TOWARD AN UNDERSTANDING OF CARPOOL FORMATION AND USE

by

Kalina Anna Soltys

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for the degree of Master of Arts
Graduate Department of Geography and Planning
University of Toronto

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Abstract

Recent transportation, economic and environmental trends demonstrate a need for altering the typical commuting practices in the Greater Golden Horseshoe (GGH) area. Travel Demand Management initiatives like Smart Commute’s, Carpool Zone, are working to reduce the negative externalities of commuting. Using a variety of secondary data sources, geographic visualization, and statistical methods, this thesis examines the carpool formation and use process in the GGH.

The results indicate that municipalities with the highest rates of carpooling are in relatively affluent exurban/suburban areas, located beyond the Smart Commute programming jurisdiction. The most significant factor in the carpool process was found to be proximity to other Carpool Zone users. Other factors include; motivations to save time, gender, and current use of public transit. These results are both relevant in a behavioural science context – advancing current understanding of shared travel behaviour, and in the policy environment, as they inform how to improve carpool practices.
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1. Introduction

1.1 Background

The Transportation Research Board recently projected that globally, the number of vehicles will reach 2 billion by the year 2030. This rise in the production of auto mobility is expected to intensify problems with congestion, energy resources, and climate change (Transportation Research Board, 2008). Looking into the Canadian context, there has been a significant increase in auto ownership within the Province of Ontario. The total number of vehicles registered in Ontario increased by 12.53% from 1999 to 2007 (Statistics Canada, 2007a). Across Canada, workers are experiencing uncertain present and future travel costs (e.g., fluctuating fuel costs, related to the ebb and flow of global energy markets), traffic congestion, environmental concerns, and longer commute times. In the period from 1990 to 2008, the average yearly price for regular gasoline in Ontario increased by 54.7 cents per litre (Ontario Ministry of Energy, 2008). The average Canadian daily roundtrip commute time increased from 54 minutes in 1992 to 63 minutes in 2005 (Statistics Canada, 2006a).

Alternative forms of transportation like carpooling are not competing very well with the dominant form of vehicle use. For example, carpool mode share in the year 2000 in the United States was 12%. This compares with 5% for transit, and 76% for single occupancy vehicle trips (Pisarski, 2006). Recent data for Canada suggest that by 2006, 7.7% of commuters were traveling as passengers. This represents a marginal increase over the previously reported 2001 participation rate of 6.9% (Statistics Canada, 2008a). However, this remains a small portion of the mode share for the daily commute. Overall, current rates

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1 Traveling as a passenger in a vehicle is not necessarily equivalent to carpooling.
of participation in carpooling are lower now, in the US, than there were 20 years ago, when 20% of commuters were carpooling (Pisarski, 2006). The limited historical mode share data available in Canada indicates that, the proportion of passenger travel 13 years ago, was marginally lower (7.4%) than recent statistics (Statistics Canada, 2008a).

Arguably, the current state of personal transportation has resulted in policy makers, planners, and consumers becoming increasingly aware of, and interested in, alternative transport options for commuting (Buliung et al., 2009). Canada’s largest metropolitan region, the Greater Golden Horseshoe (GGH), is not immune to the commuting challenges described earlier – in fact, in 2005, the City of Toronto had the highest proportion of workers who took 60 minutes or more to commute (66%) compared to other major cities in Canada (e.g., Montreal had 60%, Vancouver had 55%) (Statistics Canada, 2006a). Furthermore, the 2001 Census indicated that the median trip distance for Torontonians was 9.2 km, which was higher than the median trip distance reported for all Canadian commuters (7.2 km) (Statistics Canada, 2006a).

Situated within the GGH, the Greater Toronto and Hamilton (GTAH)’s Regional Transportation Planning authority, Metrolinx, has been working on improving the availability of alternative modes of transportation (Metrolinx, 2008a). Metrolinx is an agency created by the Government of Ontario, its mandate is to, “improve the coordination and integration of all modes of transportation in the region” (Metrolinx, 2009). Smart Commute is a program specializing in community relations and initiatives under the direction of Metrolinx (Metrolinx, 2009). Smart Commute, “encourages commuters to explore different commuter options like carpooling, telework, transit, cycling, walking or flexible work hours” (Buliung et al., 2009, p. 5).
An initiative currently being deployed and supported by the Smart Commute Association (SCA) is Carpool Zone. Carpool Zone is a free online ridematching service provided to the public. This online tool attempts to increase the formation of carpools, an alternative transportation mode, in the GTA and surrounding areas. While the term ridematching is used in the program description, the Carpool Zone matches are intended for long term carpooling as opposed to single ride scenarios (Smart Commute Association, 2009). In fact, in order to maintain this long term user base, users are forewarned, “You acknowledge that the Website is not designed to match riders with drivers for one-time or occasional trips and that SCA reserves the right to revoke Your membership and remove You from the system if it is determined that You are using the Website for such a purpose”, when registering for Carpool Zone (Smart Commute Association, 2009).

Carpooling is structured and involves the sharing of vehicles on a somewhat permanent basis; ridesharing is less structured and implies sporadic, shared passenger travel that takes place on a single ride basis. This thesis is concerned with understanding the carpooling process, however some of the ridematching literature has informed thinking about carpooling and is therefore mentioned throughout the paper. Also, the researcher is not privy to the arrangements that Carpool Zone participants set up with their matches and some may resemble a rideshare.

1.2 What is carpooling?

Carpooling has been defined both within legal and scholarly contexts. The following is an excerpt of the legal definition of carpooling as per the Public Vehicles Act of the Province of Ontario:

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“In this Act,

“Board” means the Ontario Highway Transport Board; ("Commission")

“bus” means a bus as defined in the Highway Traffic Act; ("autobus")

“car pool vehicle” means a motor vehicle as defined in the Highway Traffic Act,

(a) with a seating capacity of not more than twelve persons,

(b) while it is operated transporting no more than twelve commuters including the driver, none of whom pay for the transportation more frequently than on a weekly basis,

(c) that is not used by any one driver to transport commuters for more than one round trip per day, and

(d) the owner, or if the vehicle is subject to a lease, the lessee, of which does not own or lease another car pool vehicle unless the owner or lessee is the employer of a majority of the commuters transported in the vehicles, but does not include a motor vehicle while being operated by or under contract with a school board or other authority in charge of a school for the transportation of children to or from school; ("véhicule de covoiturage") (Public Vehicles Act, 2007)².

The definition is very specific about who may operate a carpool vehicle, how a carpool will operate, and what may be considered an acceptable compensation structure. As it is currently defined, the law restricts the full capabilities of carpooling. The issues that arise from these types of regulations will be addressed in the concluding chapter.

² The full legal definition of carpooling as per the Public Vehicles Act of the Province of Ontario can be found at http://www.elaws.gov.on.ca/html/statutes/english/elaws_statutes_90p54_e.htm
The academic definition of carpooling varies within the literature and is conceptualized in this paper as the sharing of transportation to work or school in a private vehicle with other workers or students (Huang et al., 2000). Alongside these definitions, there exist different types of carpoolers. Teal (1987) outlined three types of carpoolers: (1) household carpoolers; (2) external carpoolers who share driving responsibilities; and (3) carpool riders who do contribute the use of their vehicle to the pool and therefore only ride (technically rideshare participants). Based on the nature of the Carpool Zone tool that is under examination in this research, the individuals studied within this thesis belong to the second carpool group. However, as the researcher is not privy to the role preference data (e.g., drive, ride, share) at this time, it is possible that some individuals included in this study are solely riding in carpools and not sharing in the pooling of their vehicles (group 3).

Carpools can also be constructed in different ways. They can form either informally, within households or between friends or co-workers, or formally, within the context of an exogenously defined travel demand management program. This research is concerned with the formation of carpools in a formal setting. Furthermore, within the formal setting, there are different types of programs that could take shape, these include: (1) grassroots efforts (e.g., Craigslist, Facebook, Pickup Pal), or (2) government run initiatives (e.g., Carpool Zone). The grassroots efforts emerge as users seek out ridesharing arrangements through online sites that may have been constructed primarily for other purposes (e.g., social networking, product sales, etc.). On the other hand, government programs often work with employers, and develop extensive promotional campaigns to grow the market for travel demand management.
In comparison with less flexible systems (e.g., public transit), carpooling is somewhat similar to single occupancy vehicle (SOV) use as it provides some spatial flexibility (e.g., door to door service) for travel. However, carpool formation and use is a challenging alternative mode to develop given the issues of schedule matching and the potential increase in commute time associated with passenger pickup and drop off. Carpool formation involves the integration of schedules, values/norms, and resources. Also, it limits one’s flexibility with respect to errands, and spontaneous activity. While these individual deterrents complicate carpool formation and use, there are a number of individual financial (e.g., shared fuel costs), and social benefits (e.g., potential for acquaintanceship) in carpooling. Moreover there are potentially benefits to the environment that could arise from the reduction of personal transport by automobile (e.g., fuel consumption, emissions).

In terms of transportation planning and the development of infrastructure, carpooling does not require significant investment of public capital because it primarily makes use of existing infrastructure. The carpooling alternative represents a modification of the commuter’s use of legacy systems within urban and regional environments. This approach uses past capital investment in infrastructure, enabling a change in the culture of use of critical legacy systems (Garrison, 2007).

1.3 History of carpooling

Interest in carpooling has ebbed and flowed over time - unlike SOV use, which has grown consistently, and non-linearly, during the post- World War II era. Carpooling appears to come into focus as a possible mode choice, receiving widespread attention from the public and policy makers in times of favourable exogenous conditions (e.g., high fuel prices, or fuel
shortages). There have been three specific time periods of peak interest in carpooling within the North American context:

(1) World War II-
Carpooling was initially brought to the attention of the United States government during World War II, as one policy to help with rubber and oil shortages (Ferguson, 1997). Post war commuters essentially returned to SOV use and continued this practice until the next crisis.

(2) 1970’s Oil Crisis-
This crisis was once again revolved around issues with oil supply; taking place in the mid 1970’s. This was caused by political disruptions that led OPEC (Organization of Petroleum Exporting Countries) to take control of the international market supply by imposing an embargo against Western Europe and the United States (Ferguson, 1997). Once the crisis subsided by the early eighties, carpooling once again appeared to disappear from the policy makers and public’s attention (Ferguson, 1997). In fact, carpooling experienced the “most shocking denouement, particularly after having done better than all other alternatives to driving alone in the immediately preceding decade” (Ferguson, 1997, p.352). For example, between 1980 and 1990 there was a decline in carpooling from nearly 20% to 13% (Ferguson, 1997).

(3) 2008- onward-
Most recently, resurgence in the desire for alternative forms of transportation have re-ignited interest in carpool initiatives. Evidence of this trend is exhibited in the statistic that between 1996 and 2006, there was an increase of Canadian commuters traveling as passengers (6.9% to 7.7% respectively) (Buliung et al., 2009). It is difficult to pinpoint the single reason for this new appreciation for carpooling. However, one may hypothesize that concern for the
environment, namely, the production of carbon emissions and climate change, is stimulating interest in carpooling. Just as likely is the possibility that rational decision making around the rising cost of auto ownership and use is giving rise to some interest in carpooling and ridesharing. Since 2008, however, the North American economy has headed into a recession. Reductions in personal capital could produce increased interest in cost-reducing travel initiatives like carpooling, although it remains too early to tell. Among the array of possibilities for moving the carpool formation process along, governments and others are experimenting with on-line systems designed specifically for carpooling, and systems that were designed for other purposes, like social networking, that also facilitate the production of connections between people, with a view to sharing mobility.

1.4 Research Objectives

Given the commuting issues outlined earlier, and the emergence of information and communication technology (ICT) mediated mobilities, it is apparent that this is a crucial point in time for carpool related research. This research focuses on the carpool formation and use process through a travel demand management initiative that makes use of ICTs. The three objectives of this research are: (1) to examine whether there exist common traits and behaviour that are specific to the commuters who have begun carpooling and those who have indicated some intention to carpool, but have yet to do so; (2) to study the geography of demand for carpooling in the Greater Toronto and Hamilton area (GTAH) and; (3) to uncover factors which contribute to carpool formation and use.

The research objectives are accomplished using data from Smart Commute’s Satisfaction Survey, Carpool Zone profile data and the Canadian Census. Methodologically, the research makes use of bivariate contingency analysis, exploratory spatial and non-spatial
data visualization techniques, and logistic regression analysis. The work is intended to contribute to the study of travel behaviour, and to influence the policy and programming goals and initiatives of Metrolinx, Smart Commute – in other words, this work bridges an important gap between academic novelty and the practice of transportation planning. Contributions to practice are intended to shed light on improving Metrolinx’s carpooling initiative, with a view to enhancing access to sustainable transport options in the GTA-H area.

1.5 Outline of thesis

The thesis contains five chapters. The introduction has provided background information on carpooling and outlined the research objectives. Following the introduction, Chapter 2 provides a review of the relevant literature. The study area and methodologies employed in this research are described in Chapter 3. Chapter 4 presents and discusses the research findings. Lastly, the conclusions are presented in Chapter 5 along with recommendations for improving carpooling and an outline of future research opportunities.
2. Literature Review

This chapter reviews the literature on carpooling. The review focuses on studies that have attempted to provide insight into the following questions: What factors affect carpooling? What is the role of technology in the formation of carpools? The first section of the literature review (Section 2.1) outlines Transportation Demand Management (TDM) and explains how carpooling fits into the practice. Section 2.2 discusses factors that encourage and discourage carpooling. Section 2.3 considers the literature that examines how Information and Communications Technology (ICT) can be used to benefit carpooling. Section 2.4 summarizes the main findings of the literature review.

2.1 Transportation Demand Management (TDM)

TDM is concerned with policy initiatives that improve the efficiency of the urban transport system (Meyer, 1999). The initiatives traditionally concentrated largely on operational improvements (e.g., improved transit infrastructure), but expanded to include the mitigation of environmental effects (e.g., air pollution and energy conservation) (Meyer, 1999). Meyer (1999) identified three types of TDM:

1. creating and promoting alternative transportation options to increase occupancy in vehicles;
2. changing the amount of travel, particularly travel during peak hours through the use of incentives; and
3. eliminating the need for physical travel altogether (e.g., telecommuting).
Carpooling is associated with the first type of TDM (creating alternative transportation options to increase occupancy in vehicles). It uses existing transportation infrastructure to reduce the monetary and environmental costs of commuting.

A number of authors (Teal, 1987; Ferguson, 1997) have critiqued the usefulness of carpooling as a TDM strategy, and Morency (2007, p.242) pointed out that “lack of unity amongst different types of (TDM) organizations is a cause for concern as there is a loss of potential carpoolers due to overlapping initiatives.”

Using statistics from the United States, Meyer (1999) investigated ridesharing. Meyer showed that ridesharing’s impact as a TDM strategy is limited compared to other initiatives. He found that several strategies were more successful than ridesharing in reducing vehicle miles travelled (VMT): employer trip reduction, improvements to transit, parking pricing, congestion pricing, telecommuting, and land use planning.

While ridesharing slightly differs from carpooling, it is included in the review as its differences are what may improve the latter’s chance of success. Carpooling’s structured and permanent approach suggests that carpooling can offer commuters confidence in their daily mode of transportation. This confidence should make carpooling a more successful TDM strategy than ridesharing, and should increase the utility of carpooling as a TDM initiative worth investigating further.

2.2 Factors that affect Carpooling

Carpooling requires the public to make changes to their commuting behaviour. It is, however, difficult to alter people’s behaviour, and changes in travel behaviour usually require strong support from the business community and planning organizations (Meyer, 1999).
This section discusses factors that affect carpooling. The factors are examined individually but are also often interconnected. The factors mentioned in the literature tend to fall into three groups:

- individual factors (cost, mobility constraints, demographics, mode choice);
- spatial factors (accessibility and commuting patterns); and
- temporal factors (commuting time and scheduling).

A key stage in the carpool formation process is decision making and therefore it is appropriate to include a theory (although not created directly for transportation) that has been used in mode choice research (amongst other fields). Attitudes to carpooling, and factors that may be conducive to carpool formation should be investigated and taken into account when studying the carpool decision making process. It is also important to consider the context in which individuals make their decisions. If potential carpoolers are highly concerned with societal norms, these norms may have an influence on the decision to take up carpooling.

The Theory of Planned Behaviour (TPB) potentially offers a framework for analysing all these issues and how they interact. The authors using this theory often test the factors described above.

The TPB is a framework that takes into account normative beliefs and the human decision making process. The framework can be very useful when studying factors that encourage and discourage carpooling. The TPB is an extension of the Theory of Reasoned Action. Both theories were proposed by Ajzen (1991).

The TPB suggests that “Intentions to perform behaviours of different kinds can be predicted with high accuracy from attitudes toward the behaviour, subjective norms, and perceived behavioural control; and these intentions, together with perceptions of behavioural
control, account for considerable variance in actual behaviour” (Ajzen, 1991, p.179). The theory can be applied to carpool decision making, and used to analyse the importance of commuters’ attitudes toward carpooling, how they feel about the consequences of carpooling, how much they take into account how others might feel about carpooling, and their perception of how much control they have as carpoolers.

2.2.1 Factors that Encourage Carpooling

The literature identifies numerous factors that encourage carpooling. These factors include commuting cost, time savings, environmental awareness, mode choice, access to potential carpoolers, and demographic characteristics (such as gender, educational attainment, household income, occupation, race, and vehicle availability).

Conmuting cost

Many studies have noted the importance of cost savings in encouraging carpooling:

- Levin (1982) found that college students’ interest in joining a carpool was mainly motivated by the perceived economic advantages.

- Tischer and Dobson (1979), Rose (2002), and Alpizar and Carlsson (2003) found that monetary cost was one of the most important issues that affected the decision to carpool.

- Giuliano (1992) argued that the decision to carpool depended more on cost savings (and being able to resolve scheduling conflicts within the household) than on other factors such as time savings.

- Benkler (2004) provided details of how the costs of auto use and auto maintenance motivate carpoolers.

- Andrey et al.’s (2004) study of teleworking found that cost was a significant factor in mode choice.
• A Vancouver commuter study suggested that the increasing cost of Single Occupancy Vehicle (SOV) commuting appeared to be driving an increase in carpooling (Washbrook et al., 2006).

• Taylor (2006) suggested that alternatives to SOV use could be encouraged by increasing the cost of driving through higher taxes and the elimination of free parking.

Cost incentives
Cost incentives for carpooling are widely discussed in the literature. A cost incentive in this case is a method used to entice potential commuters to switch from their current mode to carpooling by offering financial rewards (e.g., a cash bonus for carpoolers, lower toll rates). They are considered an important issue for policy development and a key mechanism for encouraging changes in commuting behaviour. Shoup (1997) suggested that carpooling would be encouraged if, instead of providing subsidized parking, employers gave a cash incentive to employees who did not use a parking space. Meyer (1999) stressed the need to recognize both actual and perceived costs, and considered transportation pricing (cost incentives and disincentives) to be a central issue in TDM.

Time savings
A number of studies have stressed the role of time savings in carpooling. Fewer vehicles mean less congestion. Collura (1994) identified congestion as a primary reason for carpooling, and Benkler (2004) noted that being allowed to use High Occupancy Vehicle (HOV) lanes encouraged carpooling.

Environmental awareness
Some researchers have drawn attention to environmental awareness as a motivation for carpooling. This awareness may indicate a shift in societal norms. Collura (1994) identified
environmental awareness as another primary reason for carpooling. Benkler (2004) also identified environmental responsibility as a motivation for carpooling.

Carpooling as a mode choice

Mode choice is a very large subject. This review is particularly concerned with factors that encourage carpooling in the trade off with Single Occupancy Vehicle (SOV) travel:

- Levin’s (1982) study of college students pointed out that carpooling could compete with SOV commuting because drivers and riders enjoyed cost savings benefits, and riders enjoyed the additional benefit of comfort (i.e., ability to read or nap during commute).
- In their study of suburban commuting in California, Cervero and Griesenbeck (1988) also found that commuters were more likely to carpool for long distance commutes than for short distance commutes. Whereas only 17% of clerical employees who commuted 4 miles carpooled, 37% of clerical employees who commuted 50 miles carpooled.
- Levin (1982) found that carpooling was more favoured for long distance commuting than for short distance commuting. (His study of university carpooling found that females did not like to travel alone for a roundtrip longer than 30 miles.)
- Levin (1982) also noted that commuters were more in favour of carpooling when the number of riders was small. As the number of riders increased, the delays caused by meeting up with the drivers were likely to increase.
- Benkler (2004) also noted that being able to ride rather than drive could be a motivation for carpooling.
- Benkler (2004) identified having company during the commute as a motivation for some commuters to carpool.
• Van Vugt et al. (1996) provided an ordered list of SOV drivers’ opinions on the attractions of carpooling versus driving alone: (1) environmental well-being, (2) low travel cost, (3) sociability, (4) relaxation, (5) safety, (6) comfort, (7) low travel time, (8) reliable travel time, and (9) flexibility.

• Ozanne and Mollenkopf (1999) used the TPB to examine factors that influence carpool formation and use. The researchers found that attitudes are important in the decision to carpool. The attitudes considered included perceived ease of carpooling, and societal benefit. The issues considered included monetary incentives, scheduling, and access to other carpoolers.

Access to potential carpoolers

Access to potential carpoolers is an important aspect of carpool formation because in order for carpooling to be successful, an adequate number of participants is required. Teal (1987), for example, suggested that participation in carpools is highly dependent on the size of the potential list of carpoolers. Meyer (1999) stressed the need for many users in an effort to sustain rideshare, and Kaufman (2002) also found that access to potential carpoolers is important to success.

In Teal’s (1987) study, the author identified three types of carpoolers (Outlined in Section 1.2). Teal found that the household carpoolers were the most successful. This group clearly had excellent access to other carpoolers. This thesis is directed at external carpoolers for whom it is clearly important to consider how access to potential carpoolers can be facilitated. Several researchers have investigated carpool formation in the corporate setting. Collura (1994) suggested that employment based programs were a cost effective approach to encouraging carpooling. Cervero and Griensbeck (1988) and Ferguson (1990) identified
company size as a key issue. Larger firms typically produce a larger pool of participants with a common destination.

**Demographic characteristics**

The role of socio demographic factors in the carpool formation process has been widely discussed in the literature. Ferguson (1995) found that income played a role in lower income households’ decision to carpool because income influences auto ownership and use. Baldassare et al. (1998) found that the income was an important predictor of carpooling, as their California based study found that low income individuals were most likely to begin carpooling given various fees and incentives. Baldassare et al. (1998) also discovered that age was also a determinant in the choice to begin carpooling. Their study demonstrated that young commuters were most likely to engage in carpooling compared with other modes (Baldassare et al., 1998). Ferguson (1995) also found that vehicle availability and educational attainment are more influential in the choice to carpool than other characteristics like gender.

Kaufman (2002) investigated the effect of demographic characteristics on carpool formation in an Australian university based study. He was interested in the effects of, for example, age and gender on commuting behaviour, especially in terms of work location, mode choice, and the decision to carpool. Kaufman (2002) found that socioeconomic characteristics did not impact the choice to carpool. Benkler (2004) reviewed the literature and found only limited connections between demographic characteristics and carpool formation.

A number of researchers, however, have drawn attention to gender differences in travel behaviour. These researchers argue that gender and the experience of females in the
urban economy influence vehicle access, and have an indirect impact on carpooling. For example, females with pink collar occupations tend to have lower incomes than males, and may not be able to afford a vehicle.

Johnston-Anumonwo (1992) considered the length of females’ commute, and found that females had shorter commutes than males. Camstra’s (1996) research also demonstrated that females had shorter commute times than males, an outcome that was seen largely to be a function of poor vehicle access. Other research, however, has found that females have longer commute times than males (Rietvald et al., 1999). Kwan (1999a, 2000) found that females had lower levels of accessibility to opportunities than males as males were more likely to have the income required to use a vehicle to commute. Kwan (2000) also found that full time employed females had longer commutes than males. Some authors have reported that have found that carpooling mostly occurs over longer distances (Levin, 1982).

Tischer and Dobson (1979) and Kaufman (2002) found that females are more likely than males to carpool. They explained this difference in terms of the auto use constraints experienced by females. Camstra (1996) agreed that females are more likely than males to carpool. Levin (1982) found that females were more likely than males to act as riders in carpools. Males were more interested in driving.

Much of the gender-transport literature attempts to explain the difference in male and female commuting patterns and carpooling by situating these patterns and processes within the household responsibility hypothesis (HRH) and entrapment theory. According to the HRH, females tend to have shorter commutes than males because females perform a larger share of childcare and domestic responsibilities (Sermons and Koppelman, 2001), and therefore need employment, childcare and shopping to be close to home to lighten the load.
(Cristaldi, 2005; Kwan, 1999b). Camstra (1996) suggested that females have shorter commutes not only because females have vehicle access constraints, but also because females’ household responsibilities mean that females have a higher value of time than males.

Entrapment theory is related to HRH. The theory suggests that females tend to be constrained to a small travel area because of their household duties and because of the type of employment available to females (Cristaldi, 2005). The effects, however, of entrapment may be exaggerated. For example, England’s (1993) study of firms with suburban offices found that clerical workers (mainly females) had longer commutes, and that the length of the commute was not affected by having children or a second household worker. In addition, the hiring of female staff was not a major issue in the firms’ location decisions.

2.2.2 Factors that Discourage Carpooling

Factors that discourage carpooling include some aspects of transportation policy (Taylor, 2006); affluence (Rouwendal and Nijkamp, 2004); scheduling issues; problems with being unable to travel during the work day; problems with being unable to transport items (Andrey et al., 2004); lack of flexibility, inconvenience, and increased time spent commuting (Meyer, 1999; Van Vugt et al., 1996; Tsao and Lin, 1999); prevention of spontaneity and personal freedom (Andrey et al., 2004); additional time needed to pick up or meet each rider (Levin, 1982); and incompatibility with short distance commuting (Levin, 1982; Cervero and Griesenbeck, 1988).

- Points of additional interest from the literature mentioned above include the following:
• Recent research has suggested that the cost of commuting plays a smaller role in the choice to carpool than it did in the past (Rouwendal and Nijkamp, 2004). This finding suggests that increasing affluence has been working against carpooling.

• Meyer (1999) pointed out that potential carpoolers may be deterred by the inconvenience of not having a vehicle during the day, and by the time lost driving additional distance to meet fellow carpoolers.

• In a Dutch study, Van Vugt et al. (1996) found that many people were unable to carpool due to scheduling issues. The researchers also found that the advantages of being able to use HOV lanes did not overcome carpooling problems and did not promote increased carpooling.

• Using the TPB, Andrey et al. (2004) explored the role of societal norms in travel decision making. Their work discussed how society’s perceived ideal of each adult owning a vehicle and enjoying unlimited mobility might act as a deterrent to carpool formation and use. The researchers concluded that, “psycho social barriers to mode change are just as important as the practical barriers” (Andrey et al., 2004, p.272).

2.3 The Role of Information and Communications Technology (ICT) in Encouraging Carpooling

For carpooling to function well, commuters need to be able to connect with each other. This section discusses the literature on how ICT (e.g., web-based ridematching) can be used by commuters to connect with each other for the purpose of producing shared mobilities.

Research from the mid 1990s (Hasselkorn et al., 1995) noted that commuters were excited about carpooling, but found the formation of matches difficult. An early study by
Hall and Qureshi (1997) concluded that web-based carpool applications were theoretically viable, but that their “real world” utility appeared limited as there was little evidence of people finding success in matching. Hall and Qureshi found that while matches were possible, the chance of an actual carpool forming was one in five at best. This is very interesting as the time period of this work (late 1990’s) saw the beginning of widespread Internet use.

Two years later, a ridematch study conducted by Dailey and Meyers (1999) found that as more users are registered, there is an increase in carpool formation. This finding would be expected intuitively: as the pool of users becomes the larger, the diversity of commuting routes, and commuter demographics is likely to increase, and the chance of finding a suitable match is likely to increase. Dailey and Meyers’ work suggests that a small carpool program may have little impact initially, but over time, as the number of commuters becomes larger, the program’s impact may increase.

Resnick (2004) and Winter and Nittel (2006) concluded that the emergence of ridesharing has been closely associated with social conventions rather than with technological innovation. Calvo et al. (2004), however, concluded that technology played an important role in carpool creation. Their study was conducted in Europe, and concluded that ICT based solutions worked well, but the researchers presented little empirical evidence to substantiate their observations.

2.4 Literature Review Summary and Conclusions

Much of the carpooling literature has examined the factors that encourage and discourage carpooling. Important factors that encourage carpooling appear to include cost savings and cost related polices that promote carpooling over SOV commuting. Financial savings and
incentives are more likely to be effective for long distance commuting and for low income commuters who do not have access to an automobile. Other factors that appear to encourage carpooling include time savings (from using HOV lanes), environmental awareness, small carpools (so delays meeting up with other carpoolers are minimized), the comfort of traveling as a rider rather than as a driver, companionship, and easy access to potential carpoolers with similar commutes.

Factors that discourage carpooling include transportation policy that supports SOV travel, high levels of auto ownership and use, scheduling problems, increased time spent commuting (having to allow time for meeting fellow carpoolers), and lack of flexibility. Lack of flexibility includes being unable to travel during the work day, being unable to transport items, and a general loss of personal freedom.

Overall, the literature suggests that SOV travel is preferred for short commutes because carpooling increases commuting time due to the need to pick up other members of the carpool. When the commute is long, this SOV advantage is less important and commuters are more attracted to reducing their costs by carpooling.

The literature is not conclusive about many issues, and does not offer clear details or guidelines on which commuting or demographic factors have the most impact on carpooling. For example, we do not know how far carpoolers are willing to travel to meet their matches each day. Some researchers see HOV lanes as a positive for carpooling while others believe that HOV lanes do not make up for the inconveniences of carpooling. The issue of gender is also unclear. If females have low income jobs and low auto accessibility, they may be more likely than males to carpool. If, however, females tend to work near home in order to meet
domestic and family demands, their shorter commutes, and other daily activities and travel, may work against their becoming involved in carpools.

Society’s norms (such as the expectation that all adults will own and drive a car) and the psycho social barriers that impede change in travel behaviour may offer interesting insights into the factors that affect carpooling. A sound understanding of the factors that encourage and discourage carpooling, and the context in which these factors operate, should prove useful in developing recommendations for improving carpool programs. Many questions, however, remain unanswered. The literature provides only a general indication of how social conventions might affect carpooling, and can only speculate about how those conventions might be changing.

The literature review also considered the role of ICT in encouraging carpooling. If commuters are to carpool, they clearly need ready access to a large pool of potential carpoolers in their own home and work areas. ICT offers opportunities for bringing potential carpoolers together. Some researchers see a major role for ICT in bringing carpoolers together, but others place more emphasis on the role of societal norms in encouraging carpooling. Two key challenges must be overcome for ICT to contribute to the success of carpool strategies. Firstly, the technology must establish communication with potential adopters, and secondly, the technology must make available a large pool of potential users with sufficient variation in demographic and trip characteristics (e.g., timing, geography, etc.).

It is evident that the decision to carpool is multifaceted and should be studied with a multifaceted approach. This thesis attempts to rectify the tendency of existing research to focus on a limited range of issues and investigate them in relative isolation. The research
undertaken for this study adopts an inclusive approach that combines attitudes, mobility and demographic data with spatial and temporal data. The literature review provided a basis for selecting the variables included in the contingency analysis and mapping, and in the logistic regression model. Chapter 3 presents details of the study methodology.
3. Study Area, Data and Methodology

This research aims to contribute to the field of travel demand management (TDM). It examines common traits of Carpool Zone users who were either carpooling at the time of sampling, or who had expressed an intention to carpool, but had not yet been able to form an operational carpool. The study also examines the geography of Carpool Zone generated carpooling and the factors impacting the creation of a carpool. The literature review (Chapter 2) discussed existing carpooling and carpooling communications technology, and the demographic, spatial and behavioural factors that affect carpool formation. The chapter indicated areas where improvements can be made in the generation of carpooling information, and pointed out the lack of Canadian carpooling case studies.

This chapter describes the data and research methods used in this thesis. Section 3.1 introduces the study area and explains why the study area was selected for this study. Section 3.2 discusses the data used in the analysis: the Carpool Zone Satisfaction Survey, the profile data, the creation of the sample of respondents used in this research, and the 2006 Canadian Census. Section 3.3 describes the methods used in the data analysis. The methods include contingency analysis, graduated symbol and choropleth mapping, and logistic regression. Section 3.3 also defines the predictor variables. Section 3.4 discusses the data limitations, especially the limitations of using secondary data. Section 3.5 briefly summarizes the methodologies used in this research.

3.1 Study Area

The study area was the Greater Golden Horseshoe (GGH) which is situated in southern Ontario, Canada (Figure 3.1). The GGH includes the City of Toronto, and stretches from Niagara Falls in the south to Waterloo in the west, to Peterborough in the east, and to
Georgian Bay in the north. The GGH is described as “…one the fastest growing regions in North America” (Ministry of Energy and Infrastructure, Growth Plan, 2006, p.6). The region was home to 7.8 million people in 2001, and is expected to grow to 11.5 million by 2031. Good planning is clearly a necessity (Ministry of Energy and Infrastructure, Growth Plan, 2006, p.12).

The region is diverse with dense urban residential areas, low density suburban residential areas, rural towns and villages, a range of industrial and employment centres, and significant areas of prime agricultural land. Whereas the City of Toronto once dominated the area, there are now has 25 existing or emerging urban growth centres (Ministry of Energy and Infrastructure, 2008).

The GGH is part of the economically important Quebec-Windsor corridor. The area accounts for more than 50% of Ontario’s Gross Domestic Product (GDP) (Ministry of Energy and Infrastructure, Growth Plan, 2006), and Ontario contributed 40% to the national GDP ($559,778 million of a national $1,450,490 million) in 2006 (Statistics Canada, 2009).

Figure 3.1 shows the 400 series highways that transect the study area. The 400 series highways are the province’s primary routes for the transportation of people and goods. They include Highway 401 which is Canada’s busiest highway. Highway 401 is the longest 400-series highway in Ontario, and considered one of the busiest highways in North America (www.nationmaster.com). Congestion and delays in the movement of goods are, however, significant problems, and are estimated to cost Ontario $5 billion of GDP per year (Ministry of Energy and Infrastructure, Growth Plan, 2006).
The GGH faces critical commuting issues which need to be addressed through innovative transportation demand management. The estimated population increase of 3.7 million by 2031 is expected to lead to an increase of 2 million vehicles (Metrolinx, 2008b). It is certain that congestion will continue to increase (it is estimated that people will spend up to four times more time in traffic) with undesirable environmental and economic repercussions (Metrolinx, 2008b).

In terms of transportation options, the level of mobility varies across the municipalities in the GGH. Figure 3.2 shows commuting mode share by Census Metropolitan Area (CMA)/Census Agglomeration (CA). The data suggest that primary
commuter mode choice across the GGH is a private vehicle (car, van or truck). However, similarities end when examining the other modes. The second most common mode is passenger in a vehicle in most suburban/exurban areas. In Toronto, Hamilton, and Oshawa, public transit is the second most common mode for commuting. In CMA’s furthest from Toronto, the third most common mode is walking. These findings suggest that public transit is mostly used in areas that are urban and possess a well connected transit system. The findings also suggest that there may be great potential for carpooling in the GGH as so many commuters are vehicle drivers.

Figure 3.2  Mode Share in Commute by Census Metropolitan Area/Census Agglomeration (Statistics Canada, 2006b)
3.2 Data Sources

As the study’s quantitative analysis required a large sample, and the necessary information would have been very difficult to collect due to budgetary and time constraints, the study made use of secondary data. The main source of data was the Carpool Zone Satisfaction Survey conducted by the Smart Commute Association in 2007 (Section 3.2.1) Smart Commute’s survey data were used in the study because the data were extensive and provided good insight into carpooling. In addition, the data were readily available at no cost. Smart Commute used an e-mail survey to collect the data. The Smart Commute survey was used to provide the sample of respondents for the carpooling study (Section 3.2.2). To compensate for missing demographic information required for the logistic model and the mapping, additional data were obtained from the Carpool Zone profile data and the Canadian 2006 Census (Section 3.2.3).

3.2.1 Smart Commute’s Carpool Zone Satisfaction Survey

Smart Commute’s Carpool Zone Satisfaction Survey was administered to 4,774 registered Carpool Zone users in the fall of 2007. The Carpool Zone was launched in 2005, and the 2007 survey was the second survey of users. The survey included attitudinal information, behavioural data, spatial data, and demographic information.

The survey was administered by e-mail. E-mail surveys are a “faceless” data collection method that can collect a large amount of varied information which can benefit the analysis. Time constraints, however, might restrict the variety and quantity of information that could be obtained from other methods like interviews or focus groups (Montello, 2006; Bernard, 2000). E-mail surveys may also collect more honest and forthcoming answers as participants have a greater feeling of anonymity and confidentiality (Montello, 2006).
However, it must be acknowledged that there is a risk of incomplete response, as well as vague responses resulting from an inability to provide clarification to respondents.

Responses were received from 1,422 of the 4,774 Carpool Zone users, a response rate of 30%. This is a relatively good response rate within the range of possible outcomes. For example, interest in participating in e-mail surveys has apparently declined in general between 1986 and 2000, studies were producing response rates of 24% (Sheehan, 2001). Smart Commute’s survey used Likert scale questions (i.e., using a scale to rate a Carpool Zone function) to investigate the performance of Carpool Zone. The survey also probed into respondents’ carpool behaviour (e.g., level of usage and motivation). The responses were linked to each respondent’s profile data generated during the user registration process. The profile data include postal code addresses as spatial identifiers, demographic data, mobility characteristics, and details of commute times. Some of the data required for the carpooling model’s variables were unavailable in the Smart Commute survey. These data included current commute method, number of household vehicles, and other key variables. Data limitations are discussed in more detail in Section 3.4.

3.2.2 Sample of Respondents for the Carpooling Study

The 1,422 responses to the Carpool Zone Satisfaction Survey included some responses that were incomplete or otherwise unsuitable for the carpooling study. Two criteria were used to select a sample of 1,009 respondents for the carpooling study:

(1) The respondent’s postal code had to be located in the GGH. This was necessary because the research was limited to the GGH study area. The respondent’s specific location was also necessary for mapping, and for the analysis of the numerous variables discussed in Section 3.4.4.
(2) The respondent had to have answered the question on carpooling usage level. The usage level pertains to which stage of the carpool formation and use process the respondent finds themselves at (carpooling or not yet carpooling). A response to the usage question was necessary for forming the dependent variable. Usage level (the dependent variable) was central to the logistic regression model, and formed the basis of comparison in the contingency analysis, and also important to the mapping of the respondents currently carpooling and those yet to begin carpooling.

Of the 870 respondents who had reported their gender, the logit model’s sample included: 429 males (49%) and 441 females (51%). This gender split is representative of the entire Smart Commute population. Males and females in the sample were also similar in terms of their progress through the carpool formation stages. Figure 3.3 shows that more females (127 or 29%) than males (107 or 25%) had found matches and begun carpooling. Many females (198 or 45%) and many males (184 or 43%) were awaiting matches. The average age of the respondents was 38 years. The youngest respondent was 19, and the oldest was 68. The average self reported commute time was 41 minutes.

3.2.3 The 2006 Census of Canada

To compensate for some of the missing demographic information, data from the Canadian 2006 Census were used in both the logistic model and the mapping. The Census data were collected on May 16, 2006, and the data used in this analysis were released to the public in May 2008. The level of geography selected for the data used in the logistic regression model was the Forward Sortation Area (FSA) Local Delivery Unit (LDU). This level was chosen to correspond with the respondent’s location data which were recorded at the FSA LDU level.
The data retrieved from the census focused on income, population and housing characteristics. The regression model used median household income per FSA as this (FSA) is the smallest level of geography in the census that was available to the researcher.

The mapping exercise used labour force data reported at the Census Subdivision level (CSD). This level of geography was used because it reflected the mapping of respondents who were carpooling and not yet carpooling during sampling, on a municipality level. This is the appropriate scale as Smart Commute’s programming is often carried out on a municipal level.

### 3.3 Data Analysis

The data analysis of the carpooling research is discussed under four headings: contingency analysis (Section 3.3.1), choropleth mapping (Section 3.3.2), logistic regression (Section 3.3.3), and defining the predictor variables (Section 3.3.4). The contingency analysis was
used to investigate the association between behaviour, commuter characteristics, and the
carpool outcome. The results of the contingency analysis were plotted using mosaic plots.
Carpool Zone usage data was visualized using a graduated symbol map to illustrate the
spatial distribution of the sample data. To study carpooling potential, at the municipal, town
and township scales, choropleth mapping was used\(^3\). Section 3.3.2 explains the details of the
construction of choropleth maps, and explains what was mapped. The logistic regression
analysis was designed to address the study’s primary research question: What factors
influence carpool formation and use? The discussion of the logistic regression analysis
includes a list of the variables used in the model.

### 3.3.1 Contingency Analysis

The contingency analysis related differences in the respondents’ mobility, motivations and
personal characteristics to the carpool outcome (either engaging in an active carpool or not
yet carpooling at the time of survey). The motivation/mobility/demographic variables were
constructed from the Satisfaction Survey and profile datasets. The carpool outcome variable
was constructed from the responses to the usage level question. The chi-square test was used
to test hypotheses concerning the relationship between variables describing commuters, and
carpool status.

The carpool outcome variable was coded in binary form as carpooling/not carpooling
depending on the response to the usage level question in the Satisfaction Survey. Table 3.1
shows the “carpooling” and “not carpooling” responses. Table 3.1 also shows the responses
that were excluded from the analysis. This identical variable was then used in the mapping
and logistic regression model. When discussing the carpooling/not carpooling variable

\(^3\) A thematic map which uses shading to display values (in this case a rate) of a given attribute (Heywood et al.,
1998).
throughout the thesis the terms “success” and “failure” are used when describing certain outcomes. In this case, failure refers to the respondent not having started carpooling at the time of sampling, as opposed to representing some sort of overall failure with Carpool Zone. Also, the “not carpooling” category may also be interpreted as early stage users, meaning those that have not yet adopted carpooling.

<table>
<thead>
<tr>
<th>Not Carpooling</th>
<th>Carpooling</th>
<th>Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waiting for carpool matches.</td>
<td>Have started carpooling with Carpool Zone matches.</td>
<td>Not applicable.</td>
</tr>
<tr>
<td>Waiting for better matches.</td>
<td>Other.</td>
<td></td>
</tr>
<tr>
<td>Waiting for a response from a carpool suggestion sent.</td>
<td>Have not yet entered trip information.</td>
<td></td>
</tr>
<tr>
<td>Have formed a carpool, but we haven't started carpooling yet.</td>
<td>No longer interested in carpooling.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 3.1 Construction of “Carpool Outcome” Response Variable**

Mosaic plots were used to visually summarize the findings. The mosaic plots show the relationship between the selected categorical variables and the groups of users that are either not carpooling or carpooling. Figure 3.4 is an example of a mosaic plot showing the distribution of the answer “Yes” or “No” to a mock question by two imagined groups “A” and “B”. The height of the cells indicating choice “Yes” or “No” indicates the number of respondents that have chosen each response, while the width of cells indicates the number of “Group A” or “Group B” respondents that have chosen each response. The plot below indicates that overall “No” was answered more often than “Yes”. Furthermore, “Yes” was chosen by more members of “Group B” than “Group A”.
3.3.2 Mapping

A graduated symbol map was created to display the number of Carpool Zone users by municipality. The size of the circle indicates the magnitude of the production of survey responses over space, a signal perhaps, of overall interest in the Carpool Zone tool (i.e., small circles meant fewer users, while larger circles indicated a large number of users). Choropleth mapping was used to show the incidence of working carpools or cases where carpooling has not yet started. The mapping was based on the origin location of the
respondents and used the carpool status variable described in Section 3.3.1. The “carpooling” and “not carpooling” results were reported as per capita rates for each municipality. Rates were estimated separately for respondents in the “carpooling”, “not carpooling” categories. The rates express the number of respondents in each category per 100,000 employed labour force. Denominator data for the rates were extracted from the 2006 census and included members of the employed labour force aged 15 or older. The municipal scale was chosen for the mapping because individual Smart Commute groups work on a municipal level and there is interest in tracking the level of success of the program at the municipal scale.

3.3.3 Logistic Regression

The response variable used in the model is derived from the carpool outcome variable (Section 3.3.1 and Table 3.1). The dependant variable is concerned with carpooling status at the time when the survey was conducted. This variable is made up of two responses: carpooling at the time of sampling, and not carpooling at the time of sampling (reference). The not carpooling category is made up of the following responses: waiting for initial or better matches, waiting for a reply to a suggestion sent and formed a carpool group but have not yet begun carpooling (Please refer to Table 3.1).

The determinants of carpool formation and use (the predictor variables) were explored by specifying and estimating a block entry logistic regression model. A framework of factors that impact carpool use was developed using the results of the literature, to guide model specification. The framework was based on a model of bicycle use developed by Rietveld and Daniel (2004), it was redesigned for carpool use. Figure 3.5 shows the framework for carpool formation.
Due to constraints such as data availability, time and cost, it was not possible to include all the factors shown in Figure 3.5 in the model. The 15 predictor variables chosen for the model were selected from the literature on carpooling and are bolded in Figure 3.5. The variables were constructed from the survey, the commuter profiles, and from census data. The model’s predictor variables are listed in Table 3.2, described in detail in Section 3.3.4., and identified (in bold typeface) in the Framework for Carpool Formation (Figure 3.5). The variables are organized into four categories: demographics, spatial, motivations, and current commute mode. The organization of the variables is designed to test the findings.
of other studies that explore either demographic or spatial factors and carpooling individually.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>Profile data</td>
</tr>
<tr>
<td>Age</td>
<td>Profile data</td>
</tr>
<tr>
<td><strong>Spatial</strong></td>
<td></td>
</tr>
<tr>
<td>Commute time</td>
<td>Profile data</td>
</tr>
<tr>
<td>Proximity to other Carpool Zone users</td>
<td>Survey data</td>
</tr>
<tr>
<td>Distance to nearest carpool lot</td>
<td>Survey data/DMTI 4</td>
</tr>
<tr>
<td><strong>Motivation</strong></td>
<td></td>
</tr>
<tr>
<td>Environmental concerns</td>
<td>Survey data</td>
</tr>
<tr>
<td>Mobility constraints</td>
<td>Survey data</td>
</tr>
<tr>
<td>Cost savings</td>
<td>Survey data</td>
</tr>
<tr>
<td>HOV lane use</td>
<td>Survey data</td>
</tr>
<tr>
<td>Other</td>
<td>Survey data</td>
</tr>
<tr>
<td><strong>Current Commute Mode</strong></td>
<td></td>
</tr>
<tr>
<td>Driver</td>
<td>Survey data</td>
</tr>
<tr>
<td>Transit</td>
<td>Survey data</td>
</tr>
<tr>
<td>Passenger</td>
<td>Survey data</td>
</tr>
<tr>
<td>Active Transportation</td>
<td>Survey data</td>
</tr>
<tr>
<td>Other</td>
<td>Survey data</td>
</tr>
</tbody>
</table>

Table 3.2 The 15 Predictor Variables included in the Logistic Regression Model

The logistic regression model takes the form:

\[
\text{logit}(\pi) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k;
\]

---

4 DMTI Spatial is a company providing maps of streets, political boundaries and other geographic information.
where $\logit(\pi)$ is the natural log of the ratio of forming and using a carpool ($\pi$) to not doing so ($1 - \pi$), or the natural log of the odds of successfully forming and using a carpool; $\alpha$ is the regression constant; and $\beta$ represent $K$ parameter estimates associated with $K$ independent variables, $X$.

The model was estimated using a researcher controlled approach. The predictor variables were entered using the block method (whereby variables are entered by subset at the discretion of the researcher). This approach was chosen for the following reasons:

- It is best to enter the variables in block mode as when the variables are conceptually related to one another.
- Having variables in combination may produce a better model than entering the variables individually (Meyers et al., 2006).

In contrast to the stepwise method (where insignificant variables are systematically removed), all of the variables are left in the model allowing one to see the impact of individual variables on the model. This is useful in exploratory research such as this carpooling study. The variables used in this research were suggested by the carpooling literature, and it would not be prudent at this stage to allow the statistical analysis to be the sole arbiter deciding which variables should be removed from the model. With the stepwise method, the difference between the value of a variable left in the model in comparison to one removed from the model is unknown.
3.3.4 Defining the Predictor Variables

**Demographic Variables**

*Gender*

The gender variable was extracted from the profile data. The variable was constructed in binary form: male was coded as 0 (reference), and female was coded as 1. The 139 responses that failed to provide gender information were excluded from the model. It is expected that females will have less success forming a carpool than males. The gender related commute literature and entrapment theory (Chapter 2) suggests that household responsibilities could produce shorter commutes for females (while most carpools operate over longer distances), females could also be dissuaded from joining carpools because of scheduling conflicts.

*Age*

The age variable was obtained from the profile data. Individuals who gave their age as zero were given the median age (32). Replacement of null values with the median is one approach to dealing with missing information. It is expected that age will have little impact on the formation and use of carpools as this is the overwhelming conclusion in the literature (Chapter 2) on sociodemographic factors and carpool formation.

**Spatial Variables**

The “Spatial” category is made up of variables from a variety of aspects of carpooling: potential - access to a vehicle; policy and programming - carpool lots; and cost – travel time.

*Commute time*

The commute time variable was constructed using the commute time reported by respondents. The average commute time for the 752 respondents who reported their commute time was 41 minutes. The shortest time was 1 minute, and the longest was 180
minutes. The expectation is that the longer the commute time, the higher the likelihood of engaging in a carpool. One anticipates that with a longer commute, travel costs (e.g., fuel, toll fees) and social isolation potential increase. Carpooling could provide one approach to overcoming some of these issues. Furthermore, since picking up/dropping off each additional carpooler adds time to the commute, this may not be worthwhile for shorter commutes (< 20 minutes), however an additional 10 minutes to 60 minute commute may be viewed as a reasonable change in the marginal cost of the trip.

**Proximity to other Carpool Zone users**

The proximity to other Carpool Zone users variable was used to measure accessibility to other potential users. The variable is based on the “cumulative opportunities measure” discussed in Handy and Clifton (2001) and Handy and Niemeier (1997) where the number of opportunities (in this case other carpoolers) is counted within a defined distance (e.g., 1 kilometre). The cumulative opportunities equation takes the form:

\[ A_i = \begin{cases} \sum_j M_{ij}, & \text{if } c_{ij} \leq C \\ 0, & \text{if } c_{ij} > C \end{cases} \]

Where \( A_i \) is the accessibility of a carpool zone user (i) to all other carpool zone users (j) within a particular distance threshold from the residential geocode (\( c_{ij} \leq C \)). The threshold is given by the value of \( C \) (e.g., 1 kilometre), and a person is counted if the distance from his/her residential location to the user \( i \) is less than or equal to this distance.

The respondents’ postal codes were used to map all the respondents in the sample. Using a Geographic Information Systems (GIS) program feature called “count points in polygons,” the number of respondents within ten distance zones ranging from 0.5 kilometres
to 10 kilometres was calculated for each respondent. Running the model separately for each of the ten distances provided an indication of the distance at which the accessibility variable offered the greatest explanatory power in the model. The 1 kilometre radius from each origin location was found to be the most significant.

It is expected that a high number of potential carpoolers within 1 kilometre of a respondent will increase the respondent’s likelihood of carpooling. It is also expected that searches for potential carpoolers within a larger radius of a respondent will have less of an influence on carpooling, more distance matches would be more difficult to include in a carpool because of the increase in time required to pick them up.

**Distance to nearest carpool lot**

The proximity to carpool lot variable was constructed using GIS. The variable provides an idea of how far each respondent may have to travel to use a carpool lot, and how this distance impacts their likelihood of carpooling. The postal codes data provided the origin location for all respondents. The carpool lot locations were extracted from the DMTI Spatial Points of Interest for 2007. The closest path network distance was calculated from each origin point to the nearest carpool lot using a custom network file. The network file allowed for impedances and restrictions encountered in the real world (e.g., turn restrictions).

It is expected that longer distances to the nearest carpool lot will be associated with a smaller chance of carpool formation and use. Carpool lots may be more attractive to users as they attract more commuters, who might normally be located to far away from interested carpoolers for home-based pick ups.
Motivations

The abundant literature on mode choice often focuses on peoples’ motivations as well as cost issues, namely, travel time and monetary requirements (Johansson et al., 2006). Johansson et al. (2006) found the following motivations important in mode choice: environment, travel time and cost, flexibility and comfort, as well as personality traits and attitudes. Flexibility, comfort and personality traits are not included in the framework of this carpool research due to data constraints. Details of each motivation variable are given below. Respondents were asked to report their main reason for choosing carpooling, response categories included: (1) Environmental concerns (reference), (2) Saving Money (Cost), (3) HOV Lane Use (really a latent expression for the value of time), (4) Don’t drive, and (5) Car not available. The last two categories were combined to produce a Mobility Constraints category.

The expectations for the five variables in the motivation category are considered together because all five variables were derived from the responses to the question “What is your reason for carpooling?” Reflecting on the travel behaviour literature, it is anticipated that cost will unequivocally be the most significant motivation behind carpooling. In general, the a priori expectation exists that assessments of the direct cost (monetary) or generalized cost (time use, or saving time through HOV lanes) of the commute will have greater explanatory power in the model than environmental concerns (the reference category).

Current Commute Mode

“Mobility” is examined using data on the respondents’ current commute mode. Commute mode is included because it is expected that how someone commutes, or how they are typically used to commuting, could impact their interaction with the carpool formation process. Moreover, this variable provides an indication of current mobility status, which may
in some cases act as a barrier to one’s desired action (e.g., current passengers may not be successful in carpooling as they are perhaps unable to share in the driving). The addition of the commute mode category is derived from the framework presented by Jakobsson (2004) whereby car use is theorized to be determined by both motivational and volitional reasons. In this case, the volitional factor is access to a vehicle in order to partake in carpooling.

The expectations for the five variables in the current commute mode category are considered together because all five variables were derived from the responses to the question “What is your current commute mode?” This question was part of the profile data collected for each respondent. The mode categories for this variable included: (1) Drive a vehicle (reference), (2) Transit, (3) Passenger, (4) Active Transportation, and (5) Other. It is expected that commuting as a passenger will be very significant in the model. This is because passengers are clearly in need of a ride and are familiar with the experience (i.e., passenger are accustomed to the barriers most new carpoolers face in terms of scheduling and social arrangements). It is also expected that respondents who are driving a vehicle but seeking a carpool might also be significant in the model as they possess a means of transportation and are interested in finding people with whom to share the driving. Transit and active commuters (e.g., walk, bike) might be less inclined to carpool because there is no additional benefit to them.

3.4 Data Limitations

This section discusses the limitations of the data used in this research. For example, the information that is not given in the data sources is outlined. Furthermore, the drawbacks to some of the data collection techniques are discussed.
3.4.1 Limitations of using Secondary Data in this Study

When using secondary data, the researcher may be limited by the data created and collected by the outside source. In this study, the researcher would have preferred to use questions tailored to her own needs, but had to use questions designed for a different purpose and then shape the responses to her research. For example, the variable, motivations, had to be created from a question in which only several options had been provided to the users. It would have been better to have additional factors examined in this question (e.g., societal norms, social interaction).

The researcher also had no control over the clarity of the questions. Clarity is always a concern and especially when using a self-administered questionnaire. Unclear questions can produce poor results and can lead to uncertainty (Montello, 2006). For example, the self-reported commute time question did not specify one-way or return commute leading to uncertainty in how respondents interpreted and answered this question.

The limited demographic and spatial information available were a larger problem. Income level, family status, education level, employment position, and ethnicity were not collected in Smart Commute’s Carpool Zone Satisfaction Survey. To maintain respondent anonymity, origin location data were provided to the researcher at the FSA level, but this meant a loss of spatial detail. During the course of the research, destination data were not provided (following a data licensing agreement, these data will now be made available for future work).

Possible bias in the sample of respondents who provided the data requires consideration, but could not be controlled by the researcher. Firstly, as the survey collected its data through a self-administered questionnaire on the internet, all the respondents had to
be knowledgeable about computers, and have access to the internet. These requirements may have produced a sample that was biased and unrepresentative of the general GGH population or of current and potential carpoolers. This issue is of interest and importance, but it was not a grave concern as this study involves using technology to aid in travel demand management.

Secondly, the survey was available only to registered Carpool Zone users. Within this group, the respondents were self selected. No attempt was made to ensure that the sample was representative of active carpoolers and those not yet carpooling. It is, for example, possible that the sample over-represented active carpoolers, and under-represented potential carpoolers. This issue is important to consider as the survey results may be skewed by the self selection process. The data collection limitations discussed in this section should be regarded as issues to keep in mind when analysing the results. Fortunately, the limitations did not seriously restrict the analysis.

3.5 Concluding Comments

This chapter described the three methods the study used to analyse carpool formation process in the GGH: contingency analysis, mapping, and logistic regression. Contingency analysis was used to gain a better understanding of the relationship between carpoolers/those not yet carpooling and various mobility, motivation and demographic variables. The mapping of patterns of use creates an opportunity to diagnose problem areas (areas with little to no users). Logistic regression analyses was selected to improve our understanding of what leads to achievement in carpooling through a controlled analysis of the impact of individual, spatial, and other variables on carpool formation and use. The next chapter presents the results of the analyses outlined above.
4. Findings

The previous chapters have (1) outlined the importance of studying Information and Communications Technology (ICT) based carpooling, (2) placed the research within existing literature and (3) described the methodologies used to study carpooling at the regional and individual scales of analysis. Chapter 4 presents and discusses the study findings. The chapter is organized into the following three main sections:

(1) Exploratory analysis of the traits and behaviour of commuters who have begun carpooling and those who have indicated some intention to carpool, but have yet to do so;
(2) The geography of interest in using Carpool Zone, with a focus on municipalities that could require additional attention to increase patronage in the program and;
(3) Description of the most salient factors that appear to influence carpooling.

Several approaches are utilized in the analysis; namely, contingency analysis, mapping and logistic regression.

First, the chapter provides a broad description of the relationship between motivational, demographic and mobility variables and two groups of Carpool Zone users, those that were participating in operational carpools at the time of survey, and those that were not. Next, Carpool Zone usage data is visualized using a graduated symbol map to illustrate the spatial distribution of the sample data. Choropleth mapping is then used to study carpooling potential, at the municipal, town and township scales. The maps provide an indication of where further attention is needed to increase system use, and to generate some insight into the shared characteristics of places producing carpooling and not carpooling outcomes. Lastly, the factors influencing carpool formation and use are studied through the specification and estimation of a logistic regression model where the response variable is the
log odds of the ratio of having formed a carpool at the time of survey, to not having done so (e.g., carpooling or not carpooling). The modelling provides an idea of what is critical (e.g., are attitudes driving people to carpool or is it one’s access to a vehicle?) in the formation of carpools. From a programming and policy perspective, this study provides insight into where to place focus (geographically and individually) when promoting carpooling, and how to improve existing carpool related infrastructure and policy.

4.1 Contingency Analysis

The literature suggests that certain motivations (e.g., cost savings, mobility, etc.) and mobilities (e.g., access to a vehicle) are associated with the decision to carpool. The association between demographics and carpooling has been the subject of debate. This study contributes to the literature by attempting to substantiate certain hypotheses (e.g., gender and carpooling), while developing and testing new hypotheses (e.g., environmental concern versus cost savings and carpooling). The main research questions guiding this exploratory analysis were:

1. Are motivations strongly associated with carpool outcome?
2. Is there an association between gender and carpooling, and if so, are there more males or females currently carpooling?
3. How is a participant’s mobility potential (e.g., number of household vehicles, current commute method) related to their carpool outcome?

A number of variables concerned with motivations, demographics and vehicle availability were examined by conducting a cross tabulation with two groups: current carpoolers; and those who intend to carpool but at the time of survey had yet to do so. The
overall purpose of the contingency analysis was to gain better insight into the bivariate relationship between carpool formation and use, and individual level variables that are expected to correlate with the production of an operational carpool. The relative importance of these variables is then addressed in the logistic regression analysis.

Motivations for carpooling were cross tabulated with the carpool outcome to explore similarities and differences in carpool motivations across carpool and early stage users. Next, the demographic factor, gender was examined. The purpose is to identify whether certain demographic groups are carpooling more than others, in the hopes of drawing attention to those being underserved by Carpool Zone. Lastly, respondents’ access to vehicles was examined, using both current commute mode and number of household vehicles variables, in relation to carpooling outcome, to shed light on the dominate commute modes associated with the Carpool Zone community. Two different variables were used to study mobility because even though “household cars” shows vehicle presence, it does not signal vehicle access. Including the commute mode variable provides a more holistic snapshot of personal mobility because it describes how a person moves around, regardless of how many vehicles his/her household may own. Mosaic plots (See Section 3.3.1) were used to visualize the cross-tabulations, the most cited response for the sample as a whole is reflected in the height of each cell, while cross group differences are expressed by the difference in the width of each cell.

4.1.1 Motivations and Carpool Outcome

Motivations underlying commuter mode choice are expected to vary across the commuting public. In this particular study, the data describe commuter motivation for taking the decision to attempt to participate in carpooling using Carpool Zone. The main hypothesis is
that behavioural motivations influence the decision to carpool, the expectation is that cost and availability of a vehicle will be the primary motivations underlying the decision of commuters who have been able to start carpooling. The mosaic plot (Figure 4.1) demonstrates that cost and concern for the environment are the most often cited responses. However, the findings suggest that motivations are not strongly associated with the carpooling outcome ($X^2 = 7.2793, p > 0.1$).

![Motivations for Carpooling](image)

**Figure 4.1 Motivations for Carpooling by Carpool Outcome ($n = 1,009$)**

### 4.1.2 Demographics and Carpool Outcome

Next, the study examines whether there is any association between gender and carpool formation. It is expected that there will be fewer females reporting carpooling than males due to automobile access constraints, scheduling, and household responsibilities (Sermons and Koppelman, 2001). This sort of tension between mobility and household responsibilities has
already been discussed in the context of entrapment theory (Cristaldi, 2005). Scheduling inflexibility or scheduling constraints are expected barriers to carpool formation, a mode that typically takes place over longer distances, and one that requires scheduling flexibility.

While females tend to have taken up a larger share of the total number of carpools (Figure 4.2), the findings suggest that gender is not strongly associated with the outcome of the carpool formation process ($\chi^2 = 1.2587, p > 0.1$). Moreover, most users remain in an earlier stage in the carpool formation process, this will be discussed further in Section 4.3.3.

![Figure 4.2 Gender Composition by Carpool Outcome (n = 870)](image)

**4.1.3 Mobility and Carpool Outcome**

Respondents with a low number of household vehicles and therefore low potential vehicle availability were expected to be more successful than others, because of the needs of these individuals for alternative modes of transportation. Most respondents come from 1 or 2
vehicle households (Figure 4.3), and at first glance, the data appear to provide little support for the original expectation. In fact, quite the opposite relationship emerges from the analysis, with carpooling increasing across the household vehicle profile, up to 2 vehicles ($\chi^2 = 13.6198, p < 0.01$). This finding may suggest that those with higher vehicle availability could be seeking to economize on the costs of auto ownership and use, or reduce driver burden - these factors could be motivating the production of operational carpools.

![Number of Household Cars](chart.png)

**Figure 4.3 Number of Household Vehicles by Carpool Outcome ($n = 1,009$)**

The association between personal mobility and carpool outcome was also studied by looking at the current commute mode of the respondents. Drivers or passengers are expected to be carpooling more often than others because drivers could share driving duties, and passengers are already accustomed to the social and scheduling issues that typify carpooling. The data suggest that drivers and passengers are, in fact, creating more carpools than others. Moreover, the statistical analysis revealed a significant association between current commute
mode and the carpool outcome ($X^2 = 25.6594, p < 0.01$). Figure 4.4 shows that most respondents were drivers (i.e., single occupancy vehicle drivers or drivers in a carpool), followed by public transit users, or passengers.

![Figure 4.4 Current Commute Mode by Carpool Outcome (n = 901)](image_url)

**Figure 4.4 Current Commute Mode by Carpool Outcome (n = 901)**

### 4.1.4 Summary

The contingency analysis has found that both motivations and gender are not strongly associated with the carpool outcome. However, mobility factors, specifically current commute mode and number of vehicles in the household exhibit a strong relationship to being in the early stages of carpool formation or carpooling with Carpool Zone matches. The most common motivations across both levels of users were a concern for the environment and cost savings. Moving forward, the logistic regression will indicate which motivations, if any, contribute to carpooling. At the time of survey, most respondents (both male and
female) were in the early stage of carpool formation and use. The results suggest that Carpool Zone serves both females and males equally. The modelling in Section 4.3 will explore the relative importance of gender in carpool formation and use.

Lastly, the first factor to exhibit a strong association with carpool outcome, number of household vehicles, suggests that users with 2 vehicles often experience a positive carpooling outcome, perhaps seeking to overcome some of the negative aspects to Single Occupancy Vehicle (SOV) use. Further exploration into the association of mobility and carpooling found that at 86% drivers and passengers made up the largest portion of the carpool outcome group. The logistic regression model (Section 4.3) will provide additional insight into the influence of current commute mode on carpool formation and use.

4.2 Mapping Carpool Formation Levels in Municipalities

The Carpool Zone program is carried out across a number of municipalities, therefore it is useful to investigate where the carpools are formed and which areas have been slower in generating carpools. This is interesting from a programming perspective as perhaps areas with a large potential user base may require further incentives, a policy consideration for Smart Commute and Metrolinx. The first part of the analysis examines general interest in Carpool Zone by mapping the sample respondents at the municipal scale. The carpool potential for each municipality is then studied by comparing, separately, the number of carpoolers and the number of respondents at earlier stages in the process, against the size of the employed labour force within each municipality, town, or township in the Greater Golden Horseshoe (GGH). This approach is more useful than simply mapping user counts as it takes
into account the potential (i.e., people that would engage in commuting) that exists in each municipality for carpooling.

**4.2.1 Mapping the Location of Carpool Zone Users**

Somewhat expectedly, due to population size, the largest number of respondents can be found in the City of Toronto (Figure 4.5). The municipalities that follow Toronto in terms of number of cases are Markham, Brampton, Mississauga, and Hamilton. Overall, most sampled users appear to be situated within the urban core of the Greater Toronto and Hamilton Area (GTAH). This is likely both a programmatic and population size effect, Smart Commute focuses its intervention work with regional firms within this urban core of the GGH. With respect to population size, the City of Toronto is ranked first in terms of population on a national scale, while the municipalities within the next quintile, happen to rank within the top 15 populated Canadian census subdivision areas (Statistics Canada, 2007b). The municipalities without any users are located at the edge of the GGH. This is representative of a distance decay pattern, suggesting that the promotional initiatives lose their target impact at the furthest locations beyond the boundary of the area being marketed. In other words, the message to carpool gets lost with extreme distance from the intended marketing area.
4.2.2 Mapping of Carpool Zone Users that are Not Yet Carpooling

Places with large numbers of users who had yet to start carpooling at the time of survey tend to be somewhat clustered together (Figure 4.6). The spatial pattern shows that the municipalities with the largest numbers of non-carpoolers make up adjoining areas in groups of three to six municipalities.
Suburban and outer suburban municipalities, towns and townships, appear to generate a larger share of Carpool Zone users who are not carpooling but, nevertheless, have expressed some interest in Carpool Zone. The municipalities of Milton, Halton Hills, Markham and Burlington stand out as they are the municipalities with the largest number of users that are not yet carpooling in closest proximity to the urban core of Toronto. Also, these aforementioned municipalities have relatively large labour forces of more than 30,000 people as well as a major highway crossing each of them. A number of municipalities with high rates of not yet carpooling (e.g., Burlington, Halton Hills, Guelph, Oakville, Mississauga, Toronto, Shelburne etc.) also host users that have begun carpooling with their
Carpool Zone matches. These places have the potential to generate working carpools over some time.

<table>
<thead>
<tr>
<th>Region of GGHA</th>
<th>Municipalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>Burlington, Milton, Halton Hills, Erin, Guelph, and Guelph-Eramosa</td>
</tr>
<tr>
<td>North Central</td>
<td>New Tecumseth, Bradford West Gwillimbury, and Innisfil</td>
</tr>
<tr>
<td>Eastern</td>
<td>Cavan-Millbrook-North Monoghan, Asphodel-Norwood, and Otonabee</td>
</tr>
<tr>
<td>Solitary</td>
<td>Shelbourne and Markham</td>
</tr>
</tbody>
</table>

Table 4.1 Upper Quintile of Early Stage Users by Region

### 4.2.3 Mapping Carpool Zone Users Currently Carpooling

The map indicating the origin locations of users carpooling at the time of survey per employed labour force reveals some interesting results (Figure 4.7). There are several plausible explanations for the spatial patterns demonstrated in this map; these include affluence and labour force activity, population growth, and urban design, including accessibility to transportation networks.

The municipality of Toronto is not highly successful in terms of number of Carpool Zone carpoolers (63 carpoolers) when compared to the size of its labour force (1.2 million people 15 years of age or older). Places generating more carpools, per employed labour force, appear to be located in suburban and exurban areas. These places include: Oakville, Guelph, Orangeville, Shelburne, East Luther Grand Valley, Grimsby and Mulmur, places with relatively smaller pools of labour. Toronto would be the municipality with the rate of carpooling if the number of users were mapped on its own. This is to be expected considering the attention that is paid to the area in terms of marketing by Smart Commute, and given the size of the labour force and number of commuters. Many of the municipalities with high rates of carpooling, like Oakville, Burlington, Hamilton, Mississauga, and
Brampton, are located in the GTA and in close proximity to Toronto. The municipalities in the top quintile of carpool success are found to the west of the City of Toronto, however, unlike the upper quintile of users that are not yet carpooling, they are found scattered from north to south. Aside from Oakville, these municipalities with high rates of carpooling are located outside of Smart Commute’s mandate area (GTA).

![Figure 4.7 Users Currently Carpooling per Employed Labour Force (Statistics Canada, 2008b)](image)

It is helpful to examine the characteristics of the municipalities found within the top quintile of carpooling in effort to see how they might differ from all other areas and thus explain their high levels of success. Most carpooling is found in municipalities that have experienced significant employment and residential growth in the last two decades. For
example, between 2001 and 2006, Oakville, Orangeville, Guelph, and Mulmur saw relatively large population growth (14.0%, 6.6%, 8.3%, and 7.1% respectively) as compared to Toronto (0.9%) (Statistics Canada, 2007b). The increase in need for alternative transportation in high growth areas may be due to the following issue. First, an increase in population, automatically suggests a higher likelihood in people engaging in activities such as carpooling as this influx of people, increases vehicular use, leading to congestion which may incite more citizens to begin carpooling.

With respect to affluence, all seven municipalities have higher median household incomes (Table 4.2) than the Province of Ontario ($60,455) (Statistics Canada, 2008c). The high incidence of Carpool Zone related carpooling might be explained by the notion that the higher the income, the increased number of trips and distance travelled in a day, therefore, commuters in these places might be using Carpool Zone to economize on the costs of commuting associated with living in a suburban or exurban area (Pucher and Renne, 2003).

<table>
<thead>
<tr>
<th>Census Subdivision Area</th>
<th>Median household income</th>
<th>Median dwelling value</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Luther Grand Valley</td>
<td>$66,763</td>
<td>$219,494</td>
</tr>
<tr>
<td>Mulmur</td>
<td>$73,597</td>
<td>$340,076</td>
</tr>
<tr>
<td>Orangeville</td>
<td>$69,154</td>
<td>$250,131</td>
</tr>
<tr>
<td>Shelbourne</td>
<td>$61,643</td>
<td>$219,338</td>
</tr>
<tr>
<td>Oakville</td>
<td>$92,394</td>
<td>$400,537</td>
</tr>
<tr>
<td>Guelph</td>
<td>$64,319</td>
<td>$249,976</td>
</tr>
<tr>
<td>Grimsby</td>
<td>$77,528</td>
<td>$250,427</td>
</tr>
<tr>
<td>Province of Ontario</td>
<td>$60,455</td>
<td>$250,410</td>
</tr>
</tbody>
</table>

Table 4.2 Affluence Statistics of Municipalities in Upper Quintile of Carpooling Success (Statistics Canada, 2007c, 2008d)

When compared to the provincial median dwelling value ($250,410), most of the municipalities with the highest rates of carpooling (Table 4.2) are found to have dwelling values nearly exactly that of the provincial median dwelling value (Statistics Canada 2008d).
However, Oakville and Mulmur stand out as they exhibit far higher median dwelling values ($400,537 and $340,076 respectively). This is an indication of the affluence of these municipalities when compared to the rest of the province. This brings forth the issue of whether this type of on-line service in fact facilitates residential choices that are typically associated with urban sprawl/expansion into exurban or peri-urban spaces. Another issue raised in the literature is the critique of public policy and programs that facilitate congestion reduction, which in fact could largely improve the lives of affluent/time poor commuters, by providing them with higher levels of service of roads emptied of less affluent drivers (Graham, 2001).

The municipalities of Hamilton, Burlington, Halton Hills, Guelph-Eramosa, Markham, Barrie, Whitby, Clarington and Port Hope are in the second quintile in terms of carpool formation. In comparison to the City of Toronto and other urban municipalities, these areas generally have a smaller employed labour force. However, and with the exception of Hamilton and Port Hope, Table 4.3 shows that these municipalities typically have higher median incomes than the provincial median of $60,455 (Statistics Canada, 2008c). This suggests that affluent municipalities are typically more successful in carpool formation than municipalities producing lower incomes. This is arguably an important consideration as one may argue that it is those with lower incomes that have greater transport needs.
<table>
<thead>
<tr>
<th>Census subdivision area</th>
<th>Median household income</th>
<th>Median dwelling value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clarington</td>
<td>$77,627</td>
<td>$249,104</td>
</tr>
<tr>
<td>Guelph/Eramosa</td>
<td>$83,414</td>
<td>$349,282</td>
</tr>
<tr>
<td>Burlington</td>
<td>$74,969</td>
<td>$300,335</td>
</tr>
<tr>
<td>Port Hope</td>
<td>$60,382</td>
<td>$210,149</td>
</tr>
<tr>
<td>Whitby</td>
<td>$84,219</td>
<td>$299,011</td>
</tr>
<tr>
<td>Hamilton</td>
<td>$55,312</td>
<td>$219,488</td>
</tr>
<tr>
<td>Markham</td>
<td>$79,924</td>
<td>$400,184</td>
</tr>
<tr>
<td>Halton Hills</td>
<td>$85,520</td>
<td>$324,869</td>
</tr>
<tr>
<td>Barrie</td>
<td>$64,832</td>
<td>$239,674</td>
</tr>
<tr>
<td>Province of Ontario</td>
<td>$60,455</td>
<td>$250,410</td>
</tr>
</tbody>
</table>

Table 4.3 Affluence Statistics for Municipalities in Second Quintile of Carpooling Success (Source: Statistics Canada, 2007c, 2008d)

Overall this exploratory geographical analysis has shown that even in areas high rates of not yet carpooling, there is interest in Carpool Zone, and carpooling more generally, however, the supply of matches could be a barrier to carpool formation. The results suggest (including the areas with carpoolers) that there is plenty of potential (large employed labour force), and few carpools in comparison. Some of the places with little evidence of Carpool Zone participation are located outside the GTAH, Smart Commute’s planning jurisdiction, although people living there could be working at firms within the GTAH. So far, the findings indicate the existence of some relationship between affluence, potential mobility, and the carpool outcome – the next section reports on the results of a logistic regression analysis designed to tease out the relative contribution of various personal, spatial, and motivation factors on the carpool outcome.
4.3 LOGISTIC REGRESSION RESULTS

The logistic regression model has been specified to examine the relationship between residential end factors, and personal characteristics on carpool formation and use. The model tests the sensitivity of the carpool formation process to four groups of characteristics. The current research is focused on the residential aspect of carpool formation, although self-report commute times provides a reasonable approximation of the generalized cost of travel from home to work. The literature has stressed the importance of work-end concepts (Cervero and Griesenbeck, 1988), however, data limitations prevent detailed analysis, at this time, of the work end correlates, beyond the commute time variable. The analysis of work-based covariates will be addressed in future research.

The logistic regression model (Table 4.4) is made up of four variable categories: Motivations, Spatial and Temporal, Demographic, and Current Commute Mode. The model is exploratory, so a generous criterion is applied to the evaluation of statistical significance ($p \leq 0.10$). The -2 Log Likelihood statistic, measuring how well the model explains variation in the response variable, decreases in size from 814.948 to 785.726, indicating that the model’s explanatory power improves with each additional block of variables, the rise of the chi-square statistic for each step is also indicative of an improvement in model fit. The chosen variables were entered into the model using the researcher controlled block method approach. This method is useful for this particular exploratory study as it allows one to see the impact of individual variables on the model (Meyers et al., 2006).

4.3.1 Motivational Factors

Motivations are modelled using a polytonomous categorical variable with 5 categories. The motivational categories include: concern for the environment, mobility constraints, cost
savings, High Occupancy Vehicle (HOV) lane use and other. Concern for the environment is the reference category. This variable was included to control for the potential influence of attitudes toward carpooling. This variable may also help outline policies that are more effective in generating carpools, such as promoting the savings in travel time when carpooling.

Only one of the four factors in this category was found to have statistical significance in the model. The remainder of the discussion about motivations systematically examines the results for each category of the polytonomous variable describing carpooler motivations.

*Mobility constraints (Motivated by not being able to drive or no vehicle availability)*

Mobility constraints were found to not have statistical significance in the model ($p > 0.1$). This result is not surprising, while those with low mobility might need to form a carpool, they are not very successful as carpooling involves the sharing of a car, which they cannot contribute. Perhaps many people joining a program like Carpool Zone are more interested in sharing the driving experience as opposed to solely acting as a driver. An experimental college study found that the most desirable arrangement in carpooling was shared driving, as people enjoyed both the economic advantages as drivers and comfort as passengers (Levin, 1982).

*Cost savings*

The savings that are potentially included in this context are those involved with commuting (e.g., fuel savings, car maintenance, road tolls, parking costs). The respondents were not given a definition of cost savings, and therefore these findings are interpreted as though any one of the savings listed above may be considered by the respondent. The cost motivation appeared to be no more important than environmental concern ($p > 0.1$). Once again, these
research findings do not reflect the findings of Meyer (1999), Tischer and Dobson (1979), Giuliano (1992), Washbrook et al. (2006), Alpizar and Carlsson (2003), Rose (2002), Benkler (2004) and Andrey et al. (2004) who have all found that travel decisions are mostly influenced by the perceived costs of travel. It is useful to consider, though, that this model is looking not so much at a travel decision, but a process that produces the intended outcome of a travel (mode choice) decision that was taken earlier.

*HOV lane use*

HOV lane use is appealing to drivers mainly because of the reported benefits of time-saved-in-vehicle for journeys to/from work. HOV lanes was significant in each model ($p \leq .10$), suggesting the respondents motivated by HOV lane use are on average carpooling more than those with environmental concerns. The odds ratio indicates that, on average, those motivated by HOV lane use are twice as likely to carpool than those concerned with the environment. It appears as though the individual interest in saving time is more important in carpool formation than environmental concerns. These findings substantiate other work where it has been found that the desire to access HOV lanes provides some motivation behind the carpool decision (Benkler, 2004; Collura, 1994).

Measuring the influence of temporal concerns on travel decisions is fairly complex, time can be considered part of the commuting cost issue, and processes that are likely to increase commute time could direct mode choice decisions away from modes like carpooling. While Meyer (1999) cited perceived costs as being influential to travel decisions, this may also be interpreted as temporal costs because congestion and related time delays are important in the commute mode decision. One may surmise that someone motivated by HOV lane use is concerned with congestion and saving time.
### Table 4.4 Factors Influencing the Formation and Use of Carpools

<table>
<thead>
<tr>
<th>Fixed Effects</th>
<th>Step 1</th>
<th>OR +/- 95%CI</th>
<th>Step 2</th>
<th>OR +/- 95%CI</th>
<th>Step 3</th>
<th>OR +/- 95%CI</th>
<th>Step 4</th>
<th>OR +/- 95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>p-value</td>
<td>OR</td>
<td>Lower</td>
<td>Upper</td>
<td>OR</td>
<td>Lower</td>
<td>Upper</td>
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<tr>
<td><strong>Constant</strong></td>
<td>-1.141</td>
<td>0.000</td>
<td>0.319</td>
<td>0.199</td>
<td>2.371</td>
<td>0.093</td>
<td>0.091</td>
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<td><strong>Motivations</strong></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference: environmental concerns</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobility constraints</td>
<td>-0.260</td>
<td>0.393</td>
<td>0.771</td>
<td>0.425</td>
<td>1.400</td>
<td>-0.253</td>
<td>0.427</td>
<td>1.141</td>
</tr>
<tr>
<td>Cost savings</td>
<td>0.126</td>
<td>0.514</td>
<td>1.324</td>
<td>0.777</td>
<td>1.656</td>
<td>0.096</td>
<td>0.633</td>
<td>1.100</td>
</tr>
<tr>
<td>HOV lane use***</td>
<td>0.879</td>
<td>0.047</td>
<td>2.408</td>
<td>0.111</td>
<td>5.735</td>
<td>0.836</td>
<td>0.041</td>
<td>2.307</td>
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<tr>
<td>Other</td>
<td>0.736</td>
<td>0.123</td>
<td>2.087</td>
<td>0.820</td>
<td>5.315</td>
<td>0.648</td>
<td>0.179</td>
<td>1.912</td>
</tr>
<tr>
<td>Spatial and temporal</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximity to other Carpool Zone users (1 km buffer)*</td>
<td>0.083</td>
<td>0.028</td>
<td>1.086</td>
<td>1.009</td>
<td>1.170</td>
<td>0.100</td>
<td>0.009</td>
<td>1.105</td>
</tr>
<tr>
<td>Distance to nearest carpool lot</td>
<td>0.000</td>
<td>0.844</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>0.789</td>
<td>1.000</td>
</tr>
<tr>
<td>Commute time</td>
<td>0.006</td>
<td>0.121</td>
<td>1.006</td>
<td>0.998</td>
<td>1.014</td>
<td>0.006</td>
<td>0.135</td>
<td>1.006</td>
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<tr>
<td><strong>Demographics</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference: male**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
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<td>1.343</td>
<td>0.945</td>
<td>1.909</td>
<td>0.337</td>
<td>0.066</td>
<td>1.401</td>
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<tr>
<td><strong>Age</strong></td>
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<td>0.090</td>
<td>1.015</td>
<td>0.998</td>
<td>1.033</td>
<td>0.014</td>
<td>0.118</td>
<td>1.014</td>
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<td><strong>Current Commute Mode</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference: SOV use</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transit**</td>
<td>-0.803</td>
<td>0.019</td>
<td>0.448</td>
<td>0.229</td>
<td>0.879</td>
<td>-0.803</td>
<td>0.019</td>
<td>0.448</td>
</tr>
<tr>
<td>Passenger</td>
<td>0.513</td>
<td>0.152</td>
<td>1.671</td>
<td>0.828</td>
<td>3.372</td>
<td>0.513</td>
<td>0.152</td>
<td>1.671</td>
</tr>
<tr>
<td>Active Transportation (e.g., walking, cycling)</td>
<td>-20.359</td>
<td>0.999</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>-20.359</td>
<td>0.999</td>
<td>0.000</td>
</tr>
<tr>
<td>Other</td>
<td>-0.996</td>
<td>0.200</td>
<td>0.369</td>
<td>0.081</td>
<td>1.692</td>
<td>-0.996</td>
<td>0.200</td>
<td>0.369</td>
</tr>
<tr>
<td><strong>Summary Statistics</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Cases</td>
<td>1009</td>
<td></td>
<td>752</td>
<td></td>
<td>715</td>
<td></td>
<td>696</td>
<td></td>
</tr>
<tr>
<td><strong>2(1.00-β)</strong></td>
<td>786.083</td>
<td></td>
<td>779.022</td>
<td></td>
<td>773.429</td>
<td></td>
<td>755.020</td>
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</tr>
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<td>Χ²</td>
<td>7.483</td>
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<td>14.545</td>
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<td>20.137</td>
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<td>38.546</td>
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</tr>
</tbody>
</table>

**NOTES:** OR = Odds Ratio; 95% CI = Confidence Interval; HOV = High Occupancy Vehicle; SOV = Single Occupancy Vehicle

*p < 0.01, **p < 0.05, ***p < 0.1
This is rather likely seeing as though the municipalities with high rates of carpooling are in the exurban/suburban areas where people may have longer commute distances as opposed to urban areas with higher employment density and accessibility.

With respect to other observations regarding time and carpooling, Levin (1982) found that people were unhappy with large carpool sizes as this increased the time to pick up each additional rider, which points to the fact that commuters are truly concerned with travel time, savings in time generated from HOV lanes implementation are likely to be well received. In some contrast, Van Vugt et al. (1996) found that the HOV initiative was not successful over the longer term, users motivated to carpool based on the introduction of HOV lanes were soon re-evaluating their motivations and decisions.

*Other*

The *Other* category could include users motivated by multiple factors, those unable to choose a primary motivation, or users with motivations not listed in the survey. Other motivations could include concepts such as acquaintanceship (social factors), and the reduction of driver burden (Levin, 1982; Benkler, 2004). The results show no significant difference between other and environmental motivations ($p > 0.1$), although, from a behavioural science perspective, there is probably some scope to unpack further, this “other” category to consider the sort of non-instrumental motivations cited by Benkler (2004) (e.g., company, being socially and environmentally responsible).

**4.3.2 Spatial and Temporal Factors**

The role of geography in the carpooling process has been explored in the context of carpool matches, distance to carpool lots, and in terms of the generalized cost of commuting, measured as self-report commute time. Importantly, while the literature has touched upon
the importance of having an adequate pool of matches (Teal, 1987; Meyer, 1999; Kaufman, 2002), the spatial element of matching has not been examined directly. Therefore, this section begins by exploring whether proximity to Carpool Zone users associates with the carpool outcome. The guiding hypothesis is that a worker with more matches residing in close proximity to him or herself, will have a greater chance of producing an operational carpool. However, this “close proximity” is unknown, as a result, a simulation study was conducted to shed some light on the effect of various threshold values, used to operationalize the cumulative opportunities measure described earlier, on the explanatory power of the model. The purpose of the carpool lot variable is to provide more insight into the role of public infrastructures produced by the state in support of carpooling (e.g., carpool lots) on the carpooling formation process. Lastly, commute time is tested as the literature has suggested that carpooling takes place over longer distances (Cervero and Griesenbeck, 1988; Levin, 1982). Time and distance are both approximations of commuting cost, in this particular case, only self-report commute time is available. These variables could inform the best approaches to the marketing (in a community setting) of this online tool. Of the variables tested, only proximity to other users was statistically significant.

Proximity to other Carpool Zone users

This variable is concerned with the geography of the distribution of users, and the influence of this user distribution on carpooling. First, the distance best suited for finding matches and generating carpools is sought out, and then the importance of this proximity to potential matches is estimated in the model. To determine the most significant buffer distance for this variable, ‘the model was estimated repeatedly with the replacement of the accessibility variable at each interval of distance (0.5 km to 10 km)’ (Buliung et al., 2009, p.9). ‘The
results indicated that the carpool formation and use process is most sensitive to the local
distribution of potential matches, particularly within 0.5 and 2.5 km of the place of residence’
(Buliung et al., 2009, p.9). The most significant buffer distance was found to be within 1 km
of the user’s residential location (Figure 4.8). The next finding was that a distance decay
pattern resulted from conducting this test, in that the contribution of commuters to carpool
formation declines with distance from the place of residence of a commuter seeking to match
with others for the purpose of carpooling.

![Figure 4.8 Spatial Accessibility Effect](image)

This variable was found to have statistical significance ($p < 0.1$) at each step of the
model where it was included (Steps 2-4). The model indicated that the odds of forming a
carpool typically increases by 13% with the addition of each new user within 1 km of the
place of residence. The findings reflect literature that discusses the importance of pool size,
and contributes a new understanding that it’s not only pool size, and personal characteristics, but that it’s the geographical distribution of the pool that also influences carpool formation. Van Vugt et al. (1996) found that many people are unable to carpool due to a lack of matches or scheduling issues. Findings by Ferguson (1990) are also reinforced by Teal (1987), who suggested that participation is highly dependent on the size of the potential list of carpoolers. Kaufman (2002) also found that access to potential carpoolers is important to carpooling.

The two key strategies in forming and using carpools are: (1) establishing communication with potential adopters, and (2) fostering the development of a large pool of potential users with enough variation in demographic and trip characteristics (but ideally in geographic clusters).

**Proximity to nearest carpool lot**

In contrast to proximity to “others”, proximity to carpool lots has no measurable impact on the production of an operational carpool using Carpool Zone ($p > 0.1$). Importantly, these data do not suggest that the lots are not useful to others who could be constructing their carpools through other means. Based on the results for the previous accessibility variable, and this finding, there is an indication that perhaps infrastructural changes are not as important as social networking and marketing within a community setting when attempting to increase interest in carpooling.

**Commute time (self-reported)**

The variable that measures the duration of a commute was found to be statistically insignificant ($p > 0.1$) when it was first introduced into the model, as well as in the final model. The increased likelihood of carpooling with an increased commute time is very small (OR = 0.7%). While not directly pertaining to carpooling, Alpizar and Carlsson (2003) have
suggested that besides cost, travel time is an important determinant in the decision to change modes of transportation. Levin (1982) found that while driving distance was not a major factor in carpool formation, the longer someone drove, the less they desired to drive alone. In this context, the generalized cost of the commute may have influenced the earlier decision to explore the carpool option, once a worker has taken that decision, the commute time appears to have less influence on the outcome than other things.

4.3.3 Demographic Factors

The demographic category is rather sparse in terms of variables, few questions relating to personal or household characteristics were asked in the Satisfaction Survey, and few variables are available through the commuter profile dataset. While this is a perceived drawback to the data, some literature has suggested that socioeconomic and demographic factors are not key factors behind the carpooling decision (Benkler, 2004; Kaufman, 2002). The variables in this category were chosen to gain some insight into whether or not basic demographic factors influence carpool formation.

Gender

The gender issue is one that is often discussed in transportation studies, in particular when discussing mode choice (Johnston-Anumonwo, 1992; Camstra, 1996; Kwan, 1999a, 2000; Tischer and Dobson, 1979; Kaufman, 2002). This variable was explored within the scope of this model to examine whether males or females are on average, equally likely to carpool. Gender is not statistically significant until current commute method is added in the final stage of the model ($p < 0.1$). The regression analysis indicates that, on average, females are 1.4 times more likely to carpool with the aid of Carpool Zone, when compared to their male
counterparts. These results may be a result of three factors discussed in the literature: gender differences in driving arrangements; commute distance; and low female auto-mobility.

One study found that gender was important in the type of driving arrangements that were agreed upon in a carpool. Levin (1982) found that males prefer to either share driving duties or drive more often, while females were also interested in shared driving but preferred the passenger role. This difference in preferred driving arrangement may be part of the reason for the greater success of females, as perhaps it is easier to set up a carpool with someone who does not mind being a passenger, while a driver may have more trouble allowing someone else to operate the vehicle. However, the researcher is not privy to the driving arrangements taking place in Carpool Zone generated carpools and therefore this cannot be examined at this point in time.

Gender differences in commuting has been contested throughout the literature. To begin with, both Rietveld et al. (1999) and Kwan (2000) found that females travel lengthier distances to work than males. This finding is contested by the household responsibility and entrapment theories, which are prominent throughout a great deal of commuting literature (Sermons and Koppelman, 2001; Cristaldi, 2005; Camstra, 1996). The household responsibility hypothesis (HRH) suggests that females tend to commute less than males because they perform a larger share of childcare and domestic responsibilities (Sermons and Koppelman, 2001). Connected to HRH is entrapment theory. Entrapment theory suggests that females are constrained to smaller travel areas due to household responsibility and the specific sort of employment options most often available to women (Cristaldi, 2005). The results of this study may suggest that females do indeed have longer commute distances. As
literature has found that carpooling takes place over longer distances, this might explain the higher likelihood of carpool formation by females.

Both Tischer and Dobson (1979) and Kaufman (2002) have found that females are more likely to carpool than males, due to automobile constraints. This auto-access constraint might lead to females being more open and accommodating to carpool matches compared to their male counterparts, resulting in a higher likelihood of carpooling.

Age
Most users in the Carpool Zone dataset are between the ages of 24-35. In the model, age was found to be statistically insignificant ($p > 0.1$). The results of this study do not support the finding contributed by Baldassare et al. (1998) that younger commuters are more likely to begin carpooling. Although this model is not concerned with mode choice (like Baldassare et al., 1998), it is still useful to make this comparison, as the Baldassare et al. (1998) article suggests this age related trend mentioned above in carpooling that is also represented in the Carpool Zone dataset.

4.3.4 Current Commute Mode
The current commuting mode variable contains 5 categories of use: Single occupancy vehicle drivers (reference), transit, passenger, active transportation and other. The variable examined the influence of a user’s present mode of transportation on their carpooling outcome. The commute mode variable was chosen to gauge whether there is a difference in the difficulty of altering one’s commuting practice. For example, do commuters with similar modes to carpooling have an easier time forming carpools? The reference category for this variable was Single Occupancy Vehicle (SOV) drivers, because it is principally SOV use that carpooling is meant to reduce.
The primary incentives to using SOV’s as a primary mode of transportation have been reported to be: (1) time including scheduling and meeting deadlines and (2) a desire for spontaneity and independence (Andrey et al., 2004). As well, societal norms come into play as many people are eager to accomplish the perceived ideal of owning one vehicle per adult in a household (Andrey et al., 2004). Steg (2005) concluded that use of vehicles by commuters is related to emotions, namely feelings of superiority. While Mann and Abraham (2006) dealt with the choice between transit and SOV use, their findings suggested that SOV use is preferred amongst many commuters as it allows for autonomy (e.g., schedule determination), identity, and the preservation of personal space. Gardner and Abraham (2007) added to the list, reporting that safety and perceived stress associated with SOV use were important in the decision to drive alone. These psychological aspects of SOV use may also associate with positive commuter health (Ellaway et al., 2003). Overall, acting as a solo-driver clearly offers some benefits to individuals over passenger travel.

Transit

The use of public transit is the lone category of statistical significance ($p < 0.1$). The relationship between transit use and carpooling was found to be negative. The results suggest that on average, participants currently engaging in transit are nearly 45% less likely to carpool than their SOV counterparts. One might expect that from a social perspective, users that are accustomed to sharing their space with other commuters might be more successful in carpooling. However, perhaps the results are indicative of the fact that if someone has access to a good public transportation network they are not as keen on switching modes.

Passenger travel
This category enables comparison between passengers and SOV drivers with respect to the likelihood of starting to carpool. The variable is found to be statistically insignificant ($p > 0.1$). However, the analysis demonstrates that current passengers are 1.7 times more likely to carpool than their single driving counterparts.

*Active*

While the sample of active commuters is not large enough to make broad generalizations about their reaction to carpooling in comparison to SOV drivers, the evidence provides some preliminary insight into their lack of inclination to carpool ($p > 0.1$). The findings suggest that users that are satisfied and used to not being dependent on a vehicle for commuting are perhaps not as eager to adjust their commuting habits as SOV drivers. As well this may be seasonal, in that they only require carpooling in inclement weather which may decrease their opportunity in finding a match.

*Other*

The other commute method category may include those that use more than one mode for commuting, and/or individuals who were unsure about how to respond to the survey question. The results suggest that with the negative relationship, typically those partaking in other forms of transportation are 37% less likely to carpool with the aid of Carpool Zone, than their SOV counterparts ($p > 0.1$). Despite the lack of statistical significance, the result could suggest that multimodal commuting may be more difficult to accommodate with carpooling.

**4.4 Chapter Summary**

Chapter 4 has presented the findings generated from the contingency analysis, mapping and a logistic regression model. The following three research objectives were addressed in this
research: (1) explore the traits and behaviour of commuters who have begun carpooling and those who have indicated some intention to carpool, but have yet to do so; (2) examine the geography of interest in using Carpool Zone; and (3) describe the factors that appear to associate with carpool formation and use.

The results from the contingency analysis suggested that mobility factors (number of household cars and current commute mode) associated with the carpool outcome. Many of the respondents reside in the GTA (where Smart Commute carries out its programs), but the municipalities with the most carpoolers per employed labour force are found in suburban and exurban areas outside of Smart Commute’s programming jurisdiction.

The logistic regression brought focus to several factors associated with carpool formation and use, these included: savings of time with HOV lane use, proximity to other users, gender, and transit use. On a larger scale, the model has indicated that carpooling is not driven by one type of factor (e.g., demographic) rather carpool formation and use is impacted by different aspects of all four categories of factors. The implication of the results for policy and planning, and directions for future research are discussed in the next chapter.
5. Conclusion

Commuting issues have been an important part of planning and policy considerations during the last decade for several reasons including: economic issues (e.g., fuel and productivity costs), shifts in normative values (e.g., economy to environmental stewardship and perhaps back again), and development of infrastructure (e.g., roads and rail). In response to these issues, Transportation Demand Management (TDM) initiatives, focused on alternative forms of transportation, have been developed to improve the daily commute. Recently, there has been a resurgence of interest in alternative transport modes like carpooling. One such example, has been the development of an online ridematching program called Carpool Zone, an application and TDM initiative that is supported and operated by Metrolinx, Smart Commute within the Greater Toronto and Hamilton Area (GTAH).

The relative novelty of this web-based carpool program, coupled with the need for a solution to the commute issues described above, motivated the development of this study. A new program often requires extensive monitoring and feedback in order to improve its value to the public and/or its parent organization. History has shown that interest in an alternative transportation mode like carpooling tends to fluctuate in unison with external influences, like fuel prices (Ferguson, 1997). The current situation (with the economic, environmental and transportation issues mentioned in Chapter 1) provides an opportunity to not only improve carpool adoption throughout the duration of these issues, but also permanently diminish the gap between SOV use and alternative modes of personal transportation.

This research has explored the factors that influence carpool formation and use specifically when using this particular online ridematching program. The research included a descriptive analysis of commonalities found across both groups of users that are currently
carpooling and those not yet carpooling. The geography of carpooling relative to the potential carpoolers was mapped at the municipal scale. These exploratory stages were followed by a block entry logistic regression analysis constructed to identify the more salient factors related to carpooling with Carpool Zone, and more generally, using Information and Communications Technology (ICT) to facilitate carpool formation and use.

This concluding chapter summarizes the main findings of this research. Next, it identifies the policy implications of the work and provides recommendations on how to improve the practices and programming related to the Carpool Zone tool. This is followed by a brief description of the contributions this research has made in both a practical and academic capacity. The chapter concludes with a description of how this research may be expanded in the future.

5.1 Summary of key findings

This section presents the main findings of the research as they related to the following three research questions:

(1) What is the association between carpool formation stage, and the following correlates: motivations, gender, and mobility?

(2) Where are the most successful municipalities located in terms of users currently carpooling relative to the carpool potential, and where are the areas that appear to have a larger share of early stage or no users?

(3) What are the main factors associated with carpool formation and use?
(1) What is the association between carpool formation stage, and the following correlates: motivations, gender, and mobility?

The descriptive contingency analysis found that the most common motivations for carpooling were environmental concern and monetary cost. This suggests that, at the time of the survey (i.e., prior to the recent economic downturn) environmental concerns may have become as important as monetary savings. Motivations, however, appear to have no statistically significant relationship with carpool outcome. This is to say that motivations as a whole are not statistically significant to either the Carpool Zone enabled carpoolers or the Carpool Zone users that have yet to carpool. Demographic factors (e.g., gender) were not strongly associated with carpool status. Mobility (i.e., current commute mode and number of household cars) was significantly correlated with carpool status, two car households appeared to have the greatest carpool outcome. Furthermore, driving was the most commonly reported commute mode amongst both user groups, however, passengers were more likely to be found in the group of users that are carpooling.

(2) Where are the most successful municipalities located in terms of users currently carpooling relative to the carpool potential, and where are the areas that appear to have a larger share of early stage or no users?

The geographic visualization revealed that most respondents were located in the City of Toronto and its adjacent municipalities, while many places at the edge of the GGH exhibited a lack of sampled users altogether. When examining per capita rates of carpooling it was found that the municipalities with the highest rates of carpooling were in relatively affluent exurban/suburban areas, located beyond the Metrolinx, Smart Commute planning
jurisdiction (e.g., the GTA). Furthermore, the municipalities with the most users not yet carpooling were also found to be grouped together in suburban/exurban areas. Taken together, these results suggest considerable interest in carpool options within places that could be producing some of the longest commutes in the study area.

(3) What are the main factors underlying carpool formation and use process?

The research included a variety of factors that were examined when studying the carpool formation process, rather than focusing on a single type of correlate. The most significant factor in the carpool process was found to involve the geographical distribution of Carpool Zone users relative to the place of residence. The model also suggests that commuters are potentially motivated to generate carpools, with a view to saving time (interest in use of HOV lanes), as opposed to altruistic concerns related to the environment. In terms of socio-demographics, gender was found to be marginally significant, females were more likely to be participating in active carpools than males. Lastly, users currently commuting via transit were less likely to carpool when compared to SOV drivers.

5.2 Contributions

The contributions of this research are relevant in a behavioural science context, and in terms of informing planning and programming practice. The research usefully described results from US and European case studies, while identifying a knowledge gap regarding carpooling in Canada. Examining carpool formation, and doing so by simultaneously controlling for several factors, represented a unique contribution to the carpooling literature. Looking at these factors, with a view to understanding their influence on on-line ridematching was also a unique contribution. Taken together, these contributions have advanced current
understanding of carpool formation and use processes, particularly with regard to the geography of these processes.

From a practical perspective, Section 1.1 introduced the challenges presently faced by commuters, and the need for promoting and improving possibilities for commuter engagement with alternative forms of transportation. For example, the Greater Golden Horseshoe (GGH) region was home to 7.8 million people in 2001 and is expected to grow to 11.5 million by 2031, this expected population growth should be proactively met with local and regional plans that attend to the corresponding rise in demand for transport (personal and otherwise) (Ministry of Energy and Infrastructure, 2006, p.12). This research directly informed Metrolinx, Smart Commute of the demographics of carpooling, and the factors that contribute to the production of carpooling, particularly within the context of the Metrolinx planning jurisdiction. This work is expected to enhance Metrolinx, Smart Commute’s ongoing development and support of the Carpool Zone TDM initiative in the GTAH. More broadly, the findings may be used by any TDM oriented organization to enhance their understanding of the potential commuter response to carpool formation tools and practices.

From the programming perspective, using the existing dataset identified some issues with the way in which Smart Commute gathers their information (in particular the questions asked of respondents). While having to extract the variables from the given dataset was a setback, it also presented the opportunity to use the existing data in an innovative way. More specifically, the profile data was combined with the Carpool Zone Satisfaction Survey data which provided a rather novel dataset which included both user information as well as attitudinal data which is often challenging to produce in other ways.
The data issue gave the researcher the opportunity to not only provide Smart Commute with information on how to improve their ridematching program, better promote carpooling and their user base, but also gave feedback on how to improve their survey. This aspect is extremely useful as the survey aids in the development of future programming, and by improving the questions asked of the respondents, this may in turn impact the types of practices the organization undertakes.

5.3 Policy implications and recommendations

The findings of this research provide insight into the process of carpool formation and use, data which may be useful for policy and programming. To begin with, it is possible that the employer based Carpool Zone program is working well as the municipalities with the highest rates of carpooling are found outside of Smart Commute’s focus area (GTAH). Since Metrolinx Smart Commute’s TDM campaign focuses on the GTA only, users with places of residence outside the GTA boundary have likely become familiar with this program in relation to jobs located inside the GTA. It is possible that commuters from exurban or outer suburban areas have greater needs for alternative forms of transportation options, therefore more attention should be placed on increasing marketing in these areas (even if it is just through the employer program).

The research has also suggested that the origin of the commute is also very important in the carpool formation process. Matches within close proximity to one’s home are important drivers of carpooling, drawing some focus toward the trip origin, when marketing the TDM initiatives, could be a valuable experience. Smart Commute should place more focus on increasing carpooling on a community level, which may include further advertising and campaigns at smaller community events and centres.
In terms of motivating participation, a larger focus in promotional messaging should be given to the potential time savings involved with carpooling, when using routes with High Occupancy Vehicle (HOV) lanes. This messaging would need to articulate the relationship between time-saved commuting, and the additional time that could accrue through passenger pick-ups. Generally, it is apparent that unlike carpool lots, HOV lane infrastructure is important in carpool formation and use, perhaps more attention should be placed on further improving highway systems to better accommodate TDM infrastructures.

Besides improving upon policies and programming with respect to attracting more users, Smart Commute should improve the tools that influence how they conduct this programming. The data collection and analysis that Smart Commute performs aids in informing their development of new initiatives for increasing carpooling in the GTA'H. Upon performing this research, it has become evident that there are ways in which data collection could be improved. Many issues emerged from working with the survey data, a secondary data source. For example, the commute time question was vague; it was unclear whether the respondent was being asked to report travel time for a one-way or round-trip commute.

Furthermore, it was unclear what “other” might entail in questions regarding the commute method [mode] and motivation. Rather than a question that allows for only one response, it would be useful to ask respondents to rate the importance of each motivational factor, using a Likert scale, in their decision to take up carpooling. For example, “How much does inflexibility of schedules deter you from carpooling?” In addition, the literature suggests that this “other” motivational category could include issues such as seeking to develop acquaintanceship, or reduce driver burden (Levin, 1982; Benkler, 2004). The well
established relationship between carpooling and these other factors supports their potential inclusion in future versions of the survey.

Aside from the clarity of the questions being asked, there are many useful questions that were not included in the survey which Smart Commute should address. Based on the carpooling literature (Kaufman, 2002; Ferguson, 1995; Baldassare et al., 1998), it is important to include some more socio-demographic questions concerning income, profession, and ethnicity. Accessibility to cars is also an important factor that is not clearly asked of respondents. For example, while household cars and commute method provide some indication of vehicle access, it might be useful to ask: “Do you have access to a vehicle for your commute?” Adding a few questions may add value to Smart Commute’s current survey work. Nevertheless, discovering how to link up and study carpool behaviour using the existing dataset has already advanced Smart Commute’s understanding of the travel processes that they are trying to manage through Carpool Zone.

In order for these recommendations to produce positive results, the way in which carpool initiatives are regarded by the lawmakers may also require some modification. For example, where carpools that deviate from this definition (mentioned in Section 1.2 of the Public Vehicles Act) are unlawful:

“In this Act,

“Board” means the Ontario Highway Transport Board; (“Commission”)

“bus” means a bus as defined in the Highway Traffic Act; (“autobus”)

“car pool vehicle” means a motor vehicle as defined in the Highway Traffic Act,

(a) with a seating capacity of not more than twelve persons,
(b) while it is operated transporting no more than twelve commuters including the driver, none of whom pay for the transportation more frequently than on a weekly basis, (c) that is not used by any one driver to transport commuters for more than one round trip per day, and (d) the owner, or if the vehicle is subject to a lease, the lessee, of which does not own or lease another car pool vehicle unless the owner or lessee is the employer of a majority of the commuters transported in the vehicles, but does not include a motor vehicle while being operated by or under contract with a school board or other authority in charge of a school for the transportation of children to or from school; (“véhicule de covoiturage”)” (Public Vehicles Act, 2007).

This is counterproductive to the carpool TDM initiatives as it limits the way in which carpools may operate. For example, the compensation structure is imposed on the carpoolers, who may prefer to exchange payment more frequently. Carpool Zone has avoided any legality issues by requiring all new registrants to understand and comply with their terms of use. For example, the user is required to be familiar with and must abide by all laws outlined by the province. With respect to compensation, the Smart Commute Association (SCA) asserts that it, “…is providing this carpool matching service free of charge. Any agreement made between You and fellow carpoolers regarding cost sharing does not involve SCA” (Smart Commute Association, 2009).

Recently, an Ontario based online carpooling service - Pickup Pal- was fined for defying the Public Vehicles Act. While this case drew ministerial attention to the necessity of changing the law, it may have also deterred further attempts at developing entrepreneurial solutions to travel demand problems centred on the sharing of mobility. From a
governmental policy perspective, it is important to ensure that current legislation is reflective of the government’s own attempt to improve TDM initiatives (e.g., carpooling).

5.4 Future research

This research has also given rise to some potentially interesting and policy relevant directions for future research. Examining carpool formation using the framework based on Ajzen’s Theory of Planned Behaviour (TPB) could better explain the decision making process. The TPB could be helpful in the “process” context because it takes into account the following factors when predicting a specific behaviour: attitudes toward the behaviour; subjective norms; perceived behavioural control; perceptions of this behavioural control (Ajzen, 1991). While this study has examined peoples’ attitudes towards carpooling (motivations), questions remain about how subjective norms, like social status associated with using a certain commute mode, potentially influence the carpool decision. Moreover, little is known about the barriers that commuters could face when attempting to generate carpools.

With respect to the modeling work, it could be useful to improve upon some of the categories within the logistic regression model. For example, the socio-demographic category would be of more value with the inclusion of data on income, employment, or perhaps educational attainment (e.g., as a proxy for income). This is a task that will require collaborative development of future versions of the surveys issued by Metrolinx, Smart Commute to the Carpool Zone user population. Additional steps should also be taken to extend the analysis to include both the home and work-ends of the commute. The disclosure of data on complete trips will facilitate deeper analysis of the relationship between economic and transport geography, workplace TDM policies, and carpool formation. Data on commute scheduling (e.g., hours and days of work) would also improve the empirical analysis, the
literature has shown that work scheduling may influence carpool selection from among available alternatives (Andrey et al., 2004).

Lastly, and while one of the main contributions of this work has centred on understanding the role of space in carpool formation, gaining more insight into the time it takes for a user to create a carpool and learning more about the influence of role preferences like driving, riding, or sharing, on the carpool process could prove to be useful in identifying the ideal carpool situation - if one exists at all. This type of research may directly influence initiatives taken to generate more carpools. In conclusion, this thesis has provided some further insight into the carpool process. It is evident through the outline presented earlier of commuting issues in the province of Ontario, and the GGH more specifically, that there is some urgency to act in developing sustainable alternatives to today’s single occupancy commuting reality.
References


