greenfield and brownfield development that provides a transit-supportive landscape. An additional motivation for transit success can come from providing more constraints on auto use, such as reducing parking provision in downtown or new suburban nodes, increasing parking costs, or introducing tolls. Additionally, regular traffic can be limited through high-occupancy vehicle lanes, which allow transit traffic the right of way over auto users. Parking restrictions in downtowns have been particularly successful for the BRT service in Ottawa and Calgary's LRT in

capturing commuter ridership on transit (Morrall & Bolger, 1996). The prevalent free parking in Downtown Edmonton has made its LRT system less successful. Because land use is still controlled primarily at the local municipal level and transportation decisions are made by local, regional and provincial governments, there is an inherent contradiction for transit planning. The ability of the multiple jurisdictions involved in urban affairs to align policy on highway investments versus public transit funding and infrastructure can be a limiting factor on the success of a higher order transit project. These factors are largely beyond the control of the Regional government.

Thus, while it remains to be seen whether the transit potential identified in this study will come to fruition with the introduction of rapid transit, there are several indications that it will have success, particularly in the longer term and given adequate policy instruments. This policy could be modelled on the ‘transit first’ guidelines used by Ottawa to concentrate transit-supportive development around its downtown and suburban nodes (Khasnabis, 1998). LRT (rather than BRT) shows more evidence of the potential to build ridership as time moves on, but this depends on the strength of legislation and incentives and the perceived permanency of the infrastructure. A longer-term view of success for the corridor is consistent with the 40-year planning horizon currently discussed for the Region’s Growth Management Strategy, of which the CTC’s development is a component.

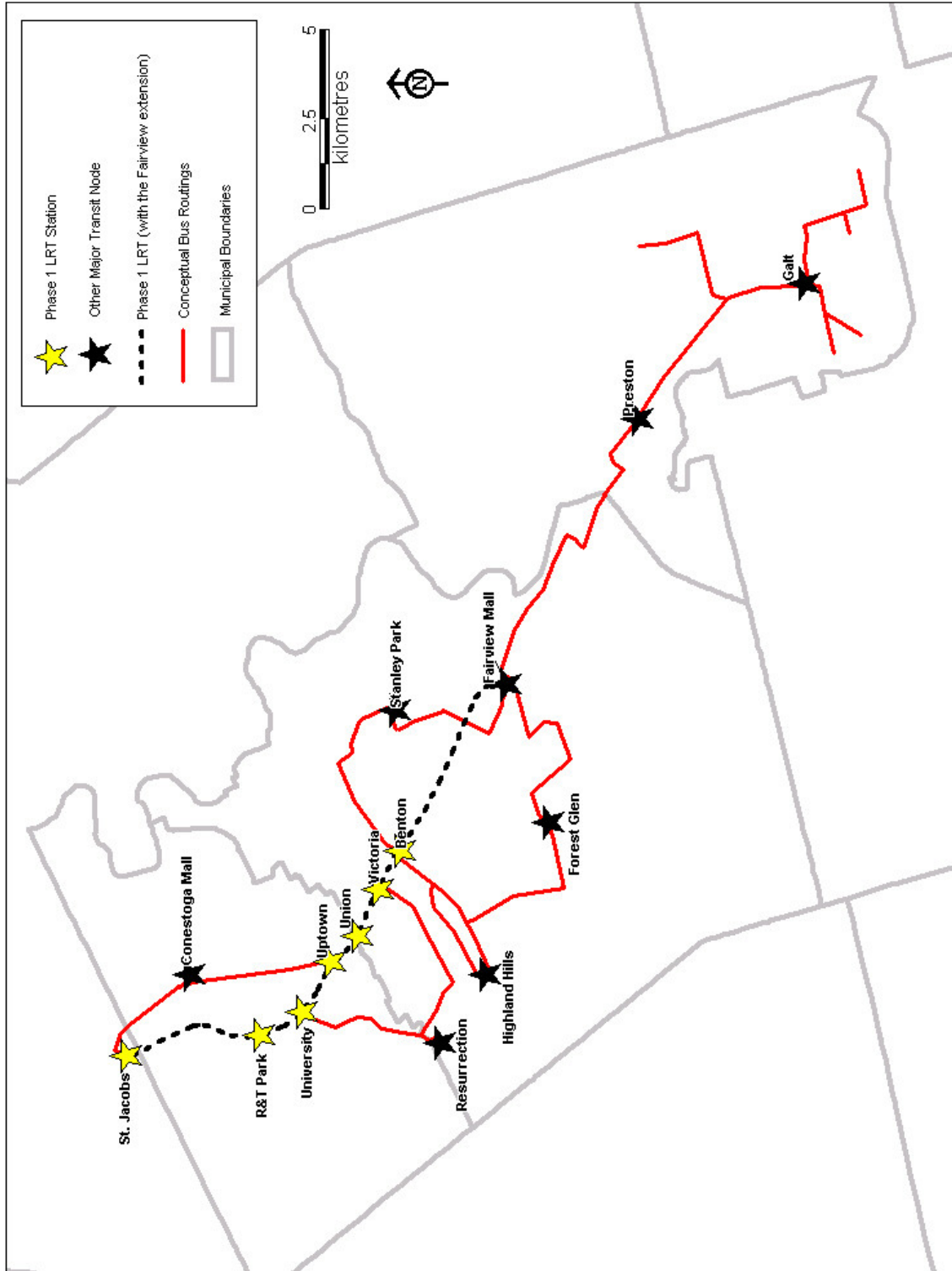


Figure 5-1 Conceptual Map of the First Phase of the CTC and Potential Bus Connections

5.2 Limitations of the Research and Results

Some limitations must be taken into account, both in the methodology and the reporting of results from this research. Two of the primary concerns concerning the interpretation of results are: (1) the disjoint between current socioeconomic and land use patterns and estimated future transit use, and (2) the fact that the calculated indices are only relative to the rest of the region's numbers. Additional issues concern the level of aggregation and timing of data and the limited definition of 'transit potential'.

Regarding the first issue, there is some question as to whether the current socioeconomic and land use patterns will be reflective of future transit use. Only a small body of literature actually examines the before and after impacts of major transit technology investment (e.g. Dewees, 1976; Gomez-Ibanez, 1985; Wood & Smith, 1992 on a priority corridor), and most of this considers only the overall change in ridership, not the level at which potential (but not current) transit riders actually begin to use the transit system after it is introduced. Also, there is the likelihood that socioeconomic and land use patterns will change after the introduction of transit which further complicates the measurement of how transit ridership among nearby residents and employees will change. Will the transit potential become even higher as more people that are likely to use transit and transit-supportive development are drawn to the corridor (as with subway investments in Toronto [Dewees, 1976])?

With the second major limiting factor, because a comparable study of this type on transit potential before the introduction of a service has never been done, the absolute index values obtained for various locations cannot be compared with those of other places. As such, the transit potential could only be weighed from one place relative to

another within the region. As a result, it cannot measure how the transit potential even in the highest areas stacks up to other communities. Hence, the use of the term “high transit potential” can only be used in a relative sense; there is uncertainty over whether or how the transit potential in Waterloo Region stacks up to other communities, particularly those that have introduced similar transit projects (e.g. Ottawa, Calgary, Edmonton, Portland, San Diego). The question of whether the region has high transit potential collectively cannot, therefore, yet be answered. However, this question could be answered in the future if a similar methodology for calculating a transit potential index were used by other communities. This would certainly be predicated on having access to comparable data sources to those used in this study. Thus, there is a need for further research to understand the question of whether there is overall transit potential in Waterloo Region, rather than the issued addressed here, which is more one of “if there indeed is potential for increased transit use in Waterloo Region, where would it be highest relative to other places?”

Another limitation is the use of the census tract as the level of aggregation. Notwithstanding the fact it is a commonly used boundary for research on Canadian urban areas, since it is readily available from Statistics Canada, it is believed that the use of finer boundaries (e.g. enumeration areas) could have provided for a more comprehensive and detailed assessment of transit potential in very specific geographic areas. It also might have enabled a more thorough examination of the factors currently defining Waterloo Region’s transit market. Time limitations and data entry considerations limited the potential to use enumeration areas for this study, although the methodology developed here would certainly be applicable were such a study to be done in the future.

An additional limitation was the slight inconsistency in time periods for the data used in the research. Most of the data were from 1996, but a few of the land use factors in particular were calculated using more recent data (2001-2002). The use of mostly 1996 data is, in and of itself a limitation, since there would presumably be some change in the variables over the years. In fact, this could be highly likely for the dependent variable in the model: the percentage of trips by transit. Because of the improvements in service in Cambridge and the Kitchener-Cambridge link established by the Regional government since taking over the bus system in 2000 (Grand River Transit, 2002), the 1996 numbers may have changed significantly, especially in Cambridge. As a result, it would be beneficial to reproduce this research using 2001 transit patronage and statistical data, which was unavailable at the time this research began.

The definition of transit potential exclusively in terms of socioeconomic, demographic and land use factors is another limitation. In reality, a myriad of factors influences individuals to use a transportation mode. Among these are auto ownership, trip purpose and length for specific trips, psychological factors, and personal motivations such as the time-cost payoff (as addressed in the earlier review of the literature). Since these variables are either difficult to obtain for Canadian cities or impossible to calculate for large groups of people (i.e. entire census tracts as was the case here), the focus of this research was necessarily limited.

5.3 Benefits of LRT Technology Applied to Waterloo Region

The implementation of an LRT or similar higher order rapid transit (even BRT) will work with adequate incentives and controls, as in the Ottawa case [Henscher, 1999])

has the potential to bring about a number of beneficial outcomes. These include the integration of Waterloo, Kitchener, and Cambridge as a 'regional' city, changes to the modal split and auto dependency, and helping to direct urban growth. Each of these will now be examined in turn.

The linear corridor connecting up to four of the five city cores and all three cities represents an opportunity to more closely integrate the urban area of Waterloo Region. Easier accessibility within and between cities is a potential benefit. The urban cores would benefit by having greater accessibility to each other and to major suburban nodes of traffic. For instance, the university students in Waterloo would have greater accessibility for frequenting or even living in the Waterloo and Kitchener cores.

A greater integration in an economic and geographic sense, however, does not necessitate steps toward amalgamation, especially given the Regional government presence as a co-ordinating body and operator of transit. Core areas and communities can come closer together while maintaining their identity and taking advantage of their unique 'sense of place' relative to other parts of the region and other nodes on the corridor.

From the perspective of modal split and auto dependency, rapid transit's introduction can also be beneficial. Assuming that increased numbers of riders are attracted to rapid transit compared to a bus-only system, more ridership on transit, accompanied by more biking and walking would be a positive outcome. Bikers and pedestrians might play a key role as they could presumably use transit for their longer-distance trips. Also there are already twice as many pedestrians as transit patrons in the region [Table 1-1], who could be encouraged to use higher order transit for some trip-

making. Decreasing the share of trips made by car in the region is a major component of the Transportation Master Plan (Regional Municipality of Waterloo, 1998b). For the CTC to be successful, in comparison with other transit systems commonly deemed so, a modal split in the order of 20 to 25 per cent (akin to that of Toronto or Ottawa) would be ideal (Region of Waterloo, 2003). Even a modal split on the order of Hamilton, which does not even have rapid transit (about 12 per cent) would certainly represent an improvement on current levels (less than 5 per cent) and move towards the Region's modal split goals.

From the perspective of growth, the implementation of rapid transit is consistent with the Region's goals in its ongoing growth management strategy. It seeks to redirect some of the anticipated outward growth inwards to existing brownfield sites, and through intensification and infill opportunities (Region of Waterloo, 2003). Many of these areas to direct growth can be developed according to transit-supportive principles and in proximity to the rapid transit corridor, to encourage transit ridership to build and reduce the potential for auto congestion in the increasingly dense urban areas.

5.4 Potential of the CTC: A Final Assessment

The most significant number of people representing the transit market niche in Waterloo Region already live along much of the CTC's proposed alignment, particularly in the northern section (the University of Waterloo to Fairview Mall). This suggests that the introduction of a transit line through the corridor has the potential to draw out some of this admittedly *latent* ridership potential (given the low patronage and lack of factors defining a transit market in the Kitchener CMA in 1996). But, this is only if the potential

transit market can be attracted to use the technology of rapid transit (BRT, LRT). This is predicated on attracting many potential transit riders away from their current reliance on the car, and also convincing more of the usual pedestrians and bikers to use transit for some of their trip-making.

It must also be remembered that the success of the corridor is not dependent on convincing *every* person to use transit for *all* of his or her trip-making. It is dependent simply on making transit a more competitive option with the alternatives for *some* trip-making and by *some* members of the population for which it can serve as a competitive option (i.e. those members of the transit market segment as identified by this research). LRT or BRT technologies allow for transit's competitiveness to become more apparent from a *perceptual* standpoint (since some of the lack of use of the current bus system is, from anecdotal evidence, based on inaccurate or exaggerated negative perceptions), and from an *actual* standpoint, such that some trips by transit (i.e. those along the CTC) become as timely and cost-effective as the same trips by car.

In summary, this paper has shown, to the extent that typical transit users are concentrated in many parts of the Central Transit Corridor and other areas, some potential for increased transit patronage does exist in the region; however, more research is needed. Questions still remain regarding the low level of current use and the limited number of factors defining the transit sub-market locally. These outstanding issues can only be addressed through a radical change in people's perceptions about auto use and the low-density, greenfield, suburban focus of development prevalent in mid-sized cities such as the Kitchener CMA. The growth management strategy and rapid transit may represent such a dynamic effort in the marketing of lifestyles and in public policy

constraints to start achieving a major shift in attitudes and perceptions (and ultimately behaviour), with regards to land use and travel choices.

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Appendix A: A Brief History of Transit in Waterloo Region

Public transit has a long and storied history in what is today the Region of Waterloo. Coincident with the growth of the ‘walking city’ in the late 19th Century, various forms of urban public transportation began to emerge allowing the city to spread out. This led to the emergence of the ‘radial city’ (Newman & Kenworthy, 1996).

In the Kitchener and Waterloo areas, transit has always been an integrated venture. The “Berlin and Waterloo Street Railway Company” began operations in 1888 of a horse-car railway system connecting the downtown areas. By 1895, the horse-drawn cars were retrofitted for use in an electric system (TrainWeb, 2002a).

In 1906, after some line expansions, the Town of Berlin (later the City of Kitchener) purchased the street railway, with the approval of the voters. In 1910, the track was doubled in Kitchener’s core area (TrainWeb, 2002a)

Other street railway systems also competed with the Berlin and Waterloo Street Railway. By 1902, a rival system, the “Berlin & Bridgeport Electric Street Railway Company”, was also in operation and connected the Berlin Town Hall with the community of Bridgeport. This company was later taken over by the City of Kitchener to become part of the “Kitchener & Waterloo Street Railway”. Additionally, in 1904, the “Preston & Berlin Street Railway” connected Kitchener to Preston (Cambridge) (TrainWeb, 2002a).

By the late 1930s, the Kitchener & Waterloo Street Railway Company had been collapsed into the “Kitchener Public Utilities Commission (P.U.C.) – Street Railway

Department”. The P.U.C. entered into the transit bus market, with the take-over of a private cross-town bus line (TrainWeb, 2002a; 2002b).

The remaining street railway services in Kitchener-Waterloo ended in 1946. Trolley coaches (similar to what it still used extensively in Vancouver) took over the service. Trolley coach service lasted until 1973, when diesel buses replaced them. The Kitchener P.U.C. was ultimately renamed “Kitchener Transit” (TrainWeb, 2002b).

One of the most recent changes to transit in Waterloo Region has been the shift of transit services from local municipal to regional control. In 2000, Kitchener Transit in Kitchener and Waterloo, merged with Cambridge Transit. They now form an integrated system operated by the regional government called “Grand River Transit”. Route adjustments, increased service, new routes, and a public transit link between Kitchener and Cambridge have since been accomplished (Grand River Transit, 2002). The introduction of higher order transit in the form of LRT and/or BRT has now been proposed (Region of Waterloo, 2002b). This represents the next phase for transit service in the region, building on past change and, in some ways, hearkening back to the streetcar era.

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Appendix C: Rationale for Variable Selection

In calculating the ‘unweighted’ transit potential index for census tracts in Waterloo Region, the indexed values to average metropolitan transit use from the Transportation Research Board’s research (TRB, 1998b) are used as a basis. Excluding the categories of data not available for the Kitchener CMA (i.e. car ownership and work/mobility limitations), six subcategories of variables are involved: gender, age, education, household income, immigrant status, and race/ethnicity.

Gender differences in transit use (male versus female) are supported in the literature (see Section 2.2.1 in the literature review). There is no particular reason why these gender differences (a weight of 1.18 for females compared to 0.85 for males) would not cause more women than men to be potential transit riders in the Waterloo Region also (e.g. due to lower incomes, status as single mothers, having clerical and professional workplaces with transit access, etc.).

Regarding the factor of age, the pattern reflected in the weights of TRB is again supported in the literature. Younger households (under age 30) and older households (over age 60) do tend to have greater than average transit use (see Section 2.2.1). In Waterloo Region, many of the 17 to 29 year olds are also likely coincident with the large post-secondary population. Given that students tend to be a ‘captive’ transit market, the predominance of students in the region supports the use of a higher weight (1.14) for this age cohort. Similarly, there is no reason to suggest that the senior age cohorts in the region would not also demonstrate a greater potential use of transit. This is supported by anecdotal evidence of the relatively large proportion of seniors already riding the Grand

River Transit bus system. Conversely, the middle-age cohorts in Waterloo Region, like in other places, are those most likely to have suburban and dispersed employment and residential locations, and stable incomes that would increase the propensity to drive rather than use transit. This lends support to the lower-than-average weight given to these age groups.

For the education factor, again the presence of the dichotomy in the local area between the large number of ‘blue collar’ workers with high school education (or less) and the large number of individuals in the professional and high-technology sectors and post-secondary students supports the use of the weights found in TRB (1998b), and throughout the literature. Although the dispersed travel patterns characteristic of mid-sized cities and the suburban location for many local educational/professional employees makes the upper end of the education factor perhaps less likely to capture the transit market niche in Waterloo Region than in other places.

The above-average weight given to the lowest household income cohorts based on the TRB report is both consistent with the other literature on the topic, and consistent with the ‘captive’ transit rider. Locally, the lower income groups currently are and in the future will continue to be a segment of Waterloo Region’s transit riders. For the upper-middle income cohorts, the TRB weights suggest transit use is higher than for middle incomes, but still less than average. This in fact may change in Waterloo Region, with the possible introduction of LRT, since it tends to attract the professionals and aging ‘baby boomers’, which are currently being marketed to live in downtown areas with good transit access (e.g. condominiums in Downtown Kitchener [Bunting et al., 2000]). However, since these populations have historically used auto travel and new

developments have tended to provide parking for this, it is not certain how many of these individuals will shift over to transit. Thus, a weight of 0.95 (just slightly less than average) is probably justified for Waterloo Region.

With Waterloo Region being a destination for relatively large numbers of new immigrants (Bunting, 1991), particularly compared to other mid-sized cities, the presence of the immigrant status variable in the index is important. The immigrant role in the ‘captive’ transit market, and even in the ‘choice’ market for immigrants who are used to using transit in their origin country, is an established one. Thus, the relative weight given to immigrants (2.08) versus non-immigrants (0.84) is justified. However, the trend toward higher income, business class immigrants, and new arrivals that directly suburbanize rather than first settling in older parts of the city (e.g. Ley & Smith, 2000) may mean this higher weight will be less justified in the near future.

Finally, for ethnic status, this factor plays a large role in the TRB weighting since it is U.S.-based, where the racial dynamic plays a role in differentiating activities such as transit versus auto use (since there is spatial and income segregation by race and ethnicity [e.g. Broadway, 1989]). This is likely less of a factor in Canadian cities, particularly mid-sized ones such as Kitchener, where geographic segregation at least is not as evident. Nevertheless, it was felt that the role of ethnicity in the transit market (particularly that not captured by immigrant status alone) justified the use of a breakdown by visible minority status. The TRB weights for ‘white’, ‘black’, ‘Hispanic’, and ‘Asian’ groups were used due to lack of alternative numbers and since the Statistics Canada data could be broken on the basis of these categories.

While the ‘unweighted’ index did not take an approach of weighting the population and land use factors relative to an average of one (1.0), the use of positive and negative signs to sum the standardized variables was reflective of the same general trends in the literature as those noted above and in Section 2.2. In the majority of cases, the status of Waterloo Region as a mid-sized city with mainly only ‘captive’ riders using the system now, combined with the shift in types of riders assumed to accompany the introduction of rapid transit (which generally receives a more positive image from potential ‘choice’ riders) is consistent with at least the direction of the variables in supporting or not supporting transit patronage, as the case may be. It is certainly debatable, given that work on potential use in advance of infrastructure and ‘before and after’ research on transit are lacking, as to how the factors should be combined (e.g. income or age versus employment or population density) or how the land use and demographics should be compared. In the present study, the factors with more subcategories (such as income or age) received more input to the final unweighted index than did others with fewer subcategories (such as gender or employment density). This will clearly have to be addressed in future research.

Appendix D (i)

Complete SPSS Output for Multiple Regression of Socioeconomic and Land Use Variables to Transit Modal Split (stepwise regression procedure)

Variables Entered/Removed(a)

Model	Variables Entered	Variables Removed	Method
1	DWEL_R		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
2	POP_DENS		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
3	PC_X_IMM		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).
4	EDU_ELEM		Stepwise (Criteria: Probability-of-F-to-enter <= .050, Probability-of-F-to-remove >= .100).

a Dependent Variable: T_TRIPS

Model Summary(e)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.502(a)	.252	.242	.8703980	
2	.605(b)	.366	.350	.8061159	
3	.642(c)	.413	.390	.7812367	
4	.669(d)	.448	.419	.7623864	1.849

a Predictors: (Constant), DWEL_R
b Predictors: (Constant), DWEL_R, POP_DENS
c Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM
d Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM, EDU_ELEM
e Dependent Variable: T_TRIPS

ANOVA(e)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	20.150	1	20.150	26.598	.000(a)
	Residual	59.850	79	.758		
	Total	80.000	80			
2	Regression	29.314	2	14.657	22.555	.000(b)
	Residual	50.686	78	.650		
	Total	80.000	80			
3	Regression	33.005	3	11.002	18.025	.000(c)
	Residual	46.995	77	.610		

	Total	80.000	80			
4	Regression	35.826	4	8.957	15.410	.000(d)
	Residual	44.174	76	.581		
	Total	80.000	80			

a Predictors: (Constant), DWEL_R

b Predictors: (Constant), DWEL_R, POP_DENS

c Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM

d Predictors: (Constant), DWEL_R, POP_DENS, PC_X_IMM, EDU_ELEM

e Dependent Variable: T_TRIPS

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2.971E-17	.097		.000	1.000	-.192	.192
	DWEL_R	.502	.097	.502	5.157	.000	.308	.696
2	(Constant)	8.637E-18	.090		.000	1.000	-.178	.178
	DWEL_R	.442	.092	.442	4.828	.000	.260	.624
	POP_DENS	.344	.092	.344	3.755	.000	.161	.526
3	(Constant)	-2.072E-17	.087		.000	1.000	-.173	.173
	DWEL_R	.404	.090	.404	4.489	.000	.225	.583
	POP_DENS	.266	.094	.266	2.828	.006	.079	.454
	PC_X_IMM	-.234	.095	-.234	-2.459	.016	-.423	-.044
4	(Constant)	3.739E-17	.085		.000	1.000	-.169	.169
	DWEL_R	.429	.089	.429	4.843	.000	.253	.605
	POP_DENS	.266	.092	.266	2.892	.005	.083	.449
	PC_X_IMM	-.239	.093	-.239	-2.577	.012	-.424	-.054
	EDU_ELEM	-.190	.086	-.190	-2.203	.031	-.361	-.018

a Dependent Variable: T_TRIPS

Excluded Variables(e)

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	PC0_14	.112(a)	1.028	.307	.116	.791
	PC15_29	.197(a)	1.922	.058	.213	.867

	PC30_39	.191(a)	2.001	.049	.221	1.000
	PC40_49	.042(a)	.418	.677	.047	.935
	PC50_59	-.173(a)	-1.777	.079	-.197	.975
	PC60_	-.219(a)	-2.233	.028	-.245	.940
	PERC_M	.006(a)	.060	.952	.007	.997
	PERC_F	-.012(a)	-.120	.905	-.014	.998
	PC_IMMIG	.324(a)	3.462	.001	.365	.952
	PC_X_IMM	-.324(a)	-3.462	.001	-.365	.952
	BLUE_C	-.151(a)	-1.540	.128	-.172	.965
	WHITE_C	.150(a)	1.536	.128	.171	.972
	VM_WHITE	-.256(a)	-2.653	.010	-.288	.945
	VM_BLACK	.182(a)	1.873	.065	.207	.967
	VM_HISPA	.096(a)	.971	.334	.109	.972
	VM_ASIAN	.184(a)	1.892	.062	.209	.966
	CARDRIVR	-.137(a)	-1.048	.298	-.118	.555
	XCARDRIV	.137(a)	1.048	.298	.118	.555
	EDU_LTHS	-.132(a)	-1.352	.180	-.151	.988
	EDU_UNIV	.094(a)	.971	.335	.109	1.000
	EDU_ELEM	-.182(a)	-1.879	.064	-.208	.981
	EDU_9_13	-.035(a)	-.359	.720	-.041	.998
	EDU_HS	.022(a)	.214	.831	.024	.948
	EDU_SCOL	.128(a)	1.291	.200	.145	.949
	EDU_COLL	.107(a)	1.090	.279	.123	.976
	HHILT20K	.068(a)	.522	.603	.059	.564
	HHIGT50K	-.033(a)	-.289	.773	-.033	.725
	W_CHILD	.110(a)	1.076	.285	.121	.904
	S_PARENT	.211(a)	2.083	.040	.230	.890
	SINGLE	.233(a)	2.010	.048	.222	.682
	EMP_DENS	.118(a)	.788	.433	.089	.423
	POP_DENS	.344(a)	3.755	.000	.391	.970
	COVERAGE	.127(a)	.680	.499	.077	.275
	ICICOVER	.187(a)	1.589	.116	.177	.674
	EPR	-.078(a)	-.800	.426	-.090	.995
	DWEL_HI	.109(a)	.831	.409	.094	.552
	DWEL_LO	-.095(a)	-.727	.469	-.082	.556
	DWEL_SF	-.221(a)	-1.840	.070	-.204	.635
2	PC0_14	.084(b)	.828	.410	.094	.786
	PC15_29	.148(b)	1.525	.131	.171	.849
	PC30_39	.161(b)	1.798	.076	.201	.991
	PC40_49	.103(b)	1.090	.279	.123	.909
	PC50_59	-.098(b)	-1.043	.300	-.118	.922
	PC60_	-.203(b)	-2.235	.028	-.247	.937
	PERC_M	.100(b)	1.072	.287	.121	.930
	PERC_F	-.105(b)	-1.125	.264	-.127	.933
	PC_IMMIG	.234(b)	2.459	.016	.270	.845

	PC_X_IMM	-.234(b)	-2.459	.016	-.270	.845
	BLUE_C	-.125(b)	-1.370	.175	-.154	.960
	WHITE_C	.128(b)	1.410	.163	.159	.968
	VM_WHITE	-.172(b)	-1.811	.074	-.202	.871
	VM_BLACK	.121(b)	1.305	.196	.147	.932
	VM_HISPA	.012(b)	.123	.903	.014	.912
	VM_ASIAN	.128(b)	1.382	.171	.156	.937
	CARDRIVR	-.069(b)	-.564	.575	-.064	.542
	XCARDRIV	.069(b)	.564	.575	.064	.542
	EDU_LTHS	-.155(b)	-1.723	.089	-.193	.984
	EDU_UNIV	.116(b)	1.285	.203	.145	.996
	EDU_ELEM	-.184(b)	-2.063	.043	-.229	.981
	EDU_9_13	-.073(b)	-.804	.424	-.091	.987
	EDU_HS	-.008(b)	-.081	.936	-.009	.942
	EDU_SCOL	.119(b)	1.287	.202	.145	.948
	EDU_COLL	.145(b)	1.593	.115	.179	.965
	HHILT20K	-.044(b)	-.352	.726	-.040	.531
	HHIGT50K	.088(b)	.798	.428	.091	.665
	W_CHILD	.087(b)	.914	.364	.104	.900
	S_PARENT	.060(b)	.557	.579	.063	.706
	SINGLE	.190(b)	1.749	.084	.195	.673
	EMP_DENS	.135(b)	.977	.332	.111	.423
	COVERAGE	.240(b)	1.385	.170	.156	.268
	ICICOVER	-.036(b)	-.282	.779	-.032	.494
	EPR	.038(b)	.391	.697	.044	.887
	DWEL_HI	-.033(b)	-.255	.800	-.029	.501
	DWEL_LO	.052(b)	.410	.683	.047	.501
	DWEL_SF	-.042(b)	-.328	.744	-.037	.511
3	PC0_14	.071(c)	.715	.477	.082	.784
	PC15_29	.076(c)	.750	.456	.086	.746
	PC30_39	.142(c)	1.623	.109	.183	.982
	PC40_49	.168(c)	1.802	.075	.202	.855
	PC50_59	-.087(c)	-.957	.341	-.109	.920
	PC60_	-.171(c)	-1.901	.061	-.213	.912
	PERC_M	.048(c)	.506	.614	.058	.872
	PERC_F	-.057(c)	-.607	.546	-.069	.884
	PC_IMMIG	.(c)	.	.	.	.000
	BLUE_C	-.150(c)	-1.695	.094	-.191	.949
	WHITE_C	.152(c)	1.720	.089	.194	.958
	VM_WHITE	-.043(c)	-.350	.727	-.040	.516
	VM_BLACK	.060(c)	.634	.528	.073	.849
	VM_HISPA	-.057(c)	-.593	.555	-.068	.839
	VM_ASIAN	.005(c)	.050	.960	.006	.643
	CARDRIVR	-.006(c)	-.049	.961	-.006	.517
	XCARDRIV	.006(c)	.049	.961	.006	.517

	EDU_LTHS	-.143(c)	-1.637	.106	-.185	.981
	EDU_UNIV	.095(c)	1.079	.284	.123	.986
	EDU_ELEM	-.190(c)	-2.203	.031	-.245	.981
	EDU_9_13	-.036(c)	-.401	.690	-.046	.956
	EDU_HS	.048(c)	.519	.605	.059	.887
	EDU_SCOL	.081(c)	.884	.379	.101	.916
	EDU_COLL	.131(c)	1.481	.143	.167	.961
	HHILT20K	-.070(c)	-.576	.566	-.066	.527
	HHIGT50K	.112(c)	1.046	.299	.119	.660
	W_CHILD	.088(c)	.953	.344	.109	.900
	S_PARENT	.030(c)	.284	.777	.033	.696
	SINGLE	.152(c)	1.421	.159	.161	.657
	EMP_DENS	.139(c)	1.032	.305	.118	.423
	COVERAGE	.256(c)	1.530	.130	.173	.267
	ICICOVER	-.042(c)	-.337	.737	-.039	.494
	EPR	.019(c)	.207	.836	.024	.881
	DWEL_HI	-.057(c)	-.455	.651	-.052	.498
	DWEL_LO	.073(c)	.585	.560	.067	.499
	DWEL_SF	.011(c)	.090	.928	.010	.495
4	PC0_14	.034(d)	.344	.732	.040	.758
	PC15_29	.054(d)	.538	.592	.062	.738
	PC30_39	.115(d)	1.328	.188	.152	.959
	PC40_49	.095(d)	.918	.362	.105	.678
	PC50_59	-.082(d)	-.916	.362	-.105	.919
	PC60_	-.112(d)	-1.160	.250	-.133	.777
	PERC_M	.004(d)	.039	.969	.005	.831
	PERC_F	-.011(d)	-.115	.909	-.013	.836
	PC_IMMIG	(d)	.	.	.	.000
	BLUE_C	-.064(d)	-.605	.547	-.070	.663
	WHITE_C	.066(d)	.630	.531	.073	.668
	VM_WHITE	.022(d)	.181	.857	.021	.485
	VM_BLACK	.039(d)	.412	.681	.048	.839
	VM_HISPA	-.044(d)	-.467	.642	-.054	.835
	VM_ASIAN	-.059(d)	-.531	.597	-.061	.601
	CARDRIVR	-.048(d)	-.394	.695	-.045	.504
	XCARDRIV	.048(d)	.394	.695	.045	.504
	EDU_LTHS	.049(d)	.311	.756	.036	.302
	EDU_UNIV	-.013(d)	-.125	.901	-.014	.689
	EDU_9_13	.027(d)	.297	.767	.034	.860
	EDU_HS	.021(d)	.229	.820	.026	.870
	EDU_SCOL	-.047(d)	-.431	.668	-.050	.615
	EDU_COLL	-.019(d)	-.149	.882	-.017	.449
	HHILT20K	.092(d)	.661	.510	.076	.382
	HHIGT50K	-.013(d)	-.103	.918	-.012	.477
	W_CHILD	.053(d)	.582	.562	.067	.870

S_PARENT	.110(d)	1.026	.308	.118	.629
SINGLE	.142(d)	1.352	.180	.154	.655
EMP_DENS	.152(d)	1.160	.250	.133	.422
COVERAGE	.301(d)	1.845	.069	.208	.264
ICICOVER	.030(d)	.234	.815	.027	.460
EPR	-.001(d)	-.014	.989	-.002	.872
DWEL_HI	.010(d)	.080	.936	.009	.467
DWEL_LO	.002(d)	.017	.986	.002	.464
DWEL_SF	-.053(d)	-.422	.674	-.049	.469
a Predictors in the Model: (Constant), DWEL_R					
b Predictors in the Model: (Constant), DWEL_R, POP_DENS					
c Predictors in the Model: (Constant), DWEL_R, POP_DENS, PC_X_IMM					
d Predictors in the Model: (Constant), DWEL_R, POP_DENS, PC_X_IMM, EDU_ELEM					
e Dependent Variable: T_TRIPS					

Casewise Diagnostics(a)

Case Number	CT_STRING	Std. Residual	T_TRIPS
62	009.03	4.288	3.3968
a Dependent Variable: T_TRIPS			

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.011457	3.437582	.000000	.6692000	81
Residual	-1.458426	3.269277	.000000	.7430824	81
Std. Predicted Value	-3.006	5.137	.000	1.000	81
Std. Residual	-1.913	4.288	.000	.975	81
a Dependent Variable: T_TRIPS					

Appendix D (ii)

Complete SPSS Output for Multiple Regression of Socioeconomic and Land Use Variables to Transit Modal Split (forcing of all variables into the model)

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	DWEL_SF, WHITE_C, PC30_39, EPR, PC_X_IMM, VM_HISPA, EDU_HS, PERC_M, POP_DENS, COVERAGE, PC40_49, VM_BLACK, W_CHILD, EDU_ELEM, EDU_SCOL, VM_ASIAN, S_PARENT, PC50_59, DWEL_R, PC15_29, EDU_9_13, CARDRIVR, HHILT20K, SINGLE, ICICOVER, DWEL_HI, EDU_UNIV, EMP_DENS, HHIGT50K, PC0_14, VM_WHITE, PERC_F, EDU_COLL, PC60_, BLUE_C, DWEL_LO, EDU_LTHS(a)		Enter
a Tolerance = .000 limits reached.			
b Dependent Variable: T_TRIPS			

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.829(a)	.688	.419	.7623832	1.998
a Predictors: (Constant), DWEL_SF, WHITE_C, PC30_39, EPR, PC_X_IMM, VM_HISPA, EDU_HS, PERC_M, POP_DENS, COVERAGE, PC40_49, VM_BLACK, W_CHILD, EDU_ELEM, EDU_SCOL, VM_ASIAN, S_PARENT, PC50_59, DWEL_R, PC15_29, EDU_9_13, CARDRIVR, HHILT20K, SINGLE, ICICOVER, DWEL_HI, EDU_UNIV, EMP_DENS, HHIGT50K, PC0_14, VM_WHITE, PERC_F, EDU_COLL, PC60_, BLUE_C, DWEL_LO, EDU_LTHS					
b Dependent Variable: T_TRIPS					

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	55.007	37	1.487	2.558	.002(a)
	Residual	24.993	43	.581		
	Total	80.000	80			
a Predictors: (Constant), DWEL_SF, WHITE_C, PC30_39, EPR, PC_X_IMM, VM_HISPA, EDU_HS, PERC_M, POP_DENS, COVERAGE, PC40_49, VM_BLACK, W_CHILD, EDU_ELEM, EDU_SCOL, VM_ASIAN, S_PARENT, PC50_59, DWEL_R, PC15_29, EDU_9_13, CARDRIVR, HHILT20K, SINGLE, ICICOVER, DWEL_HI, EDU_UNIV, EMP_DENS, HHIGT50K, PC0_14, VM_WHITE, PERC_F, EDU_COLL, PC60_, BLUE_C, DWEL_LO, EDU_LTHS						
b Dependent Variable: T_TRIPS						

		Coefficients(a)						
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
Model		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.733E-14	.085		.000	1.000	-.171	.171
	PC0_14	-.149	1.976	-.149	-.076	.940	-4.134	3.835
	PC15_29	-.269	1.494	-.269	-.180	.858	-3.281	2.743
	PC30_39	-.303	.966	-.303	-.314	.755	-2.252	1.645
	PC40_49	9.721E-03	.887	.010	.011	.991	-1.779	1.799
	PC50_59	-.411	.834	-.411	-.492	.625	-2.093	1.271
	PC60_	-.997	2.417	-.997	-.413	.682	-5.872	3.877
	PERC_M	.569	1.657	.569	.344	.733	-2.773	3.911
	PERC_F	.946	1.695	.946	.558	.580	-2.473	4.364
	PC_X_IMM	-.410	.192	-.410	-2.137	.038	-.796	-.023
	BLUE_C	-1.061	2.297	-1.061	-.462	.646	-5.693	3.571
	WHITE_C	-.790	2.278	-.790	-.347	.731	-5.385	3.805
	VM_WHITE	-.887	1.345	-.887	-.659	.513	-3.600	1.826
	VM_BLACK	-3.086E-02	.328	-.031	-.094	.925	-.691	.630
	VM_HISPA	-.554	.363	-.554	-1.528	.134	-1.286	.177
	VM_ASIAN	-.983	1.130	-.983	-.870	.389	-3.262	1.295
	CARDRIVR	-.137	.422	-.137	-.325	.747	-.988	.713
	EDU_LTHS	9.506	7.498	9.506	1.268	.212	-5.615	24.628
	EDU_UNIV	-.459	.507	-.459	-.905	.370	-1.482	.564
	EDU_ELEM	-4.753	4.213	-4.753	-1.128	.266	-13.249	3.744
	EDU_9_13	-6.153	5.546	-6.153	-1.109	.273	-17.337	5.032
	EDU_HS	2.451	1.985	2.451	1.234	.224	-1.553	6.455
	EDU_SCOL	.525	.594	.525	.884	.382	-.673	1.723
	EDU_COLL	1.257	1.390	1.257	.905	.371	-1.546	4.060
	HHILT20K	.310	.503	.310	.617	.540	-.704	1.324
	HHIGT50K	-6.818E-02	.676	-.068	-.101	.920	-1.431	1.294
	W_CHILD	-.627	.871	-.627	-.720	.476	-2.383	1.130
	S_PARENT	.250	.331	.250	.757	.453	-.417	.918
	SINGLE	2.765E-02	.600	.028	.046	.963	-1.181	1.237
	EMP_DENS	-.798	.570	-.798	-1.400	.169	-1.948	.352
	POP_DENS	.430	.242	.430	1.774	.083	-.059	.919
	COVERAGE	1.590	.821	1.590	1.937	.059	-.066	3.246
	ICICOVER	-.482	.348	-.482	-1.386	.173	-1.183	.219
	EPR	8.044E-02	.239	.080	.336	.739	-.402	.563
	DWEL_R	-.345	.410	-.345	-.841	.405	-1.172	.482
	DWEL_HI	6.633	4.070	6.633	1.630	.110	-1.575	14.841
	DWEL_LO	6.706	4.086	6.706	1.641	.108	-1.534	14.945
	DWEL_SF	.281	.357	.281	.787	.436	-.439	1.001

a Dependent Variable: T_TRIPS

Excluded Variables(b)

Model		Beta In	T	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	PC_IMMIG	.(a)	.	.	.	.000
	XCARDRIV	.(a)	.	.	.	.000

a Predictors in the Model: (Constant), DWEL_SF, WHITE_C, PC30_39, EPR, PC_X_IMM, VM_HISPA, EDU_HS, PERC_M, POP_DENS, COVERAGE, PC40_49, VM_BLACK, W_CHILD, EDU_ELEM, EDU_SCOL, VM_ASIAN, S_PARENT, PC50_59, DWEL_R, PC15_29, EDU_9_13, CARDRIVR, HHILT20K, SINGLE, ICICOVER, DWEL_HI, EDU_UNIV, EMP_DENS, HHIGT50K, PC0_14, VM_WHITE, PERC_F, EDU_COLL, PC60_, BLUE_C, DWEL_LO, EDU_LTHS

b Dependent Variable: T_TRIPS

Residuals Statistics(a)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-2.071870	4.051097	.000000	.8292104	81
Residual	-1.116037	2.161719	.000000	.5589366	81
Std. Predicted Value	-2.499	4.885	.000	1.000	81
Std. Residual	-1.464	2.835	.000	.733	81

a Dependent Variable: T_TRIPS

Appendix E: Tabular Results for All Variables (by Census Tract)1st page

Appendix E 2nd page

Appendix E 3rd page

Appendix E 4th page

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