#### Measuring Motor Vehicle Fuel Consumption in Canada

#### Jennifer Taylor, Statistics Canada R.H. Coats Building, 11<sup>th</sup> Floor, Tunney's Pasture, Ottawa, Ontario, Canada, K1A 0T6

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#### Abstract

The Kyoto Protocol, whose objective it is to reduce greenhouse gas emissions, has generated increased interest in measuring fuel consumption. It is in this context that Statistics Canada conducted a pilot survey to measure the fuel consumption of on-road motor vehicles registered in Canada. This survey was carried out in connection with Statistics Canada's Canadian Vehicle Survey which collects information on road activity such as distance traveled, number of passengers and purpose of the trip. The objectives of a continuing fuel consumption survey would be to inform federal agencies such as Transport Canada and Natural Resources Canada, both co-sponsors of the pilot survey, as well as the general populace of the quantity of fuel consumed by and the fuel efficiency of motor vehicles registered in Canada. The pilot survey conducted is described, interesting results are highlighted, and the methodological challenges presented in the design of such a survey are discussed.

#### 1. Introduction

Many organizations and governmental agencies have long been interested in energy efficiency and fuel consumption. In response to their needs, Statistics Canada conducted the vehicle-based Fuel Consumption Survey (FCS) from 1979 through the 1980's (see Royce, 1983). It was suspended in 1988 when concerns over fuel reserves waned. Funding was provided to conduct the household-based National Personal Vehicle Use Survey (NaPVUS) (see Office of Energy Efficiency, 2000) from 1994 through 1996 in order to provide up-to-date information. Since then, interest in fuel consumption data has not dwindled, but rather has increased in the context of initiatives such as the Kyoto Protocol. Nonetheless, there has not been an adequate source of road fuel use information. Statistics Canada was therefore approached to conduct a fuel consumption survey more or less integrated to the Canadian Vehicle Survey (CVS).

A pilot survey was conducted in 2002-2003 by Statistics Canada on behalf of Transport Canada and

Natural Resources Canada. The purpose of this pilot survey was to determine the proper level of integration with the CVS based on the response rates and the data quality observed.

The CVS is described in Section 2. The pilot survey conducted is described in detail in Section 3 and highlights of the results are found in Section 4. In Section 5, conclusions are drawn, and the methodological challenges in the design of such a survey are discussed in Section 6.

#### 2. The Canadian Vehicle Survey

Statistics Canada currently conducts a survey of vehicle use through the CVS, a vehicle-based survey whose frame is drawn from the provincial and territorial motor vehicle registration files. This quarterly survey collects information such as distance traveled, time of day of road travel, the number and age of passengers and the purpose of the trip. The CVS consists of a computer assisted telephone interview (CATI) followed by a log, or diary, to record trip information for seven days. In general, a sample of 5,000 vehicles is selected each quarter. A response is obtained for approximately 45% of the vehicles, which is not surprising given the duration and the detail of information requested, as well as the voluntary status of the survey. The CVS also provides limited fuel consumption data by reporting the total cost or quantity of each fuel purchase during the seven day period; however this is not sufficient to calculate on-road fuel consumption ratios. A detailed description of the survey can be found in Statistics Canada (2003).

#### 3. The Pilot Survey

In order to explore the possibility of collecting additional fuel consumption information, it was decided to conduct a pilot survey. Two possibilities for an ongoing fuel consumption survey were considered: a survey separate from the CVS (i.e. fuel consumption information collected from a sample separate from that of the CVS) or the collection of the needed information with the CVS. Conducting a separate survey has the advantage of being less burdensome for respondents. Collecting the fuel use information with the CVS also has advantages: 1) the reduction of costs by using only one sample, and 2) the use of data elements already collected by the CVS, many of which are required by Natural Resources Canada for the National Energy Use Database Initiative. However this choice has the disadvantage of increasing the response burden which could lead to lower response rates, thus potentially jeopardizing the results of the current CVS. In order to evaluate these possibilities in terms of response rates, especially given the possible negative impact on the response rates of the CVS, a pilot survey was conducted.

#### **3.1.** Survey Options Tested

There were a total of five options tested in the pilot survey.

#### Testing a separate survey:

This consisted of a separate survey in which respondents were asked to complete a log, or diary, for four weeks or a maximum of five fuel purchases. At the time of each fuel purchase, the odometer reading, type of fuel, quantity or cost of the purchase, and the unit price were recorded. Fuel consumption can be properly estimated when the tank is reported to have been filled twice or with at least some indication of the amount of fuel in the tank after the purchase. Two methods of obtaining this information were tested.

*Option 1* consisted of a fuel log (version 1) in which respondents were requested to note the fuel gauge reading before and after each fuel purchase with selections as in Figure 1.

Fuel gauge after purchase		
Q full Q 7/8 full Q 3/4 full Q 5/8 full Q 1/2 full Q 3/8 full Q 1/4 full Q 1/8 full		

**Figure 1. Fuel Gauge After Fuel Purchase** 

*Option 2* consisted of a fuel log (version 2) in which respondents were asked whether or not they filled up the fuel tank, see Figure 2, rather than reporting the fuel gauge readings. Respondents were asked to provide a fuel gauge reading when the log was received and before returning it.

Fill up indicator		
Was this purchase a fill up? O yes O no		

Figure 2. Fill Up Indicator After Fuel Purchase

## Testing a supplement to the CVS:

*Option 3* consisted of first sending out the current CVS trip log followed several weeks later by the fuel log of Option 1.

*Option 4* consisted of first sending out the fuel log of Option 1 followed several weeks later by the current CVS trip log.

*Option 5* consisted of one master diary combining the CVS trip log and the fuel log of Option 1. Respondents were asked to provide both trip and fuel data for the first week and then to continue filling out the fuel portion of the log for three more weeks or a maximum of five purchases.

## 3.2. Target Population and Survey Frame

The pilot survey was carried out in only two of the ten Canadian provinces. The selected provinces, Ontario and New Brunswick, permitted the collection instruments to be tested in both official languages of Canada, English and French. The target population for the pilot survey was thus all active motor vehicles registered in Ontario and New Brunswick except buses, trailers. motorcycles, off-road vehicles (e.g. snowmobiles), and special equipment (e.g. backhoes). This is similar to that of the CVS except that buses have been excluded due to the poor level of responses obtained from them for the CVS.

The survey population, or the frame, consisted of all active vehicles belonging to the target population that were on the provincial motor vehicle registration files for the two provinces. The information contained in these files permitted the identification and contacting of in-scope vehicle owners based on characteristics and ownership of the vehicles.

## 3.3. Sample Design

All options tested in the pilot survey were carried out according to the CVS sample design. The reference period was the first eight weeks of the fourth quarter of 2002.

The vehicles on the survey frame were stratified by province of registration and by class of vehicle: light vehicles (under 4.5t), vehicles weighing 4.5t to 15t, and vehicles weighing over 15t. The vehicles were further divided into two vehicle-age strata of newer and older vehicles.

The budget allowed for a sample size of 5,000 vehicles for the pilot: 1,000 for each option to be tested. The sample in the province of New Brunswick was sized to ensure that a sufficient number of the interviews and logs would be done in French; 60% of the 5,000 vehicles were allotted to New Brunswick and 40% to Ontario. With the number of heavy vehicles being much less than the number of light vehicles and low response rates expected, a sixth-root allocation method was applied to allocate the sample among the vehicle type – age groups so that there would be a sufficient number of heavy vehicles responding for each option to permit analysis of the results.

The sample was selected in two stages. Within each stratum, vehicles in the sample for the previous three quarters of the CVS were removed to minimize the burden on respondents. At the first stage, the remaining vehicles were sorted by postal code and a systematic sample was selected using a random start. This minimized the response burden of vehicle owners that possessed more than one vehicle, and it ensured that the sample was representative of all the subprovincial regions. The sample of 5,000 vehicles for the pilot survey was added to the number to be selected for the fourth quarter 2002 CVS sample. The units were later split between the fuel pilot survey and the current CVS; in this way, there was no sample overlap between the two surveys. For each option at the second stage, the vehicles selected at the first stage were uniformly assigned a start date from among the first eight weeks of the fourth quarter (Oct. 5 to Nov. 29, 2002).

The CATI phone calls and first mail out began in September 2002.

## 3.4. Data Collection

The pilot survey was carried out according to the CVS data collection procedure with appropriate adjustments to the mailing process for the various options.

The first contact was the CATI where it was verified that the owner on file did own or lease the vehicle. The vehicle type was verified to determine the appropriate log type (log for light vehicles weighing under 4.5t or log for heavy vehicles weighing 4.5t and over) to send. Questions on driving habits and an odometer reading were asked. The pilot survey also included additional questions pertaining to the maintenance of the vehicle and, in the case of personal use vehicles, the household characteristics of the owner of the vehicle.

Contacted owners who agreed to be sent a log were contacted by telephone at the beginning of the reporting period to inquire if they had received the log and had begun filling it out, to answer questions, and to motivate them to complete the log. Those who had not responded to the trip log in Options 3 or 4 after a period of seven weeks were then mailed a postcard to record eight odometer readings, as in the CVS. There were no follow-up questionnaires to collect fuel consumption information.

Owners who could not be contacted by the CATI were mailed a log and sent a reminder letter by mail. Those who did not respond to the trip log after a period of seven weeks were mailed a short form of the log, which is similar to the postcard of odometer readings, but with several questions that would otherwise have been asked during the CATI.

# 4. Results of the Pilot Survey

For the purpose of analysis, the data received and captured on or before April 16, 2003 were used. These data did not go through a formal edit and imputation process. After this date, some logs as well as some postcards and short forms sent as a result of the follow-up procedures were received, but these were not included in the analysis. The CVS data used for comparison were from the first eight weeks of the fourth quarter, 2002, for vehicles registered in the provinces of Ontario and New Brunswick, excluding buses. The data before the edit and imputation step were used. For the analysis, all vehicles weighing 4.5t and over were grouped together as heavy vehicles.

A detailed analysis of the results of the pilot survey is found in Nicoletta and Taylor (2003). A summary of the results follows.

# 4.1. Global response rates

Global response rates, taking into account the response to the CATI and to the log(s), were calculated in order to evaluate the survey instruments and test for significant differences among the options. In order to compare the results, the responses obtained by the follow-up procedures were not included in the calculation of the global response rates as these procedures differed among the options. The global response rates were calculated separately for the fuel consumption portion (Tables 1 and 2) and the trip portion (Tables 3 and 4) of the survey. Options 1 and 2 do not appear in Tables 3 and 4 as they consisted solely of the fuel log. The tables also indicate groups of options for which the rates were not significantly different according to tests of statistical hypotheses: pair-wise Chi-square tests were conducted at a significance level of 5%, for a level of significance greater than 5% for the group of pair-wise tests.

 Table 1. Comparison of the Global Response Rates

 of Light Vehicles to the Fuel Portion

Option	Response Rates	Statistically Similar Groups <sup>1</sup>
3 - Trip then fuel	22.9%	
5 - Trip and fuel	28.6%	•
2 - Fuel ver. 2	30.7%	•
4 - Fuel then trip	32.3%	•
1 - Fuel ver. 1	32.5%	•

 Table 2. Comparison of the Global Response Rates

 of Heavy Vehicles to the Fuel Portion

Option	Response Rates	Statistically Similar Groups <sup>1</sup>	
3 - Trip then fuel	23.9%		•
5 - Trip and fuel	29.5%	•	•
1 - Fuel ver. 1	31.4%	•	
2 - Fuel ver. 2	33.6%	•	
4 - Fuel then trip	35.4%	•	

As seen in Tables 1 and 2, low response rates to the fuel portion were obtained by all the options. An appropriate follow-up procedure would increase these response rates. The lowest response rate for the fuel log was for Option 3 at around 23-24%, when the fuel log was sent after the trip log. We note that, among light and heavy vehicles, all options with the exception of Option 3 had comparable response rates to the fuel portion; no significant differences between them were detected.

 Table 3. Comparison of the Global Response Rates

 of Light Vehicles to the Trip Portion

Option	Response Rates	Statistically Similar Groups <sup>1</sup>
4 - Fuel then trip	23.0%	
5 - Trip and fuel	28.8%	•
3 - Trip then fuel	31.0%	•
CVS	37.8%	

<sup>&</sup>lt;sup>1</sup> Options for which the response rates were not significantly different according to the Chi-square Test are joined by a line in a column under "Statistically Similar Groups".

Table 4. Comparison of the Global Response Rates
of Heavy Vehicles to the Trip Portion

Option	Response	Statistically
	Rates	Similar Groups <sup>1</sup>
4 - Fuel then trip	22.9%	
5 - Trip and fuel	29.5%	•
3 - Trip then fuel	32.6%	•
CVS	35.3%	•

As seen in Tables 3 and 4, low response rates to the trip portion were obtained by the three options testing the fuel log as a supplement to the CVS. As noted previously, an appropriate follow-up procedure would increase these rates. Based on the CVS, another 8% could be added to the trip response rates. The lowest response rate was for Option 4 at 23%, when the trip log was sent after the fuel log. The response rate to this option was significantly lower than the response rates of Options 3 and 5 and of the CVS. Receiving the trip log first in Option 3 and receiving the trip log along with the fuel log in Option 5 did not have significantly different response rates for light vehicles. For heavy vehicles, these options yielded response rates that were not significantly different from the response rate for the CVS.

The added response burden of providing fuel and trip information as well as the possible negative perception of receiving a second log resulted in very low response rates to the second log sent in Options 3 and 4. For this reason, they are not good choices for an on-going survey. Although Option 5 presented the same response burden in terms of information requested and therefore had lower response rates, these were not found to be significantly lower than for the other options.

#### 4.2. Item response rates

For both light and heavy vehicles, item response rates for the two versions of the fuel log, Options 1 and 2, were often not significantly different. When there was a difference, Option 2 tended to have the higher response rate.

In summary, the date, odometer reading and fuel type were well reported for the fuel purchases. The odometer reading, necessary to calculate the fuel consumption ratio, was reported for at least 94% of the purchases. Among light vehicles, the fill up indicator had a response rate of 91.5% among reported purchases which was significantly higher from the response rates for each other option which used the fuel gauge reading, according to multiple Chi-square tests, each with a significance of 5%. This is reasonable as indicating that the tank was filled is easier than

determining and recording the gauge reading. The price and the amount purchased in dollars were less well reported among heavy vehicles than they were among light vehicles.

#### **4.3.** Quality of the Fuel Data

Fuel consumption can be calculated without modeling when the tank is reported to have been filled twice. The greater the number of vehicles reporting two fills, the better the quality of the fuel consumption estimates. It was therefore encouraging to note that 64% to 74% of fuel purchases were reported as fills. Tables 5 and 6 provide details on the percentage of vehicles providing two or more fills.

Table 5. Comparison of the Percentage of LightVehicles that Report 2 or More Fills

Option	Report 2 or More Fills	Statistically Similar Groups <sup>2</sup>	
5 - Trip and fuel	48.5%		•
4 - Fuel then trip	60.3%	●	•
2 - Fuel ver. 2	62.8%	•	
1 - Fuel ver. 1	63.2%	•	
3 - Trip then fuel	68.1%	•	

From Table 5, we note that fuel consumption could be calculated directly for 49% to 68% of the light vehicles reporting fuel. Option 5 had the fewest vehicles with two or more fills whereas all the other options are shown to be similar. This was likely related to the fewer purchases reported by light vehicles in Option 5, perhaps as they mailed back the log as soon as the seven-day trip portion was completed. Adjustments to the log will be considered so as to correct this problem.

Table 6. Comparison of the Percentage of HeavyVehicles that Report 2 or More Fills

Option	Report 2 or More Fills	Statistically Similar Groups <sup>1</sup>	
3 - Trip then fuel	57.1%		•
1 - Fuel ver. 1	71.8%	•	•
5 - Trip and fuel	74.1%	•	•
4 - Fuel then trip	78.4%	•	
2 - Fuel ver. 2	78.6%	•	

From Table 6, we note that fuel consumption could be calculated directly for 57% to 79% of the heavy vehicles reporting fuel purchases. All options except for Option 3, which was the lowest, were found to be

similar to each other according to the Chi-square Test. However Option 3 was not significantly different from Options 1 and 5 for heavy vehicles.

# 4.4. Quality of the Trip Data

It is desired to maintain the quality of the CVS trip data. A decrease in the response rates will affect the quality of the estimates and introduce a greater potential risk of biased estimates. The amount and type of data reported may have been affected by the addition of the fuel consumption log or questions. A basic comparison of the reported trip data of Options 3, 4 and 5 and the current CVS was performed using the Tukey Multiple Comparison Procedure with a significance of 5% to give an idea of the effect of the fuel supplement on the quality of the trip data reported.

There was concern that vehicle owners would report that the vehicle was not in use more often due to respondent fatigue in Options 4 and 5; yet the average number of days not in use was not significantly different from that of the CVS in the case of each of Options 3, 4 and 5. Similarly, a decrease in the number of trips was a concern; however, the average number of trips reported was not significantly different from the CVS, except for Option 5 which reported the greatest number of trips. Furthermore, the average distance traveled did not vary significantly among the options and the CVS.

Although the data reported do not seem to be affected by the addition of the fuel supplement, response rates lower than those for the current CVS will result in estimates of lower quality. Although the sample size can be increased, this will not compensate for the potential nonresponse bias of the estimates.

## 5. Conclusions

The pilot survey provided much insight. Although a straightforward log to complete, the fuel log sent on its own did not achieve high response rates. In order to carry out a separate survey, another large sample in addition to that of the CVS would need to be selected and contacted each quarter. Given the budget of the project and that comparability between trip and fuel information could only be done at population levels, the carrying out of a separate survey was set aside in favor of collecting the information through the CVS.

The response rates obtained for Options 3 and 4, where the trip and fuel logs were sent separately, showed that a very poor response would be obtained for the second log sent. Managing the mailing of the two logs and the follow-up questionnaire given the staggered start dates

<sup>&</sup>lt;sup>2</sup> Options for which the response rates were not significantly different according to the Chi-square Test are joined by a line in a column under "Statistically Similar Groups".

proved to be complicated, and the results would not be as timely due to the longer period of time necessary to respond to both logs. Although both trip and fuel information would be available for the same vehicle, the comparability would be limited since the reporting periods are different. For these reasons, Options 3 and 4 were not recommended.

Although not originally thought to be promising, Option 5 with the combined trip and fuel log had results comparable to the other options. Like all those tested, Option 5 presents us with two important challenges: a low response rate and the problem of calculating fuel consumption in the absence of two fills of the fuel tank. It also has the disadvantage of somewhat delaying the CVS trip estimates because the fuel portion requires a four-week reporting period compared to the seven days required for the trip portion. On the other hand, collecting all the information from one sample would permit significant savings in the costs of contacting vehicle owners. Furthermore, this option offers the greatest comparability of fuel and trip data which are available for the same vehicle during overlapping periods of time.

Option 5 was thus chosen as the means to collect fuel consumption information on a continual basis.

## 6. Future Work

The challenges presented by the option chosen (sending a combined trip and fuel log) must be addressed. The problem of calculating fuel consumption in the absence of two fills was dealt with by imputation from a regression model in the case of the NaPVUS and the FCS. Further study is necessary in order to develop an appropriate model. Research in this area for the NaPVUS was conducted and can be found in Bonin (2002). The pilot survey results indicated that respondents should be encouraged to fill their tanks when purchasing fuel in order to increase the number of vehicles for which we have two fills. In addition, clearer instructions on providing the needed fuel consumption data once the trip portion has been completed may be beneficial.

The low response rates are a concern due to the increased potential for nonresponse bias and the possibility of a decrease in the quality of the key CVS estimate, vehicle-kilometers (the distance traveled by a vehicle). Some solutions to this problem will be implemented for the first run of the CVS with the fuel consumption supplement. An appropriate follow-up procedure will be put in place to obtain basic responses from more of the vehicle owners. Further examination is necessary to determine if it is possible to obtain

useful fuel consumption information in addition to daily odometer readings in the follow-up procedure. As well, the reporting period for trip information will be reduced, and it is hoped that the resulting decrease in the response burden will increase the response rates.

There are also some solutions that we expect to apply in the long-term. The feasibility of a study of nonrespondents was evaluated, and such a study seems promising. A study of nonrespondents would attempt to assess the possible bias due to nonresponse and would shed light on how the survey instrument could be enhanced in order to improve the response rate. As well, a two-phase sample approach is under consideration. At the first phase, vehicle-kilometers would be obtained from a larger sample, thus safeguarding the quality of this key estimate. At the second phase, a smaller sample of vehicles would be asked to provide the detailed trip and fuel consumption information. A two-phase design would give the flexibility of including other supplements in the CVS in the future.

The CVS with the new fuel consumption supplement is scheduled to begin in 2004. In the following months, much work needs to be accomplished in modifying the sample allocation and in developing specifications for an edit and imputation system and an estimation system for the fuel consumption supplement.

# References

- Bonin, S. (2002). Proposed approach for the imputation of data from incomplete fuel purchase diaries of the National Private Vehicle Use Survey.
  Report No. N02-10fa prepared for the Office of Energy Efficiency of Natural Resources Canada.
- Nicoletta, J. and Taylor, J. (2003), *Canadian Vehicle Fuel Pilot Survey Report on Results*, Statistics Canada Paper prepared for Transport Canada and Natural Resources Canada.
- Office of Energy Efficiency, Natural Resources Canada (2000) National Private Vehicle Use Survey – October, 1994 to September, 1996 – Detailed Statistical Report, Working Paper prepared for the National Energy Use Database.
- Royce, D. (1983). "The Passenger Car Fuel Consumption Survey", *Survey Methodology*, 9(2): 202-218.
- Statistics Canada (2003). *Canadian Vehicle Survey*, *Quarter 4*, 2002, Catalogue 53F0004XIE, quarterly. Statistics Canada.