

Propensity to participate in a peer-to-peer social-network-based carpooling system

Shahram Tahmasseby¹, Lina Kattan^{2*} and Brian Barbour³

¹*Transportation Planning, City of Calgary, Floor 7, H-9, Municipal Building, 800 Macleod Trail S.E., P.O. Box 2100, Station M, #8124, Calgary, Alberta, Canada T2P 2M5*

²*Department of Civil Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, Alberta, T2N 1N4, Canada*

³*Harbour Financial Inc., Unit#1, 3715 16 st. SW, Calgary, Alberta, T2T 4H2, Canada*

SUMMARY

This study examines the potential for a social network peer-to-peer-based carpooling system called FacePorter for the University of Calgary staff and students. In this study, a survey that combined both revealed and stated preferences was designed and distributed randomly among students and staff. The survey consisted of a sample of 210 responses, which were divided into two groups of stated preference respondents: (i) auto drivers, who were given the choice between driving alone and carpooling as drivers; and (ii) transit riders, who were given the choice between public transport and carpooling as passengers. A binomial logit model and two ordinal logit models (one for ride offerors and one for ride seekers) were calibrated to examine the impacts of various examined socio-economic, psychological, and travel characteristic variables on the propensity to participate in the hypothetical carpooling program. The results of the models clearly demonstrated that many factors have significant impacts on FacePorter demand: occupation, income, marital status, working schedule flexibility, trip characteristics (i.e., distance, travel time, and number of required transfers when riding transit), weather condition, carpooling fee, perceived rider and driver profiles, and carpooling fee would significantly influence the market demand of the examined carpooling system. Copyright © 2015 John Wiley & Sons, Ltd.

KEY WORDS: social network-based carpooling; revealed preference; stated preference; ordinal logit model; binomial log regression; choice behavior modeling

1. INTRODUCTION

Traffic congestion, parking availability, and cost are the major daily transportation challenges facing commuters in urban areas. The results of high levels of automobile traffic include inadequate mobility and accessibility, and various associated economic, social, and environmental costs. Carpooling and ridesharing are increasingly considered as efficient transport demand management tools to alleviate this situation [1]. Xu *et al.* [2] found out that the ridesharing/carpooling modal share is positively impacted by traffic congestion levels.

In North America, ridesharing/carpooling has evolved into five generations: (i) World War II ridesharing clubs; (ii) responses to 1970s energy crises; (iii) early organized ridesharing schemes; (iv) reliable ridesharing systems; and (v) technology-enabled ridematching. The last phase is characterized by the incorporation of three recent technological advances: (i) smartphone/tablet applications (apps) to request a ride; (ii) navigational devices for tracking carpool passengers during their trips; and (iii) social networks to establish trust between drivers. Currently, GoLocoTM, Gtrot, PickupPal, Zimride, Carma, Lyft, Carticipate, gocarshare, iCarpool, and Avego are implementing ridesharing programs focused on social networking [3]. This new form of carpooling is referred to as social network-based or

*Correspondence to: Lina Kattan, Department of Civil Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, Alberta, T2N 1N4, Canada. E-mail: lkattan@ucalgary.ca

peer-to-peer (P2P) carpooling. Other new ridesharing/carpooling programs that use GPS and smartphone apps to find a matching ride on the fly or minutes before the time needed, but do not necessarily use social networks, are referred to as real-time, dynamic, or flexible carpooling/ridesharing [4].

The terms carpooling and ridesharing are often used interchangeably. Carpooling is defined by Chan and Shaheen [5] as an organization-based ridesharing program. Carpoolers are usually colleagues or friends that have recurring commute trips, for example, home to work or home to school [6]. Ridesharing includes other modes, such as vanpooling, sharing a taxi, and so on. Unlike carpooling, ridesharing also includes long-haul and non-recurrent trips. In this paper, we will be using the term carpooling instead of ridesharing because we refer mainly to recurrent commuting trips made from home to work/school and vice versa.

Research into the behavioral modeling of social network-based carpooling choice is, however, still lacking. The majority of the carpooling literature focused on examining the effect of congestion pricing and high occupancy lanes (HOV) on carpooling behavior [7–11]. More work needs to be conducted to improve the understanding of the public's attitude toward this growing type of carpooling and the factors contributing to its success. This paper investigates the factors and individuals' preferences influencing the propensity to participate in a hypothetical social network-based carpooling system in the city of Calgary. In its 60-year transportation plan, the City of Calgary envisions the implementation of HOV lanes on most major arteries to help promote the idea of carpooling (www.calgary.ca). As a major trip attraction center in the city, the University of Calgary has designed a transportation demand management program that encourages the increased use of carpools and other modes of transportation. Thus, it is important to examine the factors that would help carpooling to succeed.

In this study, a combination of revealed and stated preference survey questions were used to assess the hypothetical usage of the carpool program and perspectives regarding dynamic carpooling as a mode of transportation. A sample of the University of Calgary's population, including students, support staff, and academic staff, was examined as potential users for this service. This paper presents the results of the study and summarizes findings that may be of broader applicability, especially in providing design elements and policy recommendations that would revitalize traditional carpooling.

2. LITERATURE REVIEW

The carpooling modal share has fluctuated considerably over the last few decades. The New York Times reported that carpooling declined by almost half between the years of 1980 and 2011 (NYT January 2011). However, carpooling in Canada has increased since 2001. Approximately 7% of Canadian workers commuted as a passenger in 2001, increasing to 7.7% in 2006 [12].

In traditional carpooling, participants must schedule a round-trip ride and need to commit in advance to a fixed commute schedule and to travel with particular individuals on an ongoing basis [13,14]. The potential role of information and communication technologies in coordinating and matching ridesharing and carpooling options has been investigated in several studies in the past couple of years [13,15–19]. The research regarding some recent dynamic ridesharing systems indicates that the major deficiency of such systems is related to flexibility in usage; in other words, the systems should have sufficient availability and enable participants to choose their accompanying riders [20].

Generally speaking, if participants do not get a ride within the first three attempts, they may not re-use the system. Dynamic carpooling carries great promise in bringing greater flexibility to eliminate these constraints and revitalizing such systems. Smartphone technology can significantly alleviate logistical problems and make carpooling more convenient by enabling people to easily contact potential riders in their extended social network through mobile phones rather than through a static carpooling matching program.

According to Chan and Shaheen [5], if carpooling is going to be successful, there should be (i) a time-saving incentive for passengers and (ii) a monetary incentive for drivers. In order to provide high availability of service, a dynamic system must be able to provide adequate incentives to users and, in particular, to drivers [21].

A real-time carpooling pilot project was conducted for the Massachusetts Institute of Technology (MIT) community to explore the opportunities and challenges of designing a real-time carpooling trial

for a university campus [22]. The study's findings highlighted the presence of economic, behavioral, institutional, and technological obstacles that need to be dealt with by employers at academic campuses, private carpooling providers, and public sector providers to enhance real-time carpooling market demand. Such challenges include stranger danger, power mismatch, need for mutual dependency, reliability of service, schedule flexibility, consistency of expectations in terms of vehicle type and driver behavior, imperfect information, high transaction costs, vehicle ownership, and subsidies favoring other transport modes. The MIT study results showed that large employers are a unique type of institution that can successfully influence private household travel decisions while simultaneously advancing employer-specific and societal goals.

Dorinson *et al.* [4] explored the decision factors that influence individual behavior toward participating in flexible carpooling compared with existing transportation options available to commuters, such as driving a single occupancy vehicle (SOV) and transit. They found that, depending on the network congestion level, the existence of HOV lanes and the configuration and connectivity of the transit network, flexible carpooling would attract participants from either SOV and/or public transit. They also found that the implementation of flexible carpooling along a given route has the potential to significantly reduce energy consumption, equivalent to express bus services implementation, but at lower cost. Given these societal benefits and cost savings, they concluded that flexible carpooling could be considered as an attractive additional transportation mode.

Selker and Saphir [23] examined the use of a carpooling social group system called TravelRole. The system matches people based on common interests, such as hobbies, religion, news, culture, learning, and comedy, as a way of promoting socialization via carpooling. The system was pilot tested by conducting an interactive survey with students and staff on the Silicon Valley campus of Carnegie Mellon University. The survey respondents included people who worked in the same place, but had dissimilar work schedules. The authors found that the more user information shared (i.e., time and place of the ride and information on interests and preferences), the more likely a matched ride could happen. The study results showed that all the participants who had already experienced traditional carpooling would be ready to opt for the system, if it was online. This was not the case for the remaining population. The study's outcomes also indicated that more than 50% of participants would like meet new people; however, they did perceive carpooling as a stressful activity. The study also showed that 85% of the individuals that liked to meet new people were more likely to carpool than people who were not interested in meeting new people. The authors argue that this finding stems from the fact that carpooling is not always reliable, particularly for important activities such as commuting trips.

Correia and Vagas [24] studied the efficiency of club-based carpooling systems in the Lisbon Metropolitan Area, Portugal. They found that carpooling has not been able to achieve significant results in Lisbon. Their results showed that the inconvenience of traveling with people outside the household may diminish the benefits of carpooling. Nonetheless, the authors indicated that club-based carpooling systems may be attractive to certain social groups due to their similar interests or particular attitudes. For those social groups, the club may represent an interesting platform for meeting other carpoolers. In a similar study that examined the influence of attitudes in determining carpooling propensity, Correia *et al.* [25] highlighted the importance of demographic factors, such as gender and age.

In a recent study, De Francisco *et al.* [26] evaluated the implementation of the Zimride ridesharing/carpooling program at the University of Central Florida campus using structural equation modeling. They found that the main factors influencing the participation in the program were shuttle accessibility, the car as the primary mode of transportation, commuting time to campus, and the time it takes to park. Similar to Correia *et al.* [25], they also found that demographic factors had an impact on attitudes toward carpooling.

Kladeftiras and Antoniou [27] examined whether dynamic carpooling can benefit from the huge spread and acceptance of social media platforms. A stated preference (SP) survey with three parts was distributed in Greece among 122 respondents, although an online survey service. A structural equation model was calibrated to quantify the cost of privacy and efficiency. The results showed that, given the financial situation of Greece, cost played an important role in the willingness to participate in this system. The study outcomes disclosed that frequent car users, women, and youngsters were more willing to participate and pay for carpooling service. Nonetheless, the study showed that drivers were less willing to participate. Privacy was found to be a key factor in social network-based carpooling.

Compared with non-drivers, drivers were less willing to relinquish their privacy in order to find a rider. However, youngsters were found to be more willing to reveal their personal information. The authors concluded that young people are an ideal target market for the implementation of carpooling services in Greece.

3. OVERVIEW OF FACEPORTER, STUDY AREA, SURVEY DESIGN, AND DATA COLLECTION

3.1. Overview of FacePorter

FacePorter is a hypothetical P2P social network-based carpooling program to be initiated at the University of Calgary. FacePorter adds layers on top of social networking sites (e.g., Facebook, Google+, LinkedIn, and MySpace) and integrates people's social network identity accordingly. FaceDrivers also need to register their vehicles' specifications, that is, year, make, color, and license number on their FacePorter page. The system user's profile is rated by a crowd-sourcing rating procedure (i.e., star rating system).

FacePorter has a geographical interface in the form of a publicly available map with graphical linear expressions of rides for quick graphical solution surfing for ride seeking and ride offering. The user will be able to click on these lines and access the FacePorter identity of the offeror/rider. Whenever a part of a trip coincides with the trips of other users, both ride offerors and seekers are able to communicate in order to agree on the pickup and drop off points, meeting times, and carpooling fee.

Transactions are not be classified as a "for hire" relationship with a commercial basis. The transaction procedure is executed at the beginning of the trip and involves for the offeror an incentive such as a gas, iTunes, Air Miles, CO₂ credits, or some other value-based coupons that are electronically delivered to FaceDrivers from the FaceRider's account.

3.2. Overview of the study area

The survey used to collect data for this study was conducted on the University of Calgary campus in 2013. The University of Calgary is the second largest employment concentration node in Calgary, Alberta, Canada, after the central business district. The University of Calgary is located in the northwest quadrant of the city and is well served by public transport. Based on recent data collected by the Office of Sustainability at the University of Calgary in 2012, more than 65% of university commuters ride transit as their primary or secondary commuting mode. Active modes, such as biking and walking, account for approximately 15% of total movements, whereas travel by car is around 20%. These patterns differ among the university's employees and students. The share of commuting by solo car among staff is much higher than among students (34% versus 13%). Students are more likely to use more public transportation than staff (42% versus 26%). According to the University of Calgary Fact Book 2012–2013, the share of carpooling and ridesharing modes in commuting to/from the university is relatively negligible (around 4%).

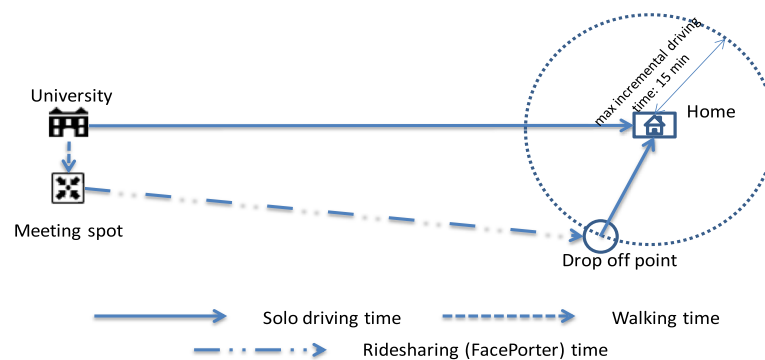
3.3. Survey design

The survey was divided into three sections and included one revealed preference (RP) section and two SP sections. Because social network-based carpooling services did not exist in Calgary, SP choices were used and an orthogonal design was used to create the SP scenarios. The first section of the questionnaire (the RP component) collected information on the personal attributes of the respondents and their commuting trip habits and characteristics. The personal attributes consisted of the socio-demographic characteristics of respondents, such as gender, age, gross income, driving license possession, car ownership, home address, occupation, and employment status. The section on commuting habits presented a series of questions related to the commuter's trip characteristics (i.e., primary and secondary commuting modes, possession of a campus parking pass, possession of a transit pass, the average waiting time for transit, the number of required transfers between transit lines to complete a commute, and the average total travel time including access/egress time). The section also include a few psychological questions based on Cattell's personality factor analysis to indirectly measure

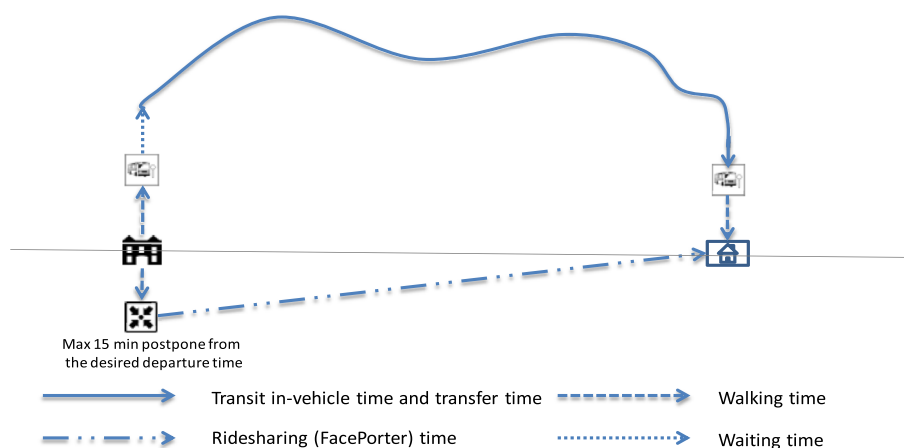
respondents' attitudes and perceptions in terms of risk taking, alteration of behavior, and degree of shyness [28]. In order to include the respondents' latent perceptions of their commute, a series of journey-based components, including the importance of travel time saving, travel safety, driving enjoyment, concerns about the environment, and conducting activities on the way, were embedded into the questionnaire using a 5-point Likert scale.

The second and third sections dealt with the propensity of using FacePorter for commuting from the university to home. The second section consisted of a series of SP choice situations for people who often drive and could offer a ride, while the third part contained SP choice situations for people who did not often drive and used other modes, such as carpooling or transit. Thus, each participant was asked to answer either the second or third section and state the likely travel alternative based on attributes of the presented SP scenario. The survey also included questions on the propensity of carpooling in the evening and offering/accepting a ride from a stranger and/or opposite gender.

For this paper, a hypothetical return trip from the university's main campus to an individual's specific home location in Calgary was tested. Commuters whose primary mode to/from the university was private car were supposed to alternate between driving alone and offering a ride on FacePorter. Once a ride seeker accepted a driver's offer, they mutually agreed on the departure time and location. The driver needed to go to a prearranged meeting spot on the university campus that was monitored by surveillance cameras 24/7 for the sake of security, meet the ride seeker at the proposed departure spot at the specified time, and take the ride seeker to an agreed upon drop off location, usually near the ride seeker's home (Figure 1(a)). Similarly, commuters whose primary mode to/from the university was



(a) Scheme for solo driving vs. FacePorting



(b) Scheme for riding transit vs. FacePorting

Figure 1. Schematic illustration of FacePorting versus traveling solo.

transit were expected to alternate between traveling alone and seeking a ride on FacePorter. Once a ride seeker found an appropriate offer from a driver, a departure time was coordinated, and the ride seeker went to the prearranged meeting spot on the university campus (Figure 1(b)). The drop off point was expected to be within walking distance to the ride seeker's destination. Table I summarizes the SP choices and their attributes.

In the second section, driving respondents could choose to either travel alone or to offer a ride on FacePorter. In the third section, passenger respondents could choose to either travel alone or to commute via FacePorter. The accumulated credits (i.e., contribution fee) from the system, which was typically valued at \$3, \$4, or \$5 for each transaction, could then be used by drivers, for example, at gas stations to fill their gas tank or to save as air miles.

As summarized in Table I, the SP scenarios were differentiated by the following attributes and their levels:

- A FacePorting credit/contribution fees (i.e., equivalent to \$3, \$4, or \$5);
- The incremental driving time given the required detour time to drop off the accompanying rider to a destination or a place nearby his/her destination was categorized into 5, 10, or 15 minutes or the required postpone/prepone departure time to coordinate the ride time with the ride offeror as categorized into 5, 10, or 15 minutes;
- The weather conditions, which were classified as inclement condition with precipitation or mild condition;
- The perceived rider's/driver's profile attractiveness, including factors such as gender, faculty, position, and validity. Profile attractiveness and its authenticity (e.g., crowd-sourcing star rating) were summarized in three perceived categories: desirable, neutral, and unpleasant.

With the list of attributes and the respective levels established, an orthogonal SP design was implemented using SPSS version 20 [29] to create well-organized SP scenarios. A well-ordered orthogonal design ensures that the attributes of a scenario presented to respondents are fully distinct from those of other scenarios. Twenty-nine different orthogonal scenarios were defined and presented to the respondents. Table II illustrates examples of three SP scenarios for ride offerors and seekers.

3.4. Data collection

The total sample size was 211 respondents, collected with an appropriate balance between ride seekers and ride offerors (115 and 95, respectively). Two hundred and one were web-based surveys, and the rest of the questionnaires were conducted face to face. The sampling size was determined to represent the existing university statistics in terms of the numbers and ratios of undergraduate, graduate students, and employees, for example, faculty/student ratio of 1 : 5.3 [30].

Table I. Attributes of stated preference scenarios presented to drivers and ride seekers.

Model type	Attributes	Alternatives
Ride offerors SP model	-FacePorting credit (\$)	- Drive alone five times per week
	-Incremental driving time (minutes)	- Offering a ride on FacePorter once per week
	-Weather condition	- Offering a ride on FacePorter twice per week
	-Rider's profile	- Offering a ride on FacePorter three times per week
Ride seekers SP model		- Offering a ride on FacePorter four times per week
		- Offering a ride on FacePorter five times per week
		- Travel alone five times per week
		- Commute via FacePorter once per week
	-Required postpone/ prepone departure time (minutes)	
	- FacePorter contribution fee (\$)	- Commute via FacePorter twice per week
	- Weather condition	- Commute via FacePorter three times per week
	- Driver's profile	- Commute via FacePorter four times per week
	- FacePorter contribution fee (\$)	- Commute via FacePorter five times per week

SP, stated preference.

Table II. Examples of stated preference scenarios.

	Required postpone/ prepone travel time (minutes)	FacePorting contribution fee (\$)	Weather condition	Offerer's profile	Number of times you likely choose FacePorting per week <<Please choose ONLY one of the following alternatives>>					
Examples of ride offerors SP model	5	3	Inclement condition	Desirable	5	4	3	2	1	Travel alone always
	15	4	Mild condition	Unpleasant	5	4	3	2	1	Travel alone always
	10	5	Inclement condition	Neutral	5	4	3	2	1	Travel alone always
Examples of ride offerors SP model	5	3	Mild condition	Desirable	5	4	3	2	1	Take transit
	15	4	Inclement condition	Unpleasant	5	4	3	2	1	Take transit
	10	5	Mild condition	Neutral	5	4	3	2	1	Take transit

The survey was conducted mainly online via the SurveyMonkey® and was designed to take approximately 10 minutes. An introductory 1-minute video clip illustrating the FacePorter system was embedded in the questionnaire, in order to familiarize the survey respondents with the system's characteristics and the way it works [31]. The survey was advertised on the university's news portal and also through the distribution of more than a thousand flyers in the university's faculties, food courts, and parking lots. As an incentive, participants completing the survey were entered in a draw with a chance of winning an iPod Nano.

4. DESCRIPTIVE STATISTICS

Table III summarizes the descriptive statistics from the survey. It is to be noted that some bias was observed in the survey (e.g., in the context of gender). In order to mitigate the impact of the sampling bias on the model calibration, a weight factor was applied [32].

The results of the SP survey revealed the following findings: some respondents (19%) stated they would never use FacePorter in any condition, and 81% of the respondents stated that they would use the system in ideal scenarios corresponding to the best offers (3 out of 29 scenarios). Furthermore, 23% of the respondents mentioned that they would use the system in all conditions (29 scenarios). However, we should recognize that this outcome strongly depends on the target groups, which are predominantly students. People's actual behavior may be different from their intended behavior during an SP survey.

Approximately, 33% of the respondents of the survey stated that they would rather not offer a ride in the evening (18:00 to 24:00). A higher percentage was found among ride seekers with more than 52% of ride seekers stating that they would not accept a ride in the evening (18:00 to 24:00). Nevertheless, the impact of carpooling in the evening hours on FacePorter demand was marginal, according to the calibration results. Further assessment is needed to confirm the factor's significance at an acceptable level of confidence.

The initial model's results showed that people who perceive their personality as trusting were more willing to participate in the system than those with a more suspicious manner. The psychological impact of trust on the success of ridesharing systems has already been confirmed by Morency [33] and a Dutch study by Wessels *et al.* [19].

5. LOGISTIC REGRESSION CALIBRATION AND RESULTS

The Maximum Likelihood MT 2.0 module of GAUSS™ software was used to estimate the logit models for the obtained SP data [34]. In total, three models — one binary and two ordinal — are presented. The binary logit model was initially applied to estimate the likelihood of using FacePorter at least once per week, and two ordinal logit models, separately calibrated for ride offeror and ride seeker groups, examined the impacts of the attributes of the alternatives on the frequency of using FacePorter

Table III. Frequency distributions for socio-economic factors.

Variable	Description	Frequency
Gender	Female	84 (42.9%)
	Male	112 (57.1%)
Age (years)	18–24	119 (60.7%)
	25–34	39 (19.9%)
	35–44	12 (6.1%)
	45–54	10 (5.1%)
	Older than 55	16 (8.1%)
Marital status	Single, divorced, and widowed	141 (72.3%)
	Married and in a common-law relationship	54 (27.7%)
Income	Prefer not to say	44 (22.6%)
	Less than 19 K	80 (41.0%)
	20–9 K	16 (8.2%)
	30–49 K	11 (5.6%)
	Higher than 49 K	44 (22.6%)
Occupation	Undergraduate student	123 (63.7%)
	Graduate student	27 (14.0%)
	Employee	43 (22.3%)
Trying a carpool program in the past	Never	170 (87.2%)
	A couple of times	22 (11.3%)
	Often	2 (1.0%)
	Always	1 (0.5%)
Primary commuting mode to the university	Car	77 (38.3%)
	Transit	87 (43.2%)
	Active modes (i.e., bike and walk)	37 (18.6%)

per week (i.e., from once per week to five times per week). It should be noted that the logarithm was used for the commuting distance due to its proven model explanatory power given the absolute value of the attribute and to capture the diminishing marginal utility [35]. Furthermore, the correlations between all variables were computed using the full database of SP responses. The results showed that most of the correlation values were not very significant. The highest correlations were observed between income and car ownership and between age and occupation, as expected given the survey design and modeling. The calibrated models are presented in Table IV.

The variables included in the models were classified into three groups:

- Variables with a very high degree of significance, that is, a p -value of asymptotically equal to 0.000. Variables that belong to this group included travel-related attributes, such as distance and commuting travel time, and stated preference attributes, such as incremental driving time, riders/drivers' profile, FacePorter contribution fee, weather condition, and postpone/prepone departure time.
- Variables with a high degree of significance at the 95% level of confidence, that is, $0.0 \leq p\text{-value} < 0.05$. Variables that belong to this group were transfer time in switching between transit service lines and possibility of engaging with activities while commuting.
- Variables with a marginal degree of significance (90% level of confidence), given the survey sample size ($0.05 \leq p\text{-value} \leq 0.1$). This included socio-economic attributes, such as occupation, existing carpooling arrangement, past carpooling experience, the stated preference variable of FacePorter credit goes to drivers, and the psychological factor of the influence of time of day on commuters' mode choice.

The variables that show insignificant or marginal effects on the respondents' behavior were eliminated from the model, thus, the final models contained only significant variables at a confidence level of 90% or higher.

Overall, the models' coefficients showed that occupation, income, marital status, working schedule flexibility, commuting related factors (i.e., distance, travel time, the number of required transfers when riding transit, the value of time, and weather conditions), perceived rider's and driver's profiles, and the FacePorter contribution fee significantly influenced the market demand for P2P real-time car-sharing

Table IV. Explanatory variables in log-regression models.

Variable	Description	Coefficient	p-value
Part (i) Binary Logit Model:			
Propensity in participation in FacePorter as a ride offeror and/or a ride seeker			
Socio-demographic characteristics			
Income (CAD\$)	Less than 10 K: +4; 10–20 K: +3; 21–30 K: +2; 31–40 K: +1; 41–50 K: 0; and 51 K and higher: –1	0.273***	0.017
Occupation	Undergraduate: +1; graduate and employee: 0	0.221*	0.082
Marital status	Single/divorced respondents: 1; Married: 0	0.503***	0.021
Work/study time flexibility	Flexible: 1; Slightly flexible: 0; Not flexible: –1	0.338**	0.018
Environment/sustainability concerns	Extremely concerned: +2; Not concerned: –2	0.691***	0.008
Commute-related characteristics			
Ln (Distance)	Distance between the university and residence	0.553***	0.000
Transfer time between transit lines	No transfer required: 0 0–5 min: +1; 6–10 min: +2; 11–15 min: +3; and 16 min and longer: +5	0.250**	0.051
Is the time of day (i.e., morning, afternoon, and evening) an influential factor in choosing your travel mode?	No impact: –2; Significant impact: +2	0.196*	0.094
Activities on the way (e.g., texting) while commuting	Not active: –1; moderately active: 0; pretty active: +1	–0.426**	0.037
Importance of commuting time saving for the commuter	Lowest importance: –2; Highest importance: +2	0.492***	0.006
Existing carpooling arrangement to/from the university	Already arranged carpooling: 1	–1.074*	0.062
No existing arrangement: 0			
Past carpooling experience	A couple of times or more: 1; Never: 0	0.559*	0.078
Chi square test: $\chi^2 = 91.02$, McFadden Goodness of Fit test: $\rho^2 = 0.26$			
Part (ii) Ordinal Logit Model:			
Impacts of the Attributes on the Frequency in participating in FacePorter as ride offeror			
FacePorter credit	\$3: –1; \$4: 0; and \$5: +1	0.014*	0.081
Incremental driving time	5 min: +1; 10 min: 0; and 15 min: –1	0.294***	0.000
Weather condition	Wintery condition: 0; Mild condition: 1	0.156***	0.000
Perceived rider's profile	Desirable: +1; Neutral: 0; Unpleasant: –1	0.674***	0.000
Chi square test: $\chi^2 = 250.10$, McFadden Goodness of Fit test: $\rho^2 = 0.15$			
Part (iii) Ordinal Logit Model:			
Impacts of the Attributes on the Frequency in participating FacePorter as ride seeker			
FacePorter contributing fee	\$3: +1; \$4: 0; and \$5: –1	0.294***	0.000
Postpone/prepone depart time	5 min: +1; 10 min: 0; 15 min: –1	0.238***	0.000
Weather condition	Wintery condition: +1; Mild condition: 0	0.291***	0.000
Perceived driver's profile	Desirable: +1; Neutral: 0; Unpleasant: –1	0.647***	0.000
Chi square test: $\chi^2 = 350.00$, McFadden Goodness of Fit test: $\rho^2 = 0.14$			

*Marginally significant at 10%. **Significant at 5%. ***Significant at 1%.

systems. Other variables that were excluded from the model due their low significance were gender, function, total transit travel time, driving license possession, prior acquaintance with the ride partner, previous experience in car-pooling program, parking permit, and psychological factors, such as desire to socialize during the trip, shyness, and trust.

5.1. Occupation

The binomial model calibration shows that undergraduate students who are between 18 and 24 years old with a relatively low income level, that is, less than CAD \$20 K per annum, were more willing to use the social network-based carpooling system. This outcome corroborates previous research findings indicating youngsters [19,33], especially those with lower earnings, as a group that would actively participate in carpooling. It is worth mentioning that other studies [36,37] concluded that younger and older people tend to be passengers, while middle-aged people tend to be drivers.

5.2. Marital status

The calibration results also demonstrate a propensity toward P2P carpooling systems among unmarried and divorced commuters (positive coefficient of 0.503). A possible explanation could be that single individuals may be more comfortable riding with a stranger than married people would be. As mentioned earlier, gender was not found to be an influential factor for differentiating between those who are willing to partake in P2P carpooling and those who are not. It is to be noted that most of the previous studies indicated that the majority of ride seekers are women, while men are usually the ride offerors [33,38,39].

5.3. Working schedule flexibility

The flexibility in one's working schedule showed a significant impact on the tendency toward real-time carpooling systems, with a positive coefficient of 0.338. Similar findings in terms of the impact of work schedule flexibility on ridesharing and carpooling demand were reported by McCoomb and Steuart [39] and Glazer and Curry [40].

5.4. Environmentalism and concerns for sustainability

A positive coefficient of 0.691 demonstrates there was a propensity toward carpooling among those who showed more concern for sustainability. The trend has been already stated in previous studies [38].

5.5. Commute characteristics

In the context of commute-related factors, traveled distance was shown to be an influencing factor, according to the study results. The positive coefficient of Ln (distance) indicates that commuters who travel longer distances to the university may be more willing to partake in a carpooling program. This may be explained by the lower frequency and coverage of transit services serving the suburbs or areas outside the inner city. The impact of longer travel distances on ridesharing attractiveness has been already reported by Wessel *et al.* [19]. Similar findings were also reported for transit riders who would need to transfer between transit lines to reach their residence, as indicated by the positive coefficient of the number of required transfers (0.250) in a binomial model. Thus, the number of required transfers between transit lines to complete a commute is a determining factor that may persuade these transit users to participate in real-time P2P carpooling systems. Our survey results indicated that transit in-vehicle time itself had a marginal impact on people's propensity toward carpooling. This trend confirmed previous research findings expressing the impact of transit quality (convenience, wait time, and transfer time) on enhancing ridesharing systems attractiveness [e.g., 33,38].

According to the binomial model calibration results, the commuters whose chose the commuting mode according to their planned departure time may be more eager to join a safe P2P carpooling program. For example, students who normally commute to the university by transit may switch to driving for more convenience and greater safety at dusk when they attend late afternoon or evening classes in fall and winter months. This finding is consistent with Tischer and Dobson [41] and Washbrook *et al.* [11], who enumerated cost savings, congestion alleviation, and particularly safety enhancement as key success factors in decisions to carpool.

The results of this study also showed that participation in activities such as reading a book, texting, or surfing the internet on their smartphone during the commute may be another influential factor relating to FacePorter demand. The negative coefficient of this factor indicates that commuters who use their journey time to participate in such activities may not be interested in a dynamic carpooling program. Some transit riders who can use their commuting time efficiently on the bus/train may not be as comfortable doing these activities while carpooling.

5.6. Importance of travel time when commuting

The value of time was found to be an important factor in the demand for real-time carpooling. This finding was based on the positive coefficient (0.492) of the importance of the commuting time saving factor among ride seekers. This value was more relevant for respondents who commuted from distant locations. It is worth mentioning that, based on their a case study in the Greater Toronto and Hamilton Area in Ontario, Buliung *et al.* [38] reported that carpooling success was susceptible to the formation of travel behavior around normative including the value of time, which indirectly reflects the impact of travel time and thus travel cost on travelers' behavior.

5.7. Existing carpooling/ridesharing arrangements

The results of the study also show that commuters who were currently benefiting from a carpooling/ridesharing arrangement were less interested in FacePorter, with a negative coefficient of -1.074 . Presumably, there was not enough motivation for these riders to switch and adapt to a new system. A similar outcome was also stated by McCoomb and Steuart [39]. However, our study indicates that past carpooling/ridesharing experiences affected university commuters' decisions. Given the positive coefficient of the factor, the commuters who tested a carpooling system in the past may have been keener to try FacePorter. This finding verifies the results of a study conducted at a New Zealand university and local research organizations, where past carpooling/ridesharing experiences had an effect in the formation of carpooling clubs among staff [42]. The psychological importance of past behavior in predicting current or future behavior has been verified in several studies as well [43,44].

5.8. Carpooling contribution fee

The ordinal log-regression model calibration result showed that the FacePorter credit was only marginally significant in influencing drivers' decision to offer a ride. This was expected, as car owners have already taken the responsibility to pay for their mobility. This is also consistent with the findings of Kladeftiras and Antoniou [27]. This result indicates that the FacePorter credit alone is not motivating enough for drivers to partake in the carpooling program compared with other parameters, such as incremental driving time. This finding is very important for carpooling organizers, because it reflects drivers' attitude toward P2P carpooling. However, the study results show the FacePorter contribution fee was an influential factor for ride seekers (given a positive coefficient of 0.294 at the 99% level of confidence): a higher contribution fee would be discouraging for ride seekers, especially for destinations that are easily accessible by public transportation.

5.9. Incremental driving time

Incremental driving time appears to be an important factor for ride offerors, with a positive coefficient of the variable (0.294) in the ordinal model part (II). Longer incremental driving times had a discouraging impact on ride offerors' perception toward FacePorter. According to the study results, the impact of incremental driving time on ride offerors' decisions was even more significant than that of FacePorter contribution fee. It should be noted that, by default, the FacePorter ridematching algorithm did not allow for longer than 15 minutes incremental driving time.

5.10. Departure time coordination

The FacePorter ridematching algorithm limited the prepone/postpone departure time in coordination with ride offerors to 15 minutes by default. In the case of posting a ride offer with a longer delay from the rider's preferred departure time, the ride match transaction is automatically canceled by the system. The postpone/prepone departure time has a similar impact on ride seekers' perception toward

FacePorter given a positive coefficient of the variable (0.238) determined in the ordinal logit model part (III). The results show that ride seekers would be interested in the offers with a minimum delay or preponement from their desired departure time. As expected, for those with a flexible working time, ride coordination would be more straightforward.

5.11. *Weather impacts*

The weather condition on the FacePorter demand had quite a significant two-fold impact. Given the ordinal models' calibration results, adverse weather conditions had a deterrent effect on drivers, but a motivating effect for non-drivers. The findings can be interpreted by assuming that drivers want to avoid an incremental drive during wintery conditions, because it is more hazardous. Conversely, carpooling may be beneficial for transit users in unpleasant weather conditions as transit service is less reliable: commuters may either have to wait outside for longer periods for the bus/train or the travel time may increase due to poor driving conditions. It is worth mentioning that the impact of weather on ridesharing demand was investigated in an old study by Tischer and Dobson [41].

5.12. *Users' profiles on a social network*

According to the ordinal models, a user's profile significantly influences P2P carpooling demand. As mentioned previously, profile attractiveness was classified in three perceived categories: desirable, neutral, and unpleasant. An unpleasant profile may refer to the incompleteness of the person's profile, inappropriate driving style, past negative feedback, and low endorsement rates and points received from others.

For drivers, a rider's profile is a determining parameter. Ride seekers whose social network profile appears unattractive or incomplete have a pretty lower chance to find a proper ride offeror on FacePorter. It is crucial that ride seekers have a trustworthy profile, including a picture and education, job, and contact information on a social network, such as LinkedIn or Facebook. Similarly, the driver's profile plays the most significant role in ride seekers' decision to accept a ride. Ride seekers are more willing to accept a ride from people who have a desirable profile on a social network. Hence, drivers whose profile is neutral or unpleasant on a social network may have a lower probability of finding an accompanying ride seeker. It is important to note that the reliability of a driver's profile is more imperative than that of a rider's profile, due to the increased vulnerability of riders compared with that of drivers.

5.13. *Parking fee*

In the context of parking fees and campus permit, there was no significant trend in willingness to participate in FacePorter between ride offerors who possessed a university parking permit and those without a parking permit. One reason could be the presence of a few parkades on and around the university campus with relatively cheap flat rates, enabling students and employees to park their car for the whole day for between \$3 and \$5.

5.14. *Prior acquaintanceship with the ride partner*

The survey's results show that the prior acquaintanceship with the ride partner was not an influential factor in carpooling programs for commuters at the University of Calgary. Only 14% of the respondents stated that they would not offer a ride to strangers. However, the trend was somehow higher among ride seekers, with 26% of ride seekers stating that they would not accept a ride from strangers. The role of this factor in ridesharing demand has been reported in previous studies [45–47]. It seems that the FacePorter mechanism in leveraging the power of social networks and, consequently, integrating people's social network identity has removed the barrier of prior acquaintanceship with ride partners.

6. CONCLUSIONS AND FINAL REMARKS

This paper presented the results of a survey with a combination of revealed and stated preference questions on the University of Calgary main campus for assessing the propensity of participating in a hypothetical social network-based carpooling system called FacePorter. Two hundred and eleven

participants were surveyed by presenting a series of SP scenarios in which respondents had an opportunity to trade off between two alternatives: carpooling versus solo driving for drivers; and ridesharing versus transit ride for transit riders. The binomial log-regression model was used to weigh the impacts of the examined factors on the propensity of the respondents toward participating in FacePorter. In addition, two ordinal logit models were applied to gauge the effects of cost, time, weather, and the profile of drivers/riders on the frequency of using FacePorter per week. It is important to note that all three models were calibrated based on a data set that was rather limited. The questionnaire and study scope were designed and limited to a university setting; thus, many of the respondents were students, predominantly undergraduate students.

Overall, the results suggest the existence of an unexploited potential for novel carpooling at the University of Calgary. The development of novel social network-based carpooling platforms similar to FacePorter may be crucial for carpooling expansion. The study showed that occupation, concern for the environment, working/school schedule flexibility, perceived rider/driver profile, carpooling fee, productive use of the commute time, and weather would significantly influence the market demand of the examined carpooling system. Accordingly, several policy recommendations can be suggested to encourage such carpooling system and reduce solo driving.

In particular, the study results showed that low-income commuters and students were more willing to partake in P2P carpooling services. The study also underlines the fact that there would be greater propensity toward and popularity of social network real-time carpooling systems among students and employees whose study/job schedule was flexible, because ride coordination between ride offerors and ride seekers would be more feasible and practical. Therefore, we conclude that target groups on academic campuses would lend themselves to the success of a carpooling service.

Environmental and sustainability incentives rather than the contribution fees seem to be an important motivation for drivers participating in such a system. This indicates that employers should put more emphasis in promoting the sustainability benefits of carpooling. Institutions need to consider marketing carpooling through environmental awareness campaigns and sponsorship programs to promote sustainable travel options. This can also be achieved by offering incentive schemes targeted to support behavioral change, such as integration of game elements (participants able to compare themselves and compete with friends or colleagues) and publicly recognized sustainability awards. While the contribution fee was not important from the driver's perspective, the study results show that it was an influential factor for ride seekers. This is an important finding that leads to the conclusion that the system should maintain a reasonable contribution fee for ride seekers, especially for those living in neighborhoods well served by transit.

Because users' profiles significantly affected the carpooling demand, a social network-based carpooling system that is able to provide updated feedback on its users and keep track of their profiles is likely to be more successful. This can be achieved by having peer endorsement or a crowdsourced user review system to share carpooling experiences with given participants.

Weather conditions also had a significant but two-fold impact on the carpooling demand. Wintery conditions had a discouraging effect on drivers for participation in carpooling, but it was motivating for ride seekers. Thus, in order to meet the increasing demand during adverse weather conditions, the system needs to provide additional incentives to ride offerors to fill the shortage of the supply during adverse weather conditions. In this case, only rides with minimal changes in departure time and driving time can be accomplished.

To sustain its market share, a carpooling system also needs to meet the mutual interests of both drivers and passengers. This can be realized by taking into account the preferences of both drivers and riders to either share activities of common interest or conduct separate activities if the later is more preferable. However, both parties should be able to agree on that before starting the trip. This feature is especially relevant for rider seekers who prefer to spend their commuting time productively (reading a book, texting friends, etc.) rather than socializing.

Our findings demonstrated that the impacts of the psychological factors, including the desire for socializing, group dependency, and shyness to disclose information (privacy) and trust, had little significance on the examined carpooling market demand; thus, further analyses need to be conducted in order to verify their impacts.

As a final remark, it should be mentioned that all findings and conclusions stated in this study were based on a limited data set collected in a university setting. Therefore, further investigations at, for example a corporate campus in a vibrant downtown area may further elucidate the impacts of socio-economic, psychological, and the commuting-related factors and attributes on people propensity toward real-time P2P carpooling.

ACKNOWLEDGEMENTS

This study was financially supported by a Mitacs Accelerated grant, the National Research Council's Industrial Research Assistance Program (NRC-IRAP), Harbour Financial Inc., and Alberta Motor Association – Alberta Innovates Technology Futures (AMA-AITF) collaborative grant in Smart Multimodal Transportation Systems

REFERENCES

1. Ferrari E, Manzini R, Pareschi A, Persona A, Regattieri A. The car pooling problem: heuristic algorithms based on savings functions. *Journal of Advanced Transportation* 2003; **37**(3): 243–272.
2. Xu H, Ordóñez F, Dessouky M. A traffic assignment model for a ridesharing transportation market. *Journal of Advanced Transportation* 2014. DOI:10.1002/atr.1300.
3. Tahmasseby S, Kattan L, Barbour B. Dynamic real-time ridesharing: literature review and early findings from market demand study of dynamic transportation trading platform at University of Calgary main campus, Canada. *Proceedings of the 93th Annual Meeting of Transportation Research Board*, Washington, DC, 2014.
4. Dorinson D, Gay D, Minett P, Shaheen S. Flexible carpooling: exploratory study. UC Davis Energy Efficiency Center, 2009.
5. Chan ND, Shaheen SA. Ridesharing in North America: past, present, and future. *Transport Reviews* 2012; **32**: 93–112.
6. Handke V, Jonuschat H. *Flexible Ridesharing: New Opportunities and Service Concepts for Sustainable Mobility*. Springer-Verlag: Berlin Heidelberg, 2013. ISBN:978-3-642-11345-1.
7. Parkany E. Can high-occupancy/toll lanes encourage carpooling? Case study of carpooling behavior on the 91 express lanes. *Transportation Research Record* 2007; **1682**: 46–54.
8. Jou R-C, Weng M-C, Chen C-C. The evaluation of high occupancy vehicle lanes on Sun Yat-Sen freeway in Taiwan. *Journal of Advanced Transportation* 2005; **39**(2): 169–193.
9. Song Z, Yin Y, Lawphongpanich S, Yang H. A Pareto-improving hybrid policy for transportation networks. *Journal of Advanced Transportation* 2014; **48**(3): 272–286.
10. Yang H. When should carpool lanes be introduced in a multi-lane highway? *Journal of Advanced Transportation* 1998; **32**(2): 242–252.
11. Washbrook K, Haider W, Jaccard M. Estimating commuter mode choice: a discrete choice analysis of the impact of road pricing and parking charges. *Transportation* 2006; **33**: 621–639.
12. Statistics Canada, 2008.
13. Deakin E, Frick KT, Shively KM. Markets for dynamic ridesharing? Case of Berkeley, California. *Transportation Research Record: Journal of the Transportation Research Board* 2010; **2187**: 131–137. DOI:10.3141/2187-17.
14. Galizzi M. The economics of carpooling: a survey for Europe, highways: cost and regulation in Europe. Workshop, University of Bergamo, 2004.
15. Brereton M, Ghelawat S. Designing for participation in local social ridesharing networks: grass roots prototyping of IT systems. *Proceeding PDC '10 Proceedings of the 11th Biennial Participatory Design Conference*, 2010; 199–202.
16. Dailey DJ, Loseff D, Meyers D. Seattle smart traveler: dynamic ride matching on the world wide Web. *Transportation Research Part C* 1999; (1): 17–32.
17. Ghelawat S, Radke K, Brerton M. Interaction, privacy and profiling considerations in local mobile social software: a prototype agile ride share system. *Proceedings of OZCHI 2010: Design – Interaction – Participation*, Queensland University of Technology, Brisbane, Queensland, 22–26 November 2010.
18. Heinrich S. Implementing real-time ridesharing in the San Francisco Bay area. *M.Sc. Thesis*, Minnesota Transportation Institute, San Jose State University, 2010.
19. Wessels R, Pueboobpaphan R, Bie J, van Arem B. Integrating social networks in ridesharing systems: effects of detour and level of friend, 2010. www.pool.nl/wp-content/uploads/2010/02/Paper.doc [accessed June 2013].
20. O'Sullivan S. *Case Study in Real-time Ridesharing: SR 520 Carpooling Pilot Project, Seattle*, WAAvego Corporation: Ireland, 2012.
21. Kleiner A, Nebel V, Ziparo M. A mechanism for dynamic ride sharing based on parallel auctions. *22th International Joint Conference on Artificial Intelligence (IJCAI)*, 2011; 266–272.
22. Amey A, Attanucci J, Mishalani R. "Real-Time" ridesharing – the opportunities and challenges of utilizing mobile phone technology to improve rideshare services. *Proceedings of 90th Annual Meeting of the Transportation Research Board (TRB)*, Washington, DC, January 2011.

23. Selker T, Saphir PH. TravelRole: a carpooling / physical social network creator. *Proceedings of 2010 International Symposium on Collaborative Technologies and Systems (CTS)*, Chicago, Illinois, 2010.
24. Correia G, Viegas JM. Carpooling and carpool clubs: clarifying concepts and assessing value enhancement possibilities through a stated preference Web survey in Lisbon, Portugal. *Transportation Research Part A* 2011; **45**: 81–90.
25. Correia G, Silva JA, Viegas JM. Using latent attitudinal variables estimated through a structural equations model for understanding carpooling propensity. *Transportation Planning and Technology* 2013; **36**(6): 499–519.
26. De Francisco J, Harb R, Radwan E. Evaluation of a carpooling program in a university setting using a stated preference survey. *Proceedings of the 93rd TRB Annual Meeting*, Washington, DC, January 2014.
27. Kladeftiras G, Antoniou C. Social networks' impact on carpooling system performance. *Proceedings of 94th Annual Meeting of the Transportation Research Board (TRB)*, Washington, DC, January 2015.
28. GAUSS 13.1. Expanding probabilities. Aptech Systems, Inc. Black Diamond, WA 98010 USA, 2013.
29. IBM. SPSS Version 20. <http://www-01.ibm.com/software/analytics/spss/> [accessed July 2014].
30. University of Calgary *Fact Book* 2012–2013.
31. FacePorter. <http://vimeo.com/67995910> [accessed June 2013].
32. Witt MB. Overview of software that will produce sample weight adjustments, section on survey research methods – JSM, 2009.
33. Morency C. The ambivalence of ridesharing. *Transportation* 2007; **34**(2): 239–253.
34. Cattell HEP, Mead AD. The sixteen personality factor questionnaire (16PF). In *The SAGE Handbook of Personality Theory and Assessment*, Personality Measurement and Testing, vol. 2, (Eds) 2008, Los Angeles, CA, 135–178.
35. Adler T, Ben-Akiva M. A theoretical and empirical model of trip chaining behaviour. *Transportation Research Part B* 1979; **13**: 243–257.
36. Baldassare M, Ryan S, Katz C. Suburban attitudes toward policies aimed at reducing solo driving. *Transportation* 1998; **25**: 99–117.
37. Bonsall P. Car sharing in the United Kingdom. *Journal of Transport Economics Policy* 1981; **15**: 35–44.
38. Buliung RN, Soltys K, Habel C, Lanyon R. The driving factors behind successful carpool formation and use. *Transportation Research Record* 2009; **2118**: 31–38.
39. McCoomb L, Steuart G. The automobile passenger– a forgotten mode. *Transportation Research A* 1981; **15**: 257–263.
40. Glazer L, Curry D. Ridesharing market analysis survey of commuter attitudes and behavior at a major suburban employment center. *Transportation Research Record* 1987; **1130**: 9–13.
41. Tischer M, Dobson R. An empirical analysis of behavioural intentions of single occupant auto drivers to shift to high occupancy vehicles. *Transportation Research A* 1979; **13**(3): 143–158.
42. Ozanne L, Mollenkopf D. Understanding consumer intentions to carpool: a test of alternative models. Research paper from New Zealand, Lincoln University, 1999.
43. Norman P, Conner M. Predicting health-check attendance among prior attenders and nonattenders: the role of prior behavior in the theory of planned behavior. *Journal of Applied Social Psychology* 1996; **26**(11): 1010–1026.
44. Van Ryn M, Lytle L, Kirscht J. A test of the theory of planned behavior for two health-related practices. *Journal of Applied Social Psychology* 1996; **26**(10): 871–883.
45. Duecker K, Bait B, Levin I. Ridesharing: psychological factors. *Transportation Engineering Journal* 1977; **103**: 685–692.
46. Ferguson E, Hodge K, Berskovsky K. Psychological benefits from vanpooling and group composition. *Transportation* 1994; **21**: 47–69.
47. Levin IP, Gray MJ. Evaluation of interpersonal influences in the formation and promotion of carpools. *Transportation Research Record* 1979; **724**: 35–39.