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An Internet-Based Stated Choices Household Survey for Alternative Fuelled Vehicles

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Abstract

The development of alternative fuelled vehicle technology is a key strategy towards environmental sustainability and improved air quality in cities. Analysis of the role of vehicle technology in fulfilling sustainability targets requires estimates of future vehicle demand. The inability to observe actual car-type preferences for cleaner vehicles has led researchers to the development of stated choice methods. This paper reports on the design and descriptive analysis of a stated choices survey on the demand for alternative fuelled vehicles in the Census Metropolitan Area of Hamilton, conducted through the Internet. Respondents were asked to select the vehicle they would most likely buy out of a set of conventional, hybrid and alternative-fuel options over a time horizon of five years. Characteristics such as vehicle purchase price, fuel and maintenance cost, acceleration, alternative fuel incentives, fuel availability and pollution levels were used to describe each vehicle presented. To our knowledge, this is the first study of its kind that focuses at the urban level and the Canadian context and also, it is the first to demonstrate the time- and cost-efficiency of the Internet in designing and collecting Stated Choices data for automobile demand.

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1.0 Introduction

Current planning perspectives and policy frameworks at all levels of government (i.e., local, regional, national) have well-established objectives to promote the adoption of cleaner vehicles namely, alternative fuelled vehicles (AFVs), for private travel. This is because, in addition to relaxing a country's dependence on fossil fuels, AFVs have considerable potential in reducing greenhouse gas emissions, local pollutants and other negative externalities attributed to the transportation system (Deakin, 2001).

In this context, the behavioural response of individuals and households to AFV options plays a key role to their successful introduction in the market. In particular, the purpose of this study is to collect household responses to AFVs demand along with background information on their socio-economic and demographic characteristics. Analysis of the demand for AFVs at the household level will allow for an explicit understanding of the conditions and incentives that may encourage households to adopt AFVs. This analysis is conducted using observations on households' vehicle-type choices and it is based on the development and estimation of discrete choice experiments (Louviere et al., 2000) and models (Ben-Akiva and Lerman, 1985). This approach provides the basis for exploring if policy handles such as incentives and subsidies that would encourage adoption of AFVs, for implementing strategies aiming at reducing petroleum dependency and for building models capable to forecast market penetration of such vehicles. While controlling for demographic and socio-economic characteristics of potential buyers, the outcome of such analysis would benefit policy makers and automotive stakeholders since both are supplied with quantitative tools for evaluation of several incentive and marketing promotions as well as of the desirability of new designs for vehicle and fuel subsystems (Bunch *et al.*, 1993).

In the absence of actual choice observations on new vehicle technologies, known as revealed preferences (RP), researchers resort to innovative methods of data collection using hypothetical options, referred to as *stated choices* (SC) (Louviere et al., 2000; Louviere and Street, 2000). In such methods, data can be obtained from the implementation of choice experiments, in which attributes of hypothetical vehicles and their values are described to households/respondents. Bunch *et al.* (1993) distinguish these attributes as: monetary, non-monetary and environmental. Monetary attributes include purchase price of the vehicle and fuel and maintenance costs. Of high importance are the non-monetary attributes, such as fuel availability, the range between refuelling or recharging, vehicle performance, refuelling time and convenience, and interior space. Reduced emissions of AFVs are considered a major benefit to the environment, because of improvements in air quality, and they are classified as environmental attributes. The pre-designed set(s) of vehicles is then presented to a sample of respondents, who are asked to select their most preferred alternative(s).

Previous efforts to study the demand for alternative fuelled vehicles (AFVs) (Dagsvik et al., 2002; Ewing and Sarigollu, 1998; Adler et al., 2003; Bunch et al., 1993; Tompikins et al., 1998) employed traditional data collection procedures using computer-aided telephone interviews (CATI) and mail-back questionnaires, with the exception of Adler et al. (2003). The latter study offered the Internet as an option, for participating in the stated choices stage, which followed the phone-recruitment stage of the survey. The Internet option achieved a 24.8 percent response rate as opposed to 10.2 percent for the phone interview and 65 percent for the mail back questionnaire. In general, the investigation for potential demand of AFVs has been limited to the

State of California with sporadic studies over the rest of the world. Perhaps part of the reason is the difficulty and expense in acquiring stated choices survey data.

In this paper, we offer an alternative way of data collection that is efficient and economically feasible. In particular, we discuss the design and implementation of a stated choices experiment for AFVs demand that is administered solely through the Internet. The implementation of the Internet is an innovative method of survey data collection (Dillman, 2000) and provides several advantages compared to traditional methods of CATI and mail interviews, with cost and time-savings being the most important. Specifically, as this study demonstrates, an internet survey eliminates those expenses by avoiding the cost and time of telephone interviews and by enabling the researcher to retrieve, code and digitally store the survey data, simultaneously with the data collection procedures (See Response Speed, Kaplowitz et al., 2004; Iraguen and Ortuzar, 2004). The survey we designed is known as **C**hoice **I**nternet **B**ased **E**xperiment for **R**esearch on **CARS** (CIBER-CARS). It is a self-administered online questionnaire, in which potential respondents are recruited via e-mail lists, business intranets and the local news. The Census Metropolitan Area of Hamilton (CMA), Canada, is the geographical area of interest for this study. To our knowledge, this is the first study of its kind that focuses at the urban level and the first in the Canadian context.

In the remainder of this paper, we first provide a detailed description of the survey design. We then discuss the implementation and data collection procedures and highlight measures for assessing the efficiency of Internet surveys. Subsequently we focus on summarizing the characteristics of the collected information, emphasizing the respondents' and households' profiles. To test the representativeness of the sample, the collected dataset is contrasted with data from other sources, such as the Canadian Census 2001 (Canadian Census Analyzer, 2001) and the Transportation Tomorrow Survey (TTS, 2001). We also examine the general efficiency in collecting Internet stated choices data for AFVs by comparing the characteristics of the sample obtained with those of a similar study conducted for the State of California. Finally, the last section summarizes the experience of this data collection effort and highlights future steps of research in this area.

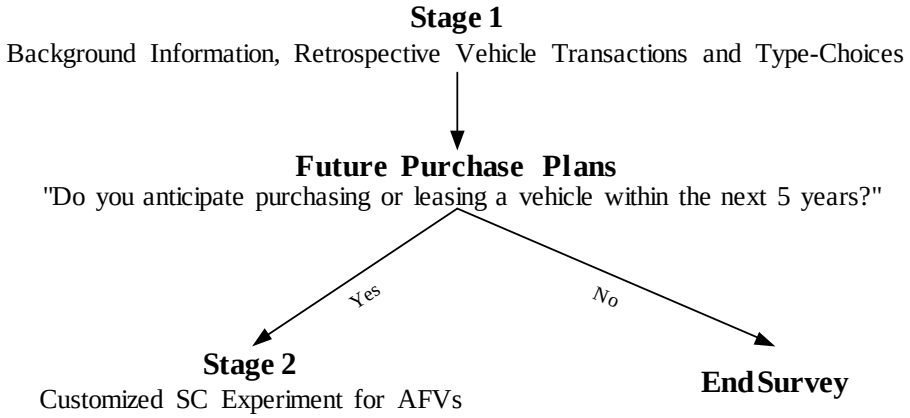
2.0 Design of the CIBER-CARS Survey

2.1 Overview of the Internet Survey

CIBER-CARS[1] was a stand-alone web-survey application developed at the Centre for Spatial Analysis (CSpA), McMaster University, Canada. It is programmed in HTML and PHP languages. Questions and responses are managed and stored on an online MYSQL server. As Figure 1 shows, the survey consisted of two major stages, which are described in the following sections.

[1] The survey is available at http://www.science.mcmaster.ca/~potogld/php/web/index2.php

Figure 1
Structure of the CIBER-CARS survey



2.2 Stage 1: Retrospective Data Collection

The first stage was of a retrospective nature on households' type and vintage of vehicles bought, sold and/or disposed during a maximum time horizon of eight years (1997 - 2005). Also, it collected general household characteristics as listed in Table 1. In general, retrospective questionnaires have the advantage of collecting panel (longitudinal) data, while eliminating the high cost of an actual panel survey (Roorda et al., 2000). The last step of this stage asked respondents about their future plans to purchase a vehicle and its specific characteristics, such as anticipated annual usage rate, the amount of money they would spend to purchase it and the vehicle type (see Figure 1 and Table 1). Respondents who were not planning to purchase a vehicle within the next five years were precluded from the second stage and the survey terminated in Stage 1.

Table 1
Core questions in Stage 1

Item	Attributes
Household	Location (six digit postal code), building type, number of members and vehicles, total household income, date household formed, date moved in the CMA of Hamilton
Person(s)	Gender, age, relationship to the respondent, work and student status, possession of a driver's licence, education level
Vehicle(s)	Make, model and year of production, main user, ownership, fuel type, date vehicle acquired, dates of trade-in(s) and/or disposal(s) of other vehicles
Household History	Members who joint or left the household, relationship to the respondent, age, gender, vehicles added-to or taken from the household
Future Vehicle Purchase Plans	New/used, vehicle type (size and class), money spent if purchased, expected annual usage rate (kilometres/year)

Also, this stage employed a number of skip patterns, based on previous answers, and it offered advanced presentations of questions using "drop-down" menus and "radio" buttons to prevent measurement errors and respondent fatigue. In addition, the survey database was integrated with the Fuel Economy Guide (Fuel Economy Guide (FEG), 1972-2005), which included more that 20,000 make/models of vehicles. This allowed respondents to query - instead of typing - the make, year and model of their vehicle(s), thereby allowing additional car characteristics, such as fuel economy, vehicle type and annual fuel cost, to be integrated with the overall responses of individuals, while minimizing response error.

2.3 Stage 2: Stated Choices Experiment for Alternative Fuelled Vehicles

The objective of this stage was to obtain household preferences for alternative fuelled vehicles and to identify trade-offs and incentives for households to switch to cleaner vehicle technologies. Vehicle options were labelled based on the fuel-type and class/size of the vehicle. The fuel-type label included three options: conventional gasoline, hybrid-electric and alternative-fuel vehicle (i.e., methanol, ethanol or natural gas solely or mixed with gasoline). The class/size label included seven categories: subcompact, compact, mid-size and large car, pick-up truck, van and sport utility vehicle (SUV). The attributes and levels of this experiment were defined based on the existing literature (Adler et al., 2003; Choo and Mokhtarian, 2004; Tompikins et al., 1998; Bunch et al., 1993; Calfee, 1985; Dagsvik et al., 2002; de Jong et al., 2004; Ewing and Sarigollu, 1998) and were adjusted by two pilot and one pre-test surveys. As a general strategy, we included the most important and relevant attributes because of the overall cognitive complexity in the choice task and respondents' fatigue.

As shown in Table 2, each choice exercise included three generic monetary attributes, which were customized per respondent. Previous research has shown that monetary attributes constitute the most important consideration of households willing to purchase a vehicle (Mohammadian and Miller, 2003). In this experiment, we summarized the monetary costs under three attributes: the *purchase price* before taxes and the *annual fuel* and *maintenance costs*. The annual fuel cost was computed as the product between the number of kilometres the vehicle would be driven per year, as specified by the respondent in Stage 1, and the average fuel cost per kilometre, which was class/size specific (in cents/km). Expression of the fuel cost in annual terms was preferred than weekly fuel cost, because the pilot surveys showed that respondents found more difficulty in assessing the weekly kilometres than the annual kilometres travelled.

Also, a set of non-monetary - performance and convenience - attributes consists of *fuel availability*, *incentives* and *acceleration*. Fuel availability was defined as the portion of existing stations offering fuels other than gasoline close to the residential area of the respondent. This attribute was applied only on the alternative fuelled vehicle option. Incentives were offered as advantages or rewards that one gains from buying a hybrid electric or an alternative fuelled vehicle. Incentives involved elimination of vehicle sales tax and parking fees or permission to drive on dedicated lanes for cleaner vehicles. These benefits are some of the most common tools that local or federal governments discuss for encouraging households to switch their choices towards cleaner private transportation options (Transport Canada, 2004). Finally, *pollution level* was introduced to assess if vehicle cleanliness would be perceived as an important factor by potential buyers.

Table 2
Attributes and levels of the discrete choice experiment

Attribute	**(Level) Value**
Purchase Price (CAN $)	(1) -20% than the base
	(2) -10% than the base
	(3) Base (response from Stage 1)
	(4) +10% than the base
Annual Fuel Cost (CAN $)	(1) -80% of the gasoline car
	(2) -60% of the gasoline car
	(3) -40% of the gasoline car
	(4) -20% of the gasoline car
Annual Maintenance Cost (CAN $)	(1) -50% than the base
	(2) -25 % than the base
	(3) Base (response from Stage 1)
	(4) +25% than the base
Fuel Availability (AFVs only)	(1) 75% of existing stations
	(2) 50% of existing stations
	(3) 25% of existing stations
	(4) 10% of existing stations
Acceleration 0 - 100 kph (sec)	(1) 6
	(2) 9
	(3) 12
	(4) 15
Incentives	(1) None
(Hybrid Electric and AFVs only)	(2) Carpool lanes
	(3) No parking or metered fees
	(4) No purchase taxes
Pollution Level	(1) 10% of present day average car
(Hybrid Electric and AFVs only)	(2) 25% of present day average car
	(3) 50% of present day average car
	(4) 75% of present day average car

2.4 Experimental Design

Respondents completed eight choice exercises, each of them involving the choice of one out of three vehicle options based on fuel type (see Figure 2). The conventional gasoline vehicle constitutes the base alternative, which was customized per respondent and its levels took values based on information elicited in Stage 1 of the survey (see Table 1, Future Plans). The other two options, that is, the hybrid electric and the alternative-fuel vehicles were constructed based on the scenarios of an experimental design matrix (Louviere et al., 2000).

For the purposes of our study, the design matrix consisted of 128 scenarios and it was developed using the SAS macros for designing discrete choice experiments (Kuhfeld, 2005). The 128-scenario matrix was the combination of two design matrices of 64 scenarios each. The first was randomly sampled from a 4^{13} orthogonal main-effects design and the second from a 2^{13} "endpoint" main- and interactions- effects for measuring two-way interactions of attributes

within the alternatives. Specifically, the second matrix took into account only the extreme levels of each attribute (i.e., minimum and maximum values), thus allowing for explanation of most of the variance embedded in two-way interactions. While the combined design was not orthogonal, it was well-conditioned and can explain effects with reasonable statistical efficiency (Louviere et al., 2000). Of the eight scenarios assigned per respondent, the first four were taken randomly without replacement from the first 64-scenario matrix (in blocks of 16 respondents) and four were also taken randomly without replacement from the second matrix. Finally, to avoid sequence effect bias (Iraguen and Ortuzar, 2004), the attributes and their values appeared in a randomized order per exercise and respondent.

Figure 2
Example of a stated choice exercise

	VEHICLE A	VEHICLE B	VEHICLE C
Fuel Type	GASOLINE	HYBRID ELECTRIC	ALTERNATIVE FUEL
Vehicle Class	MIDSIZE CAR	LARGE CAR	COMPACT CAR
Acceleration (0 to 100 kph)	9 SEC	6 SEC	6 SEC
Maintenance Cost per Year	$1400	$700	$700
Fuel Cost per Year	$2100	$1680	$420
Pollution Level	85% OF PRESENT DAY AVERAGE CAR	75% OF PRESENT DAY AVERAGE CAR	75% OF PRESENT DAY AVERAGE CAR
Fuel Availability	AVAILABLE AT ALL STATIONS	AVAILABLE AT ALL STATIONS	1 OUT OF 10 STATIONS
Incentive	NOT APPLICABLE	NONE	NO PURCHASE TAXES
Purchase Price	$35000	$38500	$28000
Choose One Vehicle	○	○	○

3.0 Survey Implementation and Evaluation of the Internet-Based Data Collection Method

Several design and programming adjustments to the online questionnaire were undertaken before the survey was administered officially. These adjustments along with revisions in the stated choices experiment were carried out with the help of two pilot-surveys in January 2005. The objective of the first pilot was to verify the clarity and structure of the survey questionnaire, especially in the first stage. Fifteen respondents were selected randomly from the e-mail list of the Faculty of Science at McMaster University were conducted by e-mail and were asked to review the survey and provide written feedback with regard to its overall performance. In addition, we tested procedures of storage, management and quality of the collected data. The second pilot survey was directed to a group of 20 academics both experts and non-experts in the fields of survey methodology, stated choices methods and transportation research. The objective of the second pilot was to test the overall presentation of the survey, giving, however, special consideration to the performance and comprehensiveness of the stated choices exercises (Stage 2). Again, individuals were conducted by e-mail and provided detailed feedback on the survey

questionnaire. Finally, one pre-test survey was conducted in February 2005. The sample frame of the pilot was the School of Geography and Earth Sciences of McMaster University. Staff, faculty and graduate students of the School received an invitation by e-mail asking them to participate in the survey within a period of one week. The pre-test measured the efficiency of the survey in terms of response times and rates as well as comprehensiveness of the questions and the stated choices exercises.

Both the pre-test and pilot surveys were used as a platform for testing the comprehensiveness of the survey tasks, especially those concerned with the stated choices experiments. Unlike the traditional paper and pencil methods, the pre-tests and the pilot showed that there was no need for further information and training of the respondents both for Stage 1 and Stage 2. While in more conventional data collection methods (e.g., paper and pencil) respondents would have received training to participate in a stated choices experiments, in our case, the computerized format of the questionnaire allowed for the development of uncomplicated directions through automatic routing which therefore eliminated the need for training in Stage 1. In addition, the stated choices experiment of Stage 2 included directions in the beginning of the choice exercise and also, it was presented with an interactive format, which allowed the respondents to retrieved information on vehicle attributes and incentives any time during the choice exercises. Participants in the pre-tests as well as the pilot study reported no problems regarding the comprehensiveness of the survey tasks, and therefore limited the need for training the respondents before participating in the survey. The latter presents one of the advantages of Internet surveys, in which respondents' training may be eliminated, if the online questionnaire is planned properly and pilot-tested.

In the actual survey task, recruitment of respondents was conducted using an e-mail address list provided by major employers in the CMA of Hamilton (i.e., McMaster University, the City of Hamilton, and Hamilton Health Sciences). Also, the invitation message was posted on local intranets and published in the news. In addition to this procedure, a snowballing method was followed asking recipients of the e-mail to recommend the survey to other residents in the CMA of Hamilton. Following the first invitation e-mail, four reminder e-mails were sent to initial list of potential respondents to stimulate participation in the survey. It is worth noting that a drawback of this type of recruitment is the inability to estimate a response rate, since the total number of recipients is unknown (Iraguen and Ortuzar, 2004).

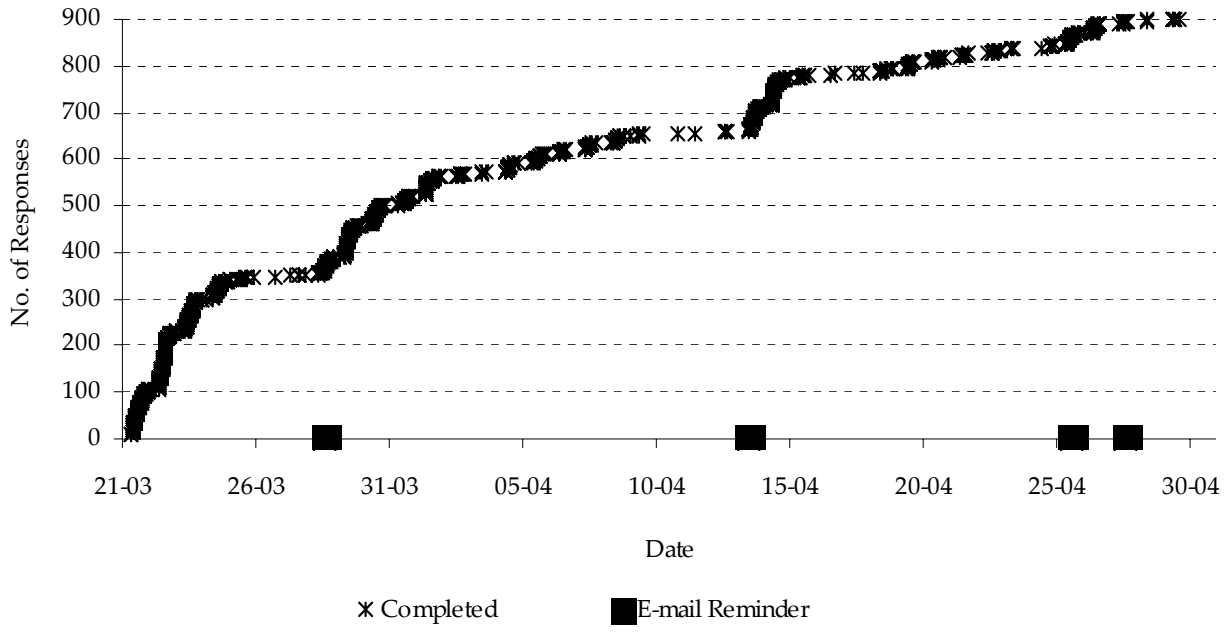
The data collection took place between March 21 and April 30, 2005, a period of six weeks. The total number of completed responses regardless of the stage of completion (i.e., Stage 1 only or both Stages 1 and 2) was 902 with average completion time of 13 minutes per questionnaire, which is a significantly short time for this kind of survey. In an analogous case testing the survey with telephone interview, for Stage 1 alone took at least a 20-minute call for a typical household with four members and two vehicles. In addition, using the conventional approach of mailing an introduction letter, conducting the first stage by telephone interview and the second stage by mail would require at least a time-period of three weeks before the collection of one complete observation. It is evident that the self-explanatory nature of the Internet survey relieves the analyst from undertaking such cost- and time- intensive tasks.

The online database management system offered the capability of recording the response rate activity and thus, evaluating the overall performance of the survey and the efficiency of reminders during the data collection. Figure 3 depicts the number of responses in the CIBER-CARs survey during the period of data collection. The response was rapid during the first three days of each e-mail dispatch, resulting in almost one completed response every five minutes.

Increased activity is indicated in Figure 3 by the steepness of the curve. Later in the first week and while approaching the first 350 responses, the response activity started levelling off. This means that after the 8th day of the survey the number of responses per hour decreased. The time-period between the first and the second reminders was longer (approx. 16 days) and it was used to test the duration of the response activity after the first reminder. Although the response rate activity decreased, it can be seen that the survey had remained active for approximately 10 days. Between the second, third and fourth reminders the response rate increased dramatically in the first few days, although it failed to achieve the response rates observed during the very first days of the survey.

Figure 3

Response activity versus e-mail reminders



Our experience from this survey suggests that online surveys consist an attractive mean of data collection. While the Internet survey requires considerable time to be prepared and tested, the distribution and administration of the survey questionnaire can be performed in minutes, thus reaching hundred or thousands of individuals at the same time (Cobanoglu et al., 2001). An Internet survey can be directed to a wide range of respondents regardless of their geographical location, while enabling the centralization of the research project management (Deutskens et al., 2006). Therefore, an online survey can achieve data collection with reduced field costs and faster response times. In most cases, the overall cost for conducting the survey drops to a fixed amount needed for developing the survey questionnaire and the web-application. In addition, online surveys can be more flexible and reach busy professionals at their place of work. The latter has been a significant problem with mail or telephone surveys in which potential respondents are contacted at home and usually decline to participate (Deutskens et al., 2006). Finally, colours and images can be used inexpensively and can possibly improve both the participation rates as well as the comprehensiveness of the survey (Cobanoglu et al., 2001).

On the other hand, Internet surveys are criticized because of the potential bias and weak representativeness of the retrieved sample. Limited access and penetration to Internet are considered the main source of bias in Internet-survey samples. This issue could be serious in countries where Internet access and penetration are limited to high income and educated individuals (Iraguen and Ortuzar, 2004) (e.g., developing countries). In the Hamilton area, however, internet access[2] and penetration[3] have been of the highest in Canada, ranked 11th in both access and penetration amongst 25 Canadian cities, with approximately 57.8 and 47.3 percent, respectively (Kellerman, 2004). In addition, such concerns can be limited when the analyst seeks responses from specific subgroups of the population. In the case of AFVs, other studies have shown that people with access to the Internet, and higher levels of education, income and environmental sensitivity are more eager to participate and purchase innovative technologies (Ewing and Sarigollu, 2000). To our knowledge, the issue of bias in Internet-survey samples remains an open research question in survey methodology. Potential adjustments of the Internet sample would require additional data collection employing more conventional methods (e.g., phone, mail, etc.).

Finally, an open theme for research remains the linkage between the data quality and collection costs. While this issue has been previously addressed in the literature, it has not been examined for online versus other more conventional methods (e.g., mail) (Cobanoglu et al., 2001; Deutskens et al., 2006). Concerning the issue of data quality, there is no consensus among researchers. From one hand, some studies found no significant differences between online and more conventional means (e.g., mail surveys), one the hands other researchers argue that computer anxiety, respondents' different process of responding might affect the responses of the participants or measurement bias can occur (Dillman, 2000; Deutskens et al., 2006).

4.0 Evaluation of the Obtained Sample

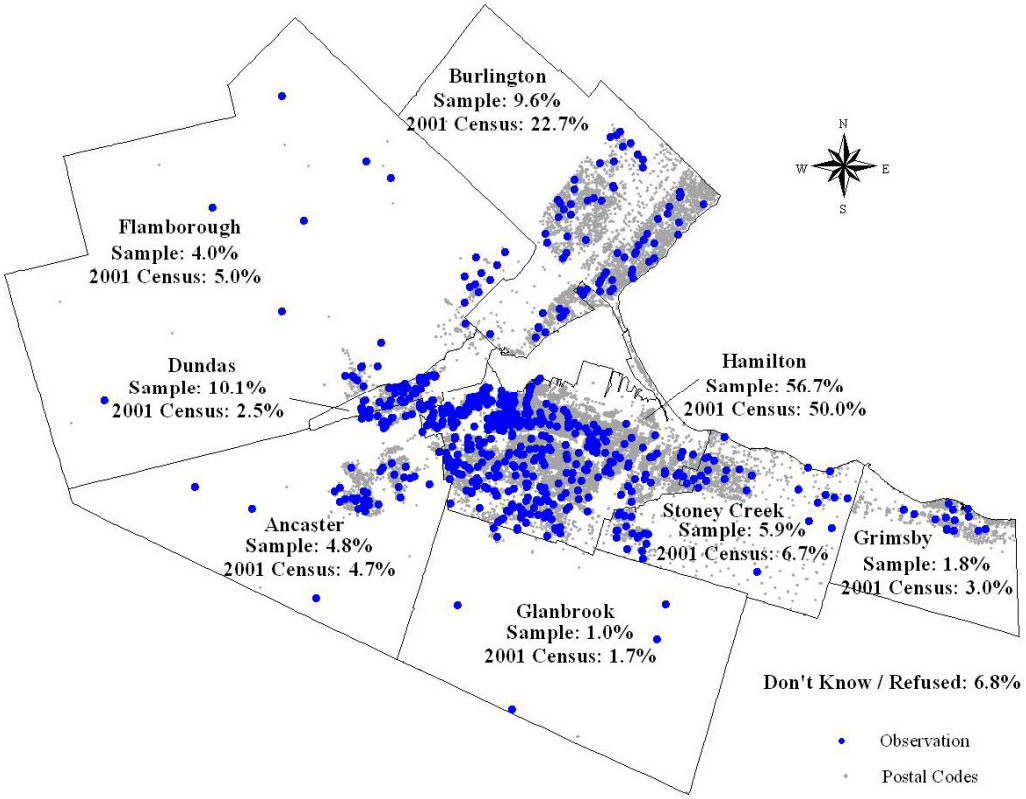
4.1 Geographical Representation

The collected sample can be geocoded based on the six-digit postal codes of the respondents' places of residence. Figure 4 shows the spatial distribution and the percentage representation of the retrieved sample per municipality in the CMA. For comparison purposes, we contrast the layer of all postal codes in the area (grey dots) and the household distribution based on information of the 2001 Canadian Census. In terms of the number of households, it can be seen that the City of Burlington and the town of Grimsby are significantly under-represented in the sample, whereas the municipality of Dundas is well over-represented. The City of Hamilton is the largest in population and is represented well along with the municipalities of Ancaster, Flamborough and Stoney Creek. It is worth noting that the percentage of "Don't Know/Refused" corresponds to individuals who did not provide the postal code of their place of residence.

[2] The percentage of population in a country or city over a certain age reaching the internet at any location (Kellerman, 2004)

[3] Relates to the percentage of households in a country or city connected to the Internet through an Internet Service Provider (Kellerman, 2004)

Figure 4
Spatial distribution of the household sample over the study area



Comparing the distribution of households by municipality between the obtained sample and the population in the area using the 2001 Census data, we make use of the chi-square criterion. The estimated value of $\chi^2 = 308.4$ (*d.f.* = 7) shows that the difference between the two samples is statistically significant at the 0.01 level, the critical value for which is 18.475. This difference is attributed mainly to discrepancies in the municipalities of Dundas, Hamilton and Burlington. Dundas and Hamilton are over-represented in the sample because they are in close proximity to McMaster University - a major source of information in the sample - and therefore is the residence of most its employees. On the other hand, Burlington is significantly under-represented in the sample mainly because of the reluctance of local agencies (e.g., City of Burlington) to act as nodes of information dissemination regarding the survey.

4.2 Individual and Household Profiles

All respondents who successfully participated in the first stage of the survey provided information of 902 households, which included 2487 individuals/members of their households and 1633 vehicles owned or leased along with those previously owned or leased within a maximum time-span of seven years. Since the respondents were recruited mainly at their place of work, it is expected that our sample is representative for households with at least one full-time employed individual with medium-to-high total household income. Table 3 shows the age-structure distribution of all individuals in the households in the collected sample. This is

compared with two other sources of data: the Canadian Census 2001 (Canadian Census Analyzer, 2001) for the CMA of Hamilton and the Transportation Tomorrow Survey 2001 (TTS, 2001).

Table 3

Age structure of the sample versus the TTS and the Canadian Census of 2001

	Females	**Males**	**DK/REF.**	**Total**
0-4 years	2.3	2.1	0.0	4.4
TTS 2001	2.7	2.9	-	5.6
CENSUS 2001	2.8	3.0	-	5.8
5-9 years	2.5	3.0	0.0	5.5
TTS 2001	3.0	3.5	-	6.5
CENSUS 2001	3.2	3.4	-	6.6
10-15 years	4.1	4.0	0.0	8.2
TTS 2001	4.0	4.2	-	8.2
CENSUS 2001	3.3	3.5	-	6.8
16-19 years	2.9	3.8	0.0	6.7
TTS 2001	2.5	2.8	-	5.3
CENSUS 2001	3.2	3.5	-	6.7
20-24 years	5.2	4.8	0.2	10.1
TTS 2001	3.0	3.0	-	6.0
CENSUS 2001	3.1	3.1	-	6.2
25-34 years	9.9	9.5	0.2	19.6
TTS 2001	6.2	5.9	-	12.1
CENSUS 2001	6.7	6.5	-	13.2
35-44 years	8.5	7.0	0.0	15.5
TTS 2001	8.5	7.9	-	16.3
CENSUS 2001	8.4	8.2	-	16.7
45-54 years	8.9	7.7	0.0	16.6
TTS 2001	7.3	7.1	-	14.3
CENSUS 2001	7.3	6.9	-	14.2
55-64 years	3.9	3.8	0.0	7.7
TTS 2001	5.2	4.8	-	10.0
CENSUS 2001	4.9	4.7	-	9.6
65 years and	1.4	1.3	0.0	2.7
over	8.7	7.0	-	15.7
TTS 2001	8.2	6.0	-	14.2
CENSUS 2001				
DK/REFUSE	0.6	0.3	2.2	3.1
Total	**50.0**	**47.3**	**2.7**	**100.0**
TTS 2001	**51.0**	**49.0**	-	**100.0**
CENSUS 2001	**51.2**	**48.7**	-	**100.0**

The TTS is a comprehensive travel survey conducted in the Greater Toronto Area (GTA) and its surrounding regions once every five years. For comparison purposes, we make use of a subset of the 2001 TTS dataset that corresponds to the New City of Hamilton. The differences

between our sample and the TTS 2001 as well as the Census 2001 data are statistically significant with chi-square equal to 506.4 and 442.9, respectively (*d.f.* = 19). Although our sample follows the general trend of male-female representation as well as the representation of individuals aged between 0 and 19 years, differences are mainly attributed to the over-representation of females and males of 24 - 34 years of age, females of 45-54 years of age and also, because of the under-representation of ages 65+ for both females and males.

A similar trend applies to the profile of the respondents, with the majority being female (57.8%), white (84.9%) with a driver's license (95%), educated[4] (83.1%), with medium ($40,000 - $99,999, 29.3%) to high total ($100,000 and over, 19.3%)[5] household income. As mentioned earlier, these trends are associated to the method of recruitment - seeking respondents at their place of work (e.g., McMaster University, the City of Hamilton) and also to the Internet, as a medium of data collection, which is oriented to young-computer-skilled individuals. Regarding general household characteristics, the obtained sample under-represents 1-person households relative to the Census (16.2% vs. 27%), as shown in Table 4. However, it depicts well 2- (34% vs. 31%) and 3-persons (17.8% vs. 16%) households. Also, there is an over-presentation of households with more than 4 members in the sample (31.5 vs. 26%). Comparison between the obtained sample and the TTS 2001 data shows the difference between the two samples is statistically significant (chi-square = 179.9, *d.f.* = 19) attributed to the under-representation of 1 person - 0 vehicles households and the over-representation of 2 persons - 3 vehicles, 4+ persons - 3 vehicles, 2 persons - 4 vehicles and 4+ persons - 4 vehicles households.

In general, the typical household in our sample has 1 to 2 household members and 1 to 2 vehicles, or 4 or more persons and 2 vehicles. This pattern follows the general trend of the 2001 Canadian Census for Hamilton. In terms of vehicle ownership and household size (Table 4), our sample fails to represent households with zero vehicles. However, for the purposes of a car ownership and vehicle-type choice study, such households constitute a small proportion of the total population and they would not be considered in the analysis. It is worth noting that in both the case of TTS 2001 data and our sample, household size and vehicle ownership are two variables with a high degree of association (chi-square = 272.7 and 316.7, respectively, *d.f.* = 12). In terms of home ownership, a significant number of households (72.7%) own their house and 50 percent have lived in the same dwelling for more than 5 years.

[4] Diploma or higher

[5] 41.4% of the respondents refused to provide information on their total household income. Only 10% of the sample belongs to the low income category

Table 4
Distribution of household size versus number of vehicles

	Number of Vehicles					
Household Size	**0**	**1**	**2**	**3**	**4+**	**Total**
1 Person	2.4	13.0	0.8	0.0	0.0	16.2
TTS 2001	9.4	14.0	0.9	0.1	0.1	24.5
CENSUS 2001	-	-	-	-	-	27.0
2 Persons	2.1	13.4	15.1	2.8	1.0	34.4
TTS 2001	3.2	16.2	12.9	0.8	0.3	33.4
CENSUS 2001	-	-	-	-	-	31.0
3 Persons	0.3	5.8	7.5	3.9	0.3	17.8
TTS 2001	1.2	4.8	7.2	2.6	0.4	16.2
CENSUS 2001	-	-	-	-	-	16.0
4+ Persons	0.8	5.0	15.7	7.0	3.0	31.5
TTS 2001	0.9	6.1	13.6	4.0	1.3	25.9
CENSUS 2001	-	-	-	-	-	26.0
Total	5.7	37.1	39.1	13.6	4.3	100.0
TTS 2001	14.7	41.1	34.7	7.5	2.1	100.0
CENSUS 2001	-	-	-	-	-	100.0

4.3 Retrieved Data in the State Choices Experiment

In addition to the collection of general information, Stage 1 questions were used to construct the customized base-alternative (i.e., the gasoline vehicle, see Figure 2) per respondent. Specifically, the last part of Stage 1 asked respondents if they planned to purchase a vehicle in the next 5 years. Out of the 902 respondents who completed the survey, 631 indicated that they would purchase a new (44%) or used (56%) vehicle for an average usage rate of 25,000 kilometres per year. Out of the 631 individuals, 602 completed successfully Stage 2, while 106 either failed to provide adequate information or were uncertain on the specific vehicle characteristics (e.g., anticipated usage km/year, vehicle type, etc.) that would allow customization and complete - in terms of attributes - presentation of the choice experiments. Therefore, the sample of respondents who successfully completed the second stage of the survey was 496. In Stage 2 repeated choices can be treated independently, thus the number of observations obtained in this stage resulted to 3968 observations (496 * 8 exercises per respondent) (Louviere et al., 2000).

Table 5 compares household and respondent characteristics of individuals who successfully completed the stated choices stage of our survey with those of a similar study, which was conducted in the State of California (Adler et al., 2003). The latter was undertaken using mixed modes of data collection including mail, phone and the Internet. In particular, the study of Adler et al. (2003) used the Internet to collect data on younger individuals with a college degree and medium-to-high household-income that the mail and phone failed to recruit. Both our study and that by Adler et al. (2003) follow the general trends of survey data collection, in which females, 25-54 years of age with at least a college degree are more likely to participate. Comparing the percentage shares in two samples (Table 5), it is evident that our sample over-represents younger individuals with at least a college diploma. Regarding the household vehicle

ownership and household income there is no clear basis for comparison, since the study areas and the population under study are different. Further analysis of vehicle choices will allow for comparisons between the Canadian and Californian context. It is evident, however, that by applying an Internet survey method with a relatively low cost and data collection time, one can achieve comparable results with those of a conventional survey in terms of population shares.

Table 5
Representativeness of completed SC sample vs. a California study

		CIBER-CARS Survey	**Adler et al. (2003)**
Total Number of Household Respondents		**496**	**2227**
Gender	Females	55.6	56.7
	Males	43.3	43.3
	DK/ Refused	1.0	-
Age	16-24 years	9.9	6.5
	25-34 years	30.6	17.6
	35-44 years	23.2	24.4
	45-54 years	26.0	22.8
	55-64 years	8.7	14.9
	65 years and over	0.6	12.3
	DK/ Refused	1.0	1.5
Education	High School or Less	14.7	22.0
	Diploma	21.8	33.3
	Bachelors Degree	33.9	25.7
	Graduate School	27.4	18.8
	DK/ Refused	2.2	0.2
Number of Household Vehicles	0	4.8	-
	1	36.3	30.9
	2	38.9	44.0
	3	15.3	17.4
	4 or more	4.6	7.7
Household Income($CAN)[6]	Less than $24,999	6.9	8.5
	$24,999 to $59,999	20.4	30.8
	$60,000 to $84,999	31.3	23.2
	$85,000 or More	28.4	28.7
	DK/ Refused	13.1	3.4

[6] Categories of income in the U.S. study have been adjusted using the corresponding exchange rate (U.S. $1 = CAN $1.20) and Consumer Price Indices (CPI).

4.4 Choices of Alternative Fuelled Vehicles

Comparing choices of individuals based on fuel and vehicle type, it is shown that there is clear preference for compact, medium size and SUV hybrid-electric vehicles (Table 6). Table 7 presents the choices of fuel-type by age, educational level, household size, home-to-work distance and total household- income of individuals in the sample. It is worth mentioning that both Tables 6 and 7 reveal only "average behaviour" and not actual attitudes of households/individuals. In this stage, it is difficult to obtain a clear picture of preferences structure by evaluating summary statistics alone. This is because the choice setting itself is rather complex with alternatives involving several attributes that vary across the SC exercises (Dagsvik et al., 2002). Full analysis of the behaviour of households can only be determined by the estimation of discrete choice models such as the Nested Multinomial and Mixed Logit models. Estimation of such models will provide more insight regarding the vehicle choice process and will reveal the importance of vehicle and household characteristics as well as the monetary trade-offs considered by households.

Table 6
Observed choices of fuel-type options by vehicle-type

	Vehicle Type							
	Compact Car	**Large Car**	**Midsize Car**	**Subcompact Car**	**Pickup Truck**	**SUV**	**Van**	**Total**
Gasoline	3.6	0.9	7.7	0.6	1.8	3.5	3.1	21.2
Hybrid Electric	15.9	3.6	17.3	6.3	2.7	6.2	4.9	56.9
Alternative Fuelled	5.9	1.6	6.5	2.7	1.1	2.3	1.9	22.0
Total	25.4	6.2	31.5	9.5	5.6	12.1	9.9	100.0

5.0 Conclusions

Assessment of the demand for AFVs by potential buyers is critical to the design of policy that would address environmental concerns in relation to the transportation system. This research employs stated choice experiments to overcome the need for actual observations in AFV preferences, since those are unavailable in the current market. The CMA of Hamilton, Canada, is the geographical focus of this research study. Participants were recruited using e-mail lists, posts at local intranets of major employment centres and the local news. Out of the 902 respondents who participated in the survey, 602 stated that they would buy a vehicle in the next five years and 496 provided valid observations for each of the eight SC exercises. The latter included three fuel-type options (gasoline, hybrid electric and alternative fuel) and eight vehicle type/size-classes, which were customized to the respondent.

Table 7

Fuel-type choices by age, education level, household size, home-to-work distance and total household-income of the survey respondents

	Gasoline	Hybrid	Alternative Fuel	Total
Age				
< 24 years	1.2	6.0	2.7	9.9
25-34 years	5.2	18.1	7.4	30.6
35-44 years	5.7	12.7	4.7	23.2
45-54 years	6.0	14.6	5.4	26.0
55-64 years	2.6	4.6	1.5	8.7
65 years and over	0.1	0.6	0.0	0.7
DK/ Refused	0.4	0.3	0.3	1.0
Education Level				
None	0.1	0.1	0.0	0.2
Junior High	0.2	0.0	0.0	0.2
High School	3.7	7.8	2.8	14.3
Diploma	5.5	11.4	4.8	21.8
Bachelors Degree	6.3	20.1	7.5	33.9
Graduate School	4.4	16.7	6.4	27.4
Don't Know / Refused	*1.0*	*0.8*	*0.4*	*2.2*
Household Size				
1	2.5	7.5	2.5	12.5
2	7.0	19.7	7.8	34.5
3	4.0	12.0	4.4	20.4
4 or more	7.7	17.7	7.3	32.7
Home-to-Work Distance				
Work at Home	0.4	0.7	0.1	1.2
Less than 1 km	0.2	1.4	0.5	2.0
1 to 3 km	2.2	5.7	3.3	11.3
4 to 6 km	3.0	9.2	2.9	15.1
7 to 10 km	5.0	12.9	3.9	21.8
11 to 25 km	5.3	13.4	5.0	23.6
More than 25 km	2.9	6.1	3.2	12.3
Don't Know / Refused	2.1	7.4	3.1	12.7
Household Income				
< CAN $ 30,000	0.8	4.4	1.7	6.9
CAN $30,000 - $ 79,999	6.8	20.6	7.9	35.3
CAN $ 80,000 and more	10.7	25.0	9.1	44.8
Income Unknown	3.0	6.8	3.3	13.1
Total	**21.2**	**56.9**	**22.0**	**100.0**

In general, investigations of AFVs demand worldwide have been few and were mainly focused to the State of California. Perhaps part of the reason is the prohibitive cost of these surveys along with complex and time-consuming procedures of data collection. In this paper, we demonstrate the collection of SC data for AFVs demand using solely the Internet. This method is both cost- and time- efficient. The full cost of the Internet survey was fixed at CAN $6,000 and independent of the number of collected responses. On the other hand, an identical survey employing phone interviews in the first and mail-back questionnaires in the second stage aiming at the same number of observations would cost approximately CAN $40,000. With regards to collection times, it is worth mentioning that 902 observations were collected during a period of six weeks, whereas using conventional methods (i.e., phone interview and mail-back) would require approximately nine months of intensive survey of participants.

Comparisons of the obtained sample with the 2001 Canadian Census and the Transportation Tomorrow survey indicate an over-representation of younger, educated and medium-to-high income individuals and an under-representation of the elderly population of the study area. However, and for the purposes of studying vehicle ownership and type choice decisions, the acquired sample would serve as a good basis for representing the active population in the vehicle market. This also applies to the demand for AFVs, where it is expected that people with access to information (e.g., the Internet) are more likely to consider new vehicle technologies. Comparisons with an analogous sample in California reveal the validity of our sample for use in estimating models of AFVs demand as indicated in section 4.3 and Table 5.

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