The "Driving" Factors Behind Successful Carpool Formation and Use

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Abstract. Sustainable transportation options are receiving increasing attention in cities across North America due to rising commute times, fluctuating fuel prices, and increased awareness of the environmental impacts of transportation choices. Carpooling represents one of many possible alternatives to single occupancy vehicle use for work or school trips. Recent attempts to encourage carpool formation in Canada now include web-based applications that facilitate connections between potential carpoolers. One such example is Carpool Zone, a service provided by Smart Commute in the Greater Toronto and Hamilton Area (GTHA). The service is coordinated regionally by the Smart Commute Team at Metrolinx (the regional transportation planning authority) and is free and open to the public. This paper uses data from Smart Commute to investigate the carpool formation and use process. Results from a logistic regression analysis of carpool use suggest that spatial accessibility to matches, household auto ownership, and socio-demographics influence carpooling more than proximity to carpool infrastructure and personal attitudes (e.g., concern for the environment, cost, etc.). With respect to policy and planning, the results suggest that increasing shared knowledge about commuting patterns at the home-end of work trips could yield beneficial returns to the carpool formation and use process.

INTRODUCTION

The productivity and environmental costs of auto ownership and use for commuting and other activities appear to have reached exceptionally high levels in both the US and Canada (*1, 2*). Fuelled by empirical evidence, and public reaction to the current state of the daily commute; policy makers, planners, and consumers are becoming increasingly interested in exploring alternative transport options for commuting. Canada's largest metropolitan region, the Greater Golden Horseshoe (GGH), is no exception. The recent *Places to Grow Act* for the GGH has identified critical metropolitan development and transport issues, and several policy and planning interventions designed to alleviate the congestion and poor air quality issues often linked to urban sprawl and auto-mobility (*3*). A goal for the Regional Transportation Plan being prepared by Metrolinx (Greater Toronto Transportation Authority) includes improving transportation choices for the commuting public (*4*).

With respect to the state of commuting in the US and Canada, the recent *US National Report on Commuting Patterns and Trends* reported that between 1990 and 2000, the average daily commute increased by approximately three minutes (one-way). During the same time period, 13 million solo drivers were added to the US transportation system *(5)*. In Canada, 1 million new drivers were added between 1996 and 2001, and the median commute increased from 7.0 km to 7.6 km between 1996 and 2006. The average one-way commute time has also increased from 54 minutes (1992) to 63 minutes (2005) (*6,7,8*). Presenting some contrast to these data, between 1996 and 2006, transit mode share increased from 10.1% to 11.0%, while between 2001 and 2006, the number of Canadian commuters travelling as passengers rose from 6.9% to 7.7%. Despite these recent, and marginal changes in mode share, the automobile dominates Canadian commuting (72.3% of work trips) between increasingly suburban places of residence and employment (*6,7,8*).

The spatial flexibility (e.g., door-to-door or near door-to-door service) offered by carpooling, in comparison with typically less spatially flexible systems (e.g., public transit), is similar to single occupancy vehicle (SOV) use. Of course, the addition of other commuters, a process that involves the mixing of schedules, values/norms, and resources, makes carpool formation and use (over the short or longer term) a challenge. Carpooling, however, does not require significant investment of public capital because it primarily makes use of existing infrastructure. The 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 (*9*). The carpooling alternative represents a modification of the commuter's use of legacy systems within urban and regional environments; systems that play a key role in ensuring economic productivity, while facilitating participation in daily activities. This approach leverages past capital investment in infrastructure, enabling a change in the culture of use of critical legacy systems (*10*).

This paper examines a recent and ongoing attempt by Smart Commute, a multi-stakeholder transportation demand management (TDM) organization based in the Greater Toronto and Hamilton Area (GTHA), Canada, to facilitate carpool formation through the deployment of a web-based carpool formation application called Carpool Zone. The broad aim of this research is to improve current understanding of the carpool formation and use processes by examining how individuals respond to the availability of an online carpool formation tool. The three main objectives of this study are to: (1) describe the current staging of carpools within the Carpool Zone user community (i.e., waiting for matches, formed and started carpooling); (2)

describe geographical patterns of demand for the Carpool Zone service, emphasizing cases where user have started carpooling; and (3) test the hypothesis that the carpool formation and use process is sensitive to individual compositional characteristics (e.g., gender, age), residential spatial context (e.g., accessibility to matches), current mobility status (e.g., household automobiles), and the construction of travel behaviour around normative values (i.e., attitudes toward cost, the environment, and the value of time). Following the introduction and literature review, the paper provides some background information on Smart Commute and the Carpool Zone software. Methods and survey data are then discussed, followed by the presentation of research findings. Lastly, the paper discusses the implications of the findings, and provides recommendations for future research, programs, and policy.

THE LITERATURE

A significant portion of the travel demand management literature discusses the development of incentives to encourage carpooling, an important issue for policy development, and a key mechanism for encouraging changes in commuting behaviour. The literature also identifies reasons for the success and failure of carpooling, and the motivations for taking up the practice. Tischer and Dobson (*11*) found cost, safety, and alleviating congestion to be key factors in the carpool decision. Similarly, a Vancouver commuting study suggested that cost is important, as increasing SOV use cost appears to be driving an increase in carpooling (*12*). Likewise, Meyer *(13)* suggests that the most effective TDM policies are those focused on the pricing of SOV use. Giuliano (*14*) argued that savings in time are not as important as cost savings and the resolution of scheduling conflicts.

More recent research suggests that the cost of commuting plays a smaller role in the choice to carpool than in the past (*15*). Alternatively, Taylor (*16*) proposed that there is a need to price driving accordingly, including taxation and the elimination of free parking. Shoup (*17*) suggested that cashing out employees in lieu of a parking subsidy has tremendous potential for increasing carpooling. A major problem with present day transportation policy is that although there is a pro-alternative transport ideal, there are incentives in place that promote SOV use (*16*). Alternatively, Collura (*18*) identified environmental awareness, poor transit service between suburbs, and congestion, as the primary motivations for pursuing carpooling.

With respect to personal characteristics, Kaufman (*19*) indicated that socio-economic characteristics do not play a large role in the choice to carpool. Furthermore, some research has found that vehicle availability and educational attainment play a larger role in the carpool process than other demographic variables or socially constructed qualities of the labour force (e.g., gender) (*20*). However, gender and the experience of females in the urban economy arguably mediate vehicle access, thereby indirectly influencing carpooling outcomes. Ferguson (*20*) also found that income has only an indirect impact on the choice to carpool in lower income households, as income influences auto ownership and use. Frequently cited barriers to carpool formation and use include: (1) rigid scheduling, (2) lack of matches, (3) inflexibility of travel during the work day, and (4) social issues or differences in systems of values (*21*).

Regarding carpool formation in a corporate setting, firm size appears to impact carpool establishment because of the incentive structure and the presence of a larger pool of participants (*22*). Similarly, Collura (*18*) suggested the improvement of programs in employment environments as a cost effective approach to stimulating carpooling because of access to people for promotion. Findings by Ferguson (*22)* are also reinforced by Teal (*23*), who suggested that

participation is highly dependent on the size of the potential list of carpoolers. Kaufman (*19*) also found that access to potential carpoolers is important to success. Two key challenges then, in achieving success with carpool strategies are: (1) establishing communication with potential adopters, and (2) fostering the development of a large pool of potential users with sufficient variation in values/habits, demographics and trip characteristics (e.g., timing, geography, etc.). Looking beyond the challenges facing individual programs, some thought should also be given to compositional (who is in the carpool) and competition effects. Morency (21) found that in Montreal, the majority of passengers in carpools are from the same household. With respect to competition, she argued that, "The issue of a lack of unity amongst different types of organizations is a cause for concern as there is a loss of potential carpoolers due to overlapping initiatives*" (21, p.242).*

Research has also looked into the behavioural process that gives rise to carpooling. Ozanne and Mollenkopf (*24*) situated carpooling within the *Theory of Planned Action Behaviour* and the *Theory of Reasoned Action* to determine what drives carpooling and, like Horowitz and Sheth (*25*), found that attitudes are important. The perceived ease of carpooling plays a role, which includes societal benefit, monetary incentives, scheduling, and access to other carpoolers (*24*). As a result, the research suggested that policy should focus on influencing attitudes. Other research found that race and ethnicity may play a role in carpool formation (*26*).

With respect to spatial factors, Teal (*23*) proposed that carpool users tend to travel further distances than SOV drivers; therefore, the choice to carpool may also be location and destination driven. The temporal regularity with respect to scheduling and work hours has also been shown to influence successful carpool formation (*22*). Tsao and Lin (*27*) found that the sacrifice of time and scheduling flexibility are significant deterrents. The evidence suggests that it is potentially easier to create carpools with commuters that have consistent and typical work hours (e.g., 9-5), as scheduling is easier (*22, 28*). Travel time is also an important factor in carpooling use, as it potentially increases with an increase in carpool passengers. Increasing travel time, in response to carpool formation, could feedback into the carpool decision process, leading to dissolution of newly formed carpools and a return to SOV use. Suggestions have been made that emphasis should be placed on improving carpool infrastructure (*12*); HOV lanes are one example where policy makers appeal to the commuter's value of time as an approach to encouraging carpool formation and use (*29*).

CASE STUDY: SMART COMMUTE AND CARPOOL ZONE

In the presence of a jointly constructed framework for knowledge transfer that includes practitioners and academics, research into commuting can inform the development of policy and programs to mitigate negative externalities associated with interactions between transportation, land use, environmental, and human systems. An attempt to improve the carpooling mode share involves understanding the, who, why, and where of carpool formation in order to plan for significant factors accordingly (*23*). It is the intent of this research to inform policy and programming at Smart Commute, with a view to enhancing the quality of the program and commuting conditions within the study area.

Smart Commute works to reduce traffic congestion and take action on climate change by improving transportation efficiency in the GTHA. Smart Commute is a workplace-based TDM program of Metrolinx that encourages commuters to explore different commuter options like carpooling, teleworking, transit, cycling, walking or flexible work hours. Ten transportation

management associations (TMAs), also known as "local Smart Commutes", and a central coordinating body at Metrolinx form a network of organizations delivering the Smart Commute program across the GTHA. Local Smart Commutes work directly with over 50 large employers, region-wide, to offer customized commuter services.

Within the GTHA, carpool formation is partially facilitated by Smart Commute's Carpool Zone service (www.carpoolzone.ca). Other informal web-based solutions to the carpool formation problem also exist within the GTHA. Commuters can organize using Facebook, Kijiji, Craigslist, and other social marketing and product sharing websites that now include commuter applications. The extent to which these tools compete for market share, in the manner suggested by Morency (*21*), remains uncertain. These other tools, however, do not possess the personal data management, contact management, and spatial matching capabilities of Carpool Zone.

The Carpool Zone is a state-of-the-art online ridematching service that matches commuters who live and work near each other and travel at similar times. It includes features such as: interactive mapping, pinpoint geocoding, intelligent route matching, EnRoute matching, as well as security, privacy and administrator functions. The Carpool Zone is free of charge and open to the public, and is complemented by a premium service offered to Smart Commute member and partner employers. The Carpool Zone was developed by the Smart Commute Association in partnership with a third-party developer; it is maintained by the Smart Commute central office at Metrolinx.

Notably, internet usage rates in the study area appear to be higher than the provincial average. For example, data from the 2005 Canadian Internet Use Survey suggest that 75% of individuals living in the Toronto Census Metropolitan Area use the Internet (a "user" is defined as someone who has used the Internet from "any" location in the survey year), the provincial rate is 72%. Consequently, Internet access, while not explicitly studied here, is expected to have relatively less influence on the success or failure of web-based ridematching than other factors (e.g., access to potential matches, vehicle availability, etc.).

DATA AND METHODS

The Carpool Zone project began in 2005. In the fall of 2007, Smart Commute conducted its second electronic survey on the performance of Carpool Zone and the behaviour of its participants. Survey recruitment involved sending an e-mail with a personalized link to every registered user of Carpool Zone. A draw for an iPod Touch ($375.00) and a $50.00 iTunes gift card was offered as an incentive. A reminder was sent six days prior to the end of the survey. An additional 319 responses were submitted following the reminder. The *Carpool Zone User Satisfaction Survey* was sent out to 4,774 registered users, resulting in 1,422 responses (a 29% response rate). For modelling purposes, a sample of 1,042 respondents reporting an address in the study area, and responding to the question concerning carpool status was selected.

The survey consists of a series of Likert scale questions to capture respondent attitudes concerning their experience with Carpool Zone. Survey responses were linked with profile data (e.g., demographics, household cars, etc.) generated during user registration. Household and personal income, family status, educational attainment, employment tenure, and ethnicity are among the unknown variables, Metrolinx is required to maintain respondent anonymity. Future work will include incorporation of work-end data to assess the relative importance of home and work-end correlates on the carpooling process. A data licensing agreement has been executed that will ultimately release destination relevant information to the researchers.

The study area extends beyond the GTHA, Smart Commute's service district, to the broader Greater Golden Horseshoe (GGH) (see inset map in Figure 2). The rationale for looking beyond the service district is that resident firms of the GTHA have non-resident employees living in other parts of the GGH. Moreover, the population of the GGH is expected to grow from 7.9 million (2001) to 11.5 million, by 2031 (*3*). As one of North America's fastest growing regions, the GGH has become the centrepiece for regional growth management and planning in the province of Ontario, Canada.

Methods

This study aims to broaden current understanding of the carpool formation and use process, and to feedback results from this research to Metrolinx, with a view to improving Smart Commute programs and services. The main objectives are to: (1) describe the current status of carpools being formed through the use of Carpool Zone; (2) describe geographical patterns of demand for Carpool Zone, emphasizing cases where users have started carpooling; and (3) test the hypothesis that the carpool formation and use process is sensitive to demographic, spatial, motivational, and mobility characteristics.

The carpool formation process facilitated by Carpool Zone ends with individuals either remaining at early stages in the process (e.g., waiting for a match, waiting for a better match, waiting for a response), moving through the system to complete carpool formation (e.g,. formed without starting), or ultimately starting to carpool. The first objective of the study was met by graphing the sample proportion of male and female Carpool Zone users within the aforementioned usage categories.

The second objective involved mapping the incidence of carpool successes by municipality of origin, relative to the size of the employed labour force (carpoolers per 10,000 employed labour force ≥ 15 years) across the GTHA. The per capita labour force expression of carpool formation and use provides further insight into the performance of Carpool Zone relative to the size of the labour force (who could be commuting and carpooling) within each municipality. Smart Commute provides services on a region-wide basis and works closely with several municipal governments, the municipal scale is appropriate for this particular mapping exercise. Moreover, the individual Smart Commute groups work closely with large employers within the GTHA municipalities, there is considerable interest in tracking the successes of the program at the municipal scale.

The third objective was achieved through a logistic regression analysis constructed to identify and document the relative importance of residential-end demographic, spatial, motivational, and mobility (e.g., household automobiles) correlates of carpool formation and use. The categorical response in this study was constructed for each respondent from the survey data, where the value 1 indicates the successful start of a respondent carpool. Responses coded as 0 include cases where respondents were: waiting for matches, waiting for better matches, had yet to hear back from contacted *potential* matches, or who had formed a carpool but had yet to start using it. The subsample used for model estimation included only those respondents who were active users of Carpool Zone at the time of the survey, engaged in the carpool formation and use process.

The logistic regression model used in the study assumed the form:

$$logit(\pi) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \; ;$$

where *logit(π)* is the natural log transformation of the odds of having started carpooling (π) to not having done so (1- π), α is the regression constant, and the β represent k parameter estimates associated with k independent variables, X. The model enables the exploration of how the log odds of successfully starting to carpool varies as a function of a linear predictor specified to include, in this case, several independent variables organized into four categories: (1) *Demographics*, (2) *Spatial Variables*, (3) *Motivation for Carpooling*, and (4) *Household Automobility*. Model specification has been guided by the existing literature on carpooling, and the identification of a gap in the literature concerning the influence of residential-end accessibility to potential carpool matches on the formation and use process.

FINDINGS

Aggregate Results

The response variable was constructed for each respondent from a survey question about carpool status. The data indicate that there are 1,042 respondents within the study area who reported the status of their carpool, 901 of these respondents reported their gender. Of the original 1,042 respondents, 19 (1.8%) have formed and not started carpooling, and 288 (27.6%) have started carpooling. Overall, more females (14.8%) have started carpooling than males (12.4%) (Figure 1).

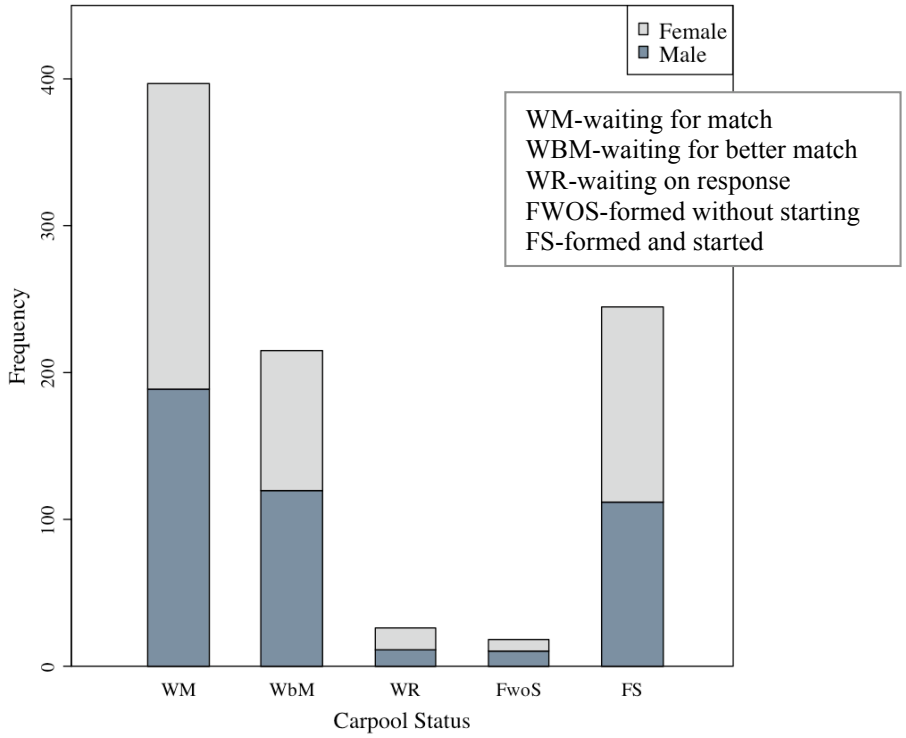

FIGURE 1 Carpool Status by Gender of Respondent

At this relatively early stage in the Carpool Zone initiative, the data suggest that Smart Commute appears to be engaging a small proportion of the employed labour force located in the employment and population rich municipalities immediately adjacent to Lake Ontario (Figure 2). In addition, the program has attracted participation from individuals living within several of the suburban municipalities that have experienced considerable employment growth since the 1980s (e.g., Mississauga, Brampton). Individuals located within the key commuter corridors, particularly within the GTHA (e.g., Highways 401, 403, 400), also appear to be making some use of Carpool Zone.

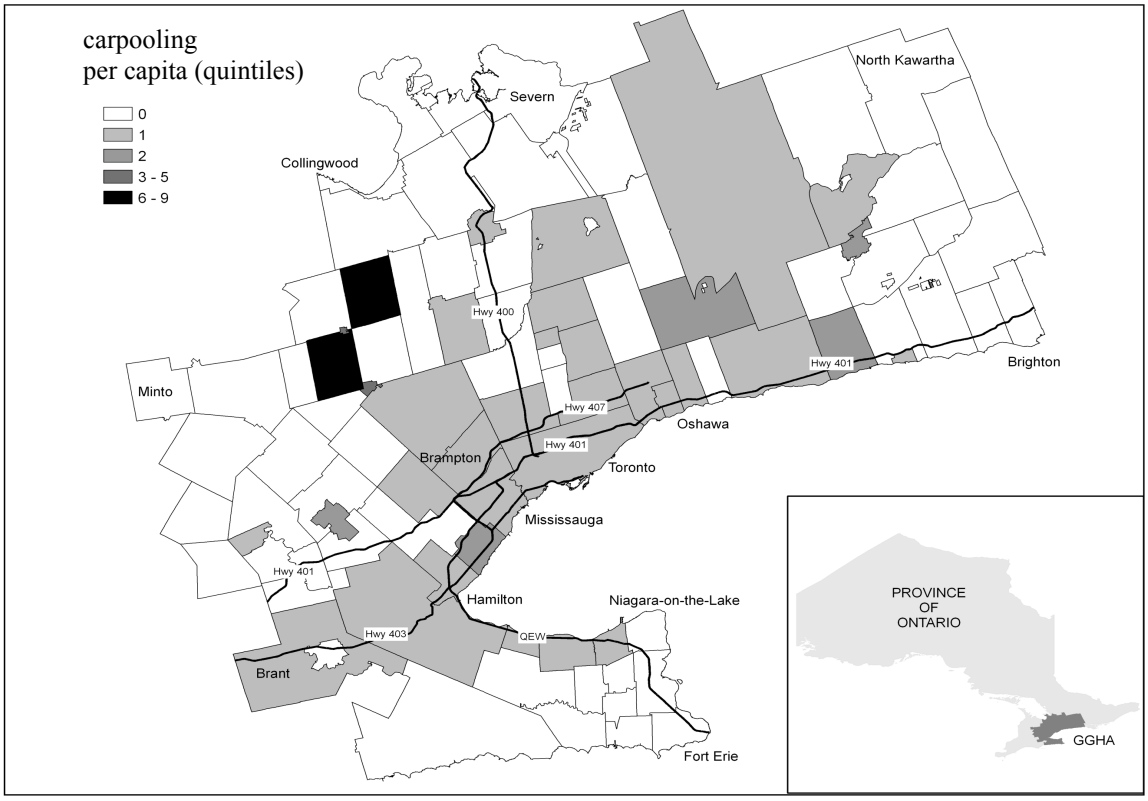

FIGURE 2 Carpooling respondents per 10,000 employed labour force.

Over the longer term, and as more employers begin to participate in Smart Commute initiatives, the expectation is that Carpool Zone will ultimately achieve greater success in these areas. In addition, there appears to be less activity at the urban edge and ex-urban subareas of the region. Interesting exceptions include the two diagonally connected districts (Mulmur and Amaranth) to the north-west of the City of Toronto. Firms participating in Smart Commute's workplace initiative may have few employees living at or beyond the urban edge.

Model Estimation Results

The logistic regression model has been specified to ascertain the qualities of the association between several residential-end factors hypothesised to influence carpool formation and use (Table 1). The four variable categories are: *Demographics*, *Spatial Variables*, *Motivation for Carpooling* and *Household Auto-mobility*. The model is exploratory, and so a relatively

generous criterion is applied here for the evaluation of statistical significance ($p \leq 0.10$). The spatial and motivational variables have been included to provide some insight into the development of effective promotional strategies and potential shifts in the development of carpool specific infrastructure. From the original sample of 1,042 cases, 172 have been excluded due to missing values.

TABLE 1 Logistic Regression Results, Carpool Formation and Use

Fixed Effects				**OR +/- 95% CI**	
	β	**p-value**	**OR**	**Lower**	**Upper**
Constant*	-1.87	0.00	0.15		
Demographics					
Gender (*reference:* Male)***	0.26	0.10	1.30	.96	1.77
Age (in years)**	0.02	0.05	1.02	1.00	1.03
Median Household Income (by FSA)	0.00	0.31	1.00	1.00	1.00
Spatial Variables					
Suburban vs. Urban Residence (*reference:* Urban)	0.20	0.40	1.22	0.77	1.91
Carpool Zone users within 1 km of residence*	0.15	0.00	1.16	1.07	1.27
Road Distance to nearest carpool lot	0.00	0.51	1.00	1.00	1.00
Motivation for carpooling (reference: Environmental Concerns)					
Don't drive, or Don't have access to a car	-0.27	0.29	0.76	0.46	1.26
Cost ($) savings	-0.02	0.90	0.98	0.70	1.38
Use of HOV lanes	0.40	0.35	1.49	0.65	3.45
Other	0.51	0.24	1.67	0.71	3.94
Household Auto-mobility					
Number of Household Automobiles***	0.17	0.08	1.19	0.98	1.42
Summary Statistics					
$n = 870$					
$-2[L(0) - L[\bar{\beta}]] = 994.97$					
$X^2 = 27.96$					

NOTES: **OR**: Odds Ratio, 95% **CI**: Confidence Interval, FSA: Forward Sortation Area
*p < 0.01, **p < 0.05, ***p < 0.1

Of the demographic variables included in this analysis, gender appears to have the greatest affect on the odds of starting to carpool, followed by age. Females are, on average, 1.3 times more likely than males to form a successful carpool. Age is shown to have a marginal positive influence on the odds of starting to carpool, i.e., older users tend to be more likely to have success with the Carpool Zone initiative than younger users. Median household income (in the postal zone surrounding the respondent) was found to be statistically insignificant. Personal or household income data were not available.

Spatial factors entered into the model include the urban/suburban situation of the place of residence, the number of Carpool Zone users within 1 km of the place of residence, and the shortest network distance to the closest carpool lot. The first measure indicates that living in a suburban area (outside of the City of Toronto boundary) has little impact on one's likelihood of

successfully starting to carpool. Proximity to other Carpool Zone users is measured as the number of users that are found within a 1 km radius of the respondent's residential location. Respondent postal addresses were geocoded to locate each respondent's place of residence within the study area. The specification of this variable was determined by conducting a simulation to examine the association between residential accessibility to potential carpoolers and the logged odds of starting to carpool (Figure 3).

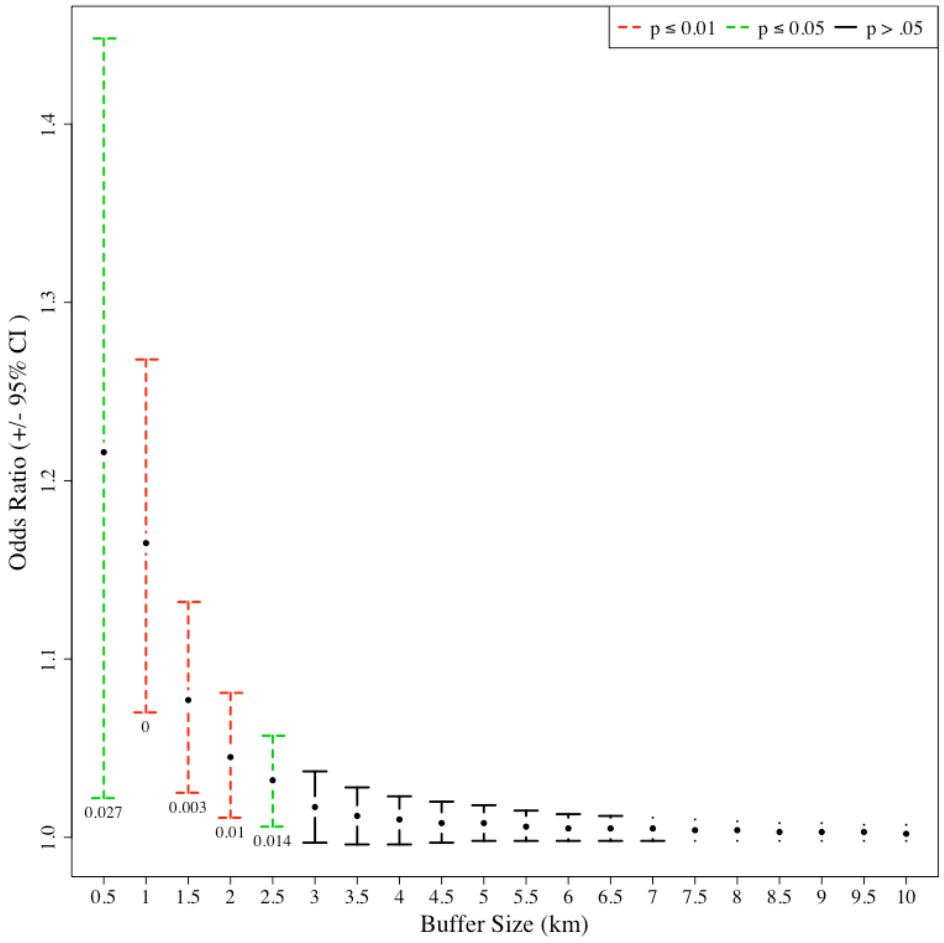

FIGURE 3 Spatial accessibility effect

Fixed radius buffers were generated, at 0.5 km increments, around respondent residential geocodes. For each individual, the number of Carpool Zone respondents within each buffer was recorded, generating a series of distance-based cumulative opportunity accessibility measures. The model described in Table 1 was estimated repeatedly, with replacement of the accessibility variable constructed for each buffer distance interval. The results suggest that the formation and use process is sensitive to the local distribution of potential matches, particularly within 0.5–2.5 km of the place of residence. The most significant effect was found at a buffer distance of 1 km (Figure 3).

The final model suggests that the addition of a potential match within 1 km of the place of residence increases the odds of starting to carpool by 7-27% (interval estimate at 1 km).

Notably, this spatial variable explained a larger share of the systematic variation in the logged odds of starting to carpool than any other variable included in the model. The simulation results also demonstrate an interesting distance decay effect, with the accessibility effect declining geometrically with buffer size. The availability of potential matches within the broader region (i.e., buffer distances in excess of 3 km) appears to have little impact on carpooling. Proximity to carpool lots is measured as the uncongested network (shortest path) distance to the closest carpool lot for each respondent. Adjusting for the other covariates, lot proximity does not appear to meaningfully impact the likelihood of carpooling ($p > 0.10$; $OR = 1.000$).

The user registration process prompts for some indication of the potential carpooler's motivation for seeking to engage in carpooling. The options emphasize automobile access, cost, use of HOV lanes, and environmental concerns. This study facilitates the simultaneous assessment of the relative importance of attitudes or the motivations behind carpooling, and other objective and spatial correlates (e.g., household cars, access to matches). The motivational data have been included as a polytonomous categorical variable, the reference category is concern for the environment. The lack of statistical significance for the motivational variables ($p > .10$) suggests that the motivation for beginning the carpool formation process with Carpool Zone has less impact on the production of a successful outcome (i.e., starting to carpool) than demographics, spatial access to matches, and household auto-mobility.

The availability of household cars has been identified in the literature as being an important dimension of the carpooling decision (*20,23*). Research has shown relatively high rates of carpooling within households with low vehicle to worker ratios (*23*). This study does not explore the impact of auto-availability on the broader mode choice process, rather, it examines the impact of auto-availability on carpooling, given that an individual has selected themselves into the carpool formation process. The logistic regression suggests that an increase in the number of household vehicles has a positive impact on the odds of starting to carpool ($p < .10$, OR = 1.19).

DISCUSSION

This study revealed a number of interesting findings regarding the efficacy of developing web-based tools that facilitate carpool formation and use. The logistic regression analysis led to the identification of several demographic, spatial, and mobility correlates of the carpool formation and use process. The mapping exercise demonstrated that there are few municipalities in the broader Greater Golden Horseshoe without Carpool Zone users. The highly urbanized areas have the largest gross number of Carpool Zone survey respondents, whether successful or awaiting carpool formation. With regard to Carpool Zone performance, this is an important finding because it is arguably within these areas where the greatest sustainable transport challenges can be found. However, municipalities in the top quintile, in terms of per capita market share, tend to be located in the suburban and ex-urban parts of the study area. A closer look into some of the ex-urban districts, particularly to the north-west of Toronto, suggests there is some interest in carpooling originating from within the affluent, transit-poor ex-urban segment of the commuter market. While there are benefits to facilitating the shared mobility of commuters, some scholars have been critical of public policy and programs that improve the mobility of 'cash-rich/time-poor' commuters (*30*). Closer examination of this ex-urban effect remains an important direction for future research.

With respect to the logistic regression analysis, the data suggest that gender and age could be important demographic determinants of the process of establishing successful carpools, once an individual has decided to engage in the carpool formation process. The gender finding is perhaps best contextualized by examining the expansive literature on gender and travel behaviour. Within the literature three dominant themes persist, household responsibility, entrapment, and gender-mediated mobility. The household responsibility hypothesis proposes that females tend to commute less than males because they perform a larger share of childcare and domestic responsibilities (*31*). Entrapment theory suggests that females tend to be constrained to a smaller travel area due to household responsibility and the sort of employment available to females (*32*).

The scheduling issue (*27*), and the application of carpooling typically to longer commutes, combined with the manifestation of the household responsibility and entrapment theories in the GTHA's female commuter population, could have potentially negative consequences for female carpooling. This study, however, suggests that females are more likely to form carpools than males, signalling that perhaps these theories do not apply to females from this particular sample. Or, as other research suggests, that entrapment effects are potentially exaggerated. The expansion of demographic variables could provide more insight into the relationship between gender and carpooling found here. Scholars have recently reported some measure of gender convergence in travel behaviour, particularly within subpopulations at each end of the commuting cost-income spectrum (*33*). In addition, other studies suggest that females are more likely to carpool because they face greater mobility constraints (e.g., vehicle access) than males (*11*, *19*).

The age effect is particularly interesting, the literature suggests that older workers are less likely to participate in travel demand management initiatives, even in the presence of economic incentives (*34,35*). Other research suggests that participation in carpooling may increase across the age profile, up to 55 years of age (*36*). Given that the study's population is commuters participating in a carpooling TDM initiative, the expectation is that the majority of users will be under 55 years of age. In fact, 94% of the sample is less than or equal to 54 years of age, and so it is no unexpected to observe the positive effect of age on the odds of starting to carpool. The model suggests that once an individual takes the decision to engage in the carpool formation process, the likelihood of achieving a successful outcome increases with age.

Motivations for engaging in carpooling were apparently overwhelmed by the effects related to gender, age, space, and household auto-mobility. Notably, the model considers the carpooling process after respondents have done some thinking about mode choice, where attitudes may play a larger role. Once they have elected to participate in some way in carpool formation, other factors appear to have a greater influence on the production of a successful outcome. With respect to the role of household cars, Carpool Zone participants from households with relatively high levels of auto ownership appear to have greater success in carpooling. Perhaps individuals with automobiles seek reciprocal arrangements wherein the *a priori* expectation is that carpool participants will share in the driving duties, and in the direct and indirect costs of automobile commuting. On the one hand, the "pooling" of cars that occurs through Carpool Zone could yield marginal returns to the program's environmental goals, on the other hand, some additional thought could be given to the adaptation of the system to better accommodate the mobility needs of individuals from households with relatively low levels of auto ownership.

The examination of the role of spatial accessibility to carpool matches on the production of functional carpools is one of the more unique contributions of this research. While proximity to carpool lots and the urban versus suburban location of the place of residence were not found to be statistically significant predictors, residential accessibility to other Carpool Zone users was found to be positively associated with carpool formation and use. This is an important finding, substantiating the access hypothesis advanced by Kaufman (*19*). This result suggests that shifting or targeting resources toward developing shared spatial knowledge about commuting patterns, within neighbourhoods, could yield beneficial returns to the carpool formation and use process. It will be important to examine, in future work, the sensitivity of this result to the configuration of commuters at the work-end of the commute, or en-route.

The employer based focus of Smart Commute appears to be translating into the organization of carpools at the home-end of the trip. From a policy and programming perspective, the results suggest that there could be some utility in broadening the capacity of Smart Commute to facilitate the regular survey of users at a fine geographical scale, with a view to identifying key hubs of carpool activity within the GTHA commuter-shed. There could also be some advantage to ensuring that social marketing initiatives, established to stimulate demand for web-based carpooling, embrace a business model that acknowledges the full range of possibilities in terms of the geography of commuting (e.g., home, work, route, etc.).

CONCLUSIONS

Ridesharing has been singled out as one of the most difficult forms of mode choice to achieve (*14*). Nevertheless, carpooling initiatives have met with varied levels of success and represent one approach to using the transportation system in a creative way to achieve economic and environmental policy goals. Carpool formation occurs through the reconciliation of a range of temporal, spatial, personal characteristics and constraints, and value laden criteria, across a population of interested participants. ICT-based applications provide a "virtual" forum within which the process of criteria reconciliation can occur, with a view to establishing mobility pools. In view of the evidence, and this initial experience working with Smart Commute, several lessons have been learned regarding the carpool formation process, the ongoing evaluation of system performance, and future research and development requirements.

A number of different factors have been found to associate with successful carpool formation and use, however, it is also meaningful to consider the determinants with little explanatory value. For example, the surprising absence of evidence concerning the use of carpool lots suggests that the maintenance and/or expansion of carpool facilities (e.g., lots or HOV lanes) could be complemented by grass-roots and/or government programs that give rise to the construction of shared knowledge about commuting patterns at either end of the work trip. With respect to future research, some effort will be taken to evaluate differences in transport supply and travel behaviour within municipalities exhibiting lower success. This may indicate that in place of a broad-based regional plan, community-based programs could yield greater returns to the overarching policy goals. Additional modelling work will be undertaken to include destination or work-end covariates, and cost variables in the analysis. This represents an important next stage, as we continue to develop joint research capacity with Metrolinx.

Cyber-mediated carpooling has worked elsewhere with, for example, Calvo et al. (*37*) reporting successful implementation in the European context. While data in this study are somewhat limited, and while Carpool Zone is still in its early days, it is perhaps useful to

consider the influence of place-based differences in societal "norms" and attitudes regarding the sharing of mobility resources; the historic development of cities and regions; and prevailing geographies of travel behaviour on the successful implementation of tools like Carpool Zone. The current matching capacity of the system is primarily a function of the size of the database. To encourage increased patronage, Smart Commute could experiment with the allocation of program resources to the promotion of carpooling, with an emphasis on residentially focused social marketing. In the last three years since the launch of Carpool Zone, there has been continual growth in the user base and formation of carpools, it is the intent of this research that with the latest findings the program can continue to improve and carry out its vision of sustainable transportation use.

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