

THE PASSENGER CAR FUEL CONSUMPTION SURVEY

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The oil crisis of the mid-1970's triggered a new awareness among Canadians of the importance of energy conservation. The resulting government programs in the transportation sector demanded basic data about on-the-road fuel consumption by motor vehicles operating in Canadian conditions. This paper describes the Passenger Car Fuel Consumption Survey which was developed jointly by Statistics Canada and Transport Canada to meet this need. The methodology of the survey is described and some examples of the results are presented. The paper concludes with some speculation about future directions for the survey and for vehicle-usage statistics in general.

1. INTRODUCTION

1.1 The Need for Fuel Consumption Data

The world oil crisis of the 1970's triggered significant changes in energy policy in Canada. Although it is a net exporter of energy, Canada did not escape the effects of rapidly rising world oil prices and concerns about supply interruptions. By 1980, imports of foreign oil had reached 425,000 barrels a day, or one quarter of total Canadian oil consumption.

The transportation sector is the largest consumer of petroleum products. Transportation accounts for three out of every five barrels of oil consumed, with nearly four-fifths of this consumed by road motor vehicles. Consequently, energy conservation measures for automobiles have been a top priority. Among the actions which the federal government has taken are:

- (a) the establishment of new car fuel consumption standards, with the goal of reducing automobile fuel consumption by 40 percent by 1990;

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- (b) the publication of The Fuel Consumption Guide and The Car Economy Book, intended to aid consumers in buying, driving and maintaining their cars to save energy;
- (c) the encouragement of lower speed limits, which have now been implemented in all provinces

The evaluation of such programs, and the development of future government policy in the transportation energy field, require basic data about on-the-road fuel consumption by motor vehicles driven in Canadian conditions.

1.2 Development of the Fuel Consumption Survey

In mid-1977, Transport Canada approached Statistics Canada with a proposal to conduct a survey on the use of Canadian motor vehicles. Working closely with officials of Transport Canada, Statistics Canada developed detailed survey objectives and data requirements, identified operational problems that would have to be overcome, and laid out a strategy for the implementation of an ongoing survey by 1979. Because this was the first time such a survey had been attempted, Transport Canada and Statistics Canada agreed to limit it initially to passenger cars operated for personal use.

The three major objectives identified during preliminary discussions were: (a) to monitor both seasonal changes and long-term trends in fuel consumption and vehicle use, (b) to measure improvements in the fuel efficiency of new cars under actual operating conditions, and (c) to characterize the relationship between fuel consumption and vehicle characteristics (e.g., weight, number of cylinders and type of transmission), how the vehicle was maintained (e.g., tune-ups and maintenance of correct tire pressure), and how it was used (e.g., commuting versus long distance travel).

The remainder of the feasibility study was devoted to developing a tentative sample design and data collection methodology. Since no similar survey had been tried before, a period of pilot testing and refinement was required. In the fall of 1978, a series of tests was conducted to evaluate the sampling and

data collection activities. The results of these tests were encouraging, and were used to refine the methodology for a full-scale survey carried out in seven provinces during the July-September 1979 quarter. The methodology was further refined during this quarter, and a regular cycle of data collection, processing and publication began for all ten provinces in the fourth quarter of 1979. Personal use light trucks and vans were added to the survey at the beginning of 1981.

Results are published in quarterly bulletins which contain basic tabulations of vehicles operated, distance travelled, fuel consumed, fuel consumption ratios, and average price per litre. More detailed tabulations and analyses are contained in an annual publication on the survey. Microdata tapes are also available, and special tabulations can be run on request.

2. METHODOLOGY OF THE SURVEY

2.1 Sample Design

The population for the survey is personal use passenger cars operated at any time during the survey reference month. Both privately owned and leased vehicles are included. A vehicle is classified as a "passenger car" on the basis of body style. A vehicle is "personal use" if it is operated for personal reasons at any time during the reference month, even though it may also be used for other reasons. Certain exclusions from the population are made for operational reasons. For example, the survey does not include vehicles from the Yukon or Northwest Territories. As well, new model vehicles are not included until they have been on the market for approximately one year. To avoid the difficulties that arise in locating the owners of very old cars, vehicles more than fifteen years old are excluded.

The sampling frame for the survey is constructed from the ten provincial motor vehicle registration files which are supplied specifically for the survey every three months. This approach is much less expensive than the use of a sample of households would be, and there is considerable vehicle data on the files that is very useful in the sample design. As well, all maintenance of

the files is done by the provincial governments. The potential of the files as a source of statistics on vehicles not directly included in the survey is another point in their favour.

There are also several problems with using the registration files. For example, the information on the file may be several months out of date by the time fieldwork is underway. Although the files contain the most recent name and address of the registered owner, tracking down a specific vehicle still requires special procedures. The fact that most provinces now use a plate-to-owner system rather than plate-to-vehicle further complicates this tracing operation. Another problem is that some provinces do not supply all records. Some records may contain errors which are awaiting corrections, and even though these vehicles may be in use, the records are not available. Provinces also make changes to their systems and procedures fairly frequently. However, the co-operation of the provincial governments in resolving such problems has been excellent, and they have often made changes to accommodate the needs of the survey. Several provinces are now realizing the usefulness of their files for statistical as well as administrative purposes and are actively considering such needs when they redesign their systems.

Once the files have been reduced to a standard format, a computerized exclusion of vehicles not in the target population is made based on data on the files. The sample is drawn in two phases from the remaining vehicles. A relatively large first phase sample of vehicles is selected and the records are printed out. The owner's name is scanned visually and further exclusions (e.g., those with company names) are made. The vehicles that still remain are then subsampled (the second phase) and split into three random portions for use in the next three months of fieldwork. This two-phase design permits a reduction in sampling variance with very little extra work, and is in fact a special case of double sampling for stratification (Cochran, 1977). More importantly, it reduces the proportion of out-of-scope vehicles that must be handled during field operations. To reduce respondent burden, any vehicle which was in the sample within the previous year is dropped.

The sample is selected in the same manner in both phases. Vehicles are stra-

tified by province, model year class, and either vehicle weight or wheelbase. Because separate data are required for each province and model year class (current year, all previous years), a disproportionate allocation is used. Each province is allocated an equal number of vehicles, and within each province about 40 percent of the sample is allocated to current model year vehicles. Within these two major stratification criteria, the allocation to sub-strata is proportional. Within each stratum, the file is sorted by postal code and a systematic sample of vehicles is selected, thus spreading the sample geographically as well.

A considerable amount of extra sample is selected and sent to the field in anticipation of a certain degree of out-of-scope vehicles being encountered, as well as to compensate for non-response. Whenever a non-response or out-of-scope vehicle is encountered, it is replaced by another vehicle from the same stratum. However, several attempts are made to get a response before a vehicle is replaced in order to avoid introducing more non-response bias than necessary.

2.2 Collection

Data collection for the survey is carried out in two steps. The first involves a telephone interview conducted with the registered owner approximately two weeks before the reference month. Because the sampling frame contains only a name and mailing address, it is necessary to trace the telephone number using telephone books, city directories, and other means. In cases where the vehicle has been sold, the new owner is traced if possible. In cases where the owner absolutely cannot be traced, either due to an unlisted number, the vehicle being sold, or the owner not having a telephone, the vehicle is replaced by another in the same stratum. In the case of leased vehicles, leasing companies are contacted by letter with a list of vehicles in the sample and then are followed up by telephone to request the name and telephone number of the lessees. Once the current owner or lessee is contacted, a screening interview containing questions on the type of vehicle, whether the vehicle will be used for personal reasons, and a few others, is administered. If the vehicle is eligible for the survey, the name and address of the principal

driver (if different from the owner) are obtained, and permission to mail out a Fuel Purchase Diary is requested.

The Fuel Purchase Diary, which the principal driver keeps for the one-month reference period, is the second step in the data collection process. The diary itself is large and bright orange to encourage the driver to keep it in a visible location in the vehicle, and a heavy duty vinyl cover is used to prevent it from cracking during the winter. The respondent is also provided with a pen and a table with instructions on how to calculate his fuel economy. For each purchase, the respondent is asked to record the date, odometer reading, amount and type of fuel purchased, price per litre (or gallon), amount paid, and whether the purchase was made in the U.S.A. The respondent is also asked to fill the tank at the first and the last purchase so that the total fuel consumed can be calculated. The diary also contains a few questions asking for basic data on the vehicle, such as the number of cylinders, the type of transmission, and whether it has air-conditioning.

At the end of the reference month, the respondent mails the completed diary pages back to the Regional Office in a postage paid envelope. To improve response, a telephone reminder call is made during the first week of the reference month to answer any questions the respondent might have. After the end of the reference month, non-respondents are followed up several times by telephone to remind them to mail back the diaries or, if the diary was not kept, to determine the reason for non-response.

Table 1 shows an example of the response rates and eligibility rates for the survey, from the first quarter of 1981. During the telephone screening operation, interviews were attempted for 4,968 vehicle owners. Completed interviews were obtained with 3,626 owners for a response rate of 73.0%. The major reason for non-response at this stage was an untraceable telephone number for the registered owner. Of those respondents to the telephone screening, 2,921 were eligible to take part in the survey, a rate of 80.6%. The major reasons for non-eligibility were that the vehicle would not be used, or that it would not be used for personal reasons. Of those eligible, usable diaries were returned for 2,044, a response rate of 70.0% to this part of the study.

TABLE 1. Survey Response Rates and Eligibility Rates (1981 Quarter 1)

| | | |
|--------------------------------|-------|---------|
| Telephone Interview Attempts | 4,968 | |
| Telephone Interviews Completed | 3,626 | (73.0%) |
| Vehicles Eligible for Survey | 2,921 | (80.6%) |
| Usable Diaries Returned | 2,044 | (70.0%) |

2.3 Data Processing

At the present time, all data processing is carried out at Head Office. Prior to data entry, the completed screening questionnaires and diaries are groomed to improve legibility and to catch obvious errors (e.g., diaries with no purchases). In addition, the vehicle's curb weight is coded based on the Vehicle Identification Number, and response codes for both the telephone interview and the diary are added to the screening questionnaire. During data capture, the most important fields are verified on a 100 percent basis. After data entry, the screening questionnaires and diaries are edited separately.

The computer edit of the diaries checks for completeness, validity of codes, internal consistency of data, and reasonableness of derived data such as distance travelled and fuel consumed. The basic strategy in these edits is to use the computer to do mathematical calculations and to identify errors but to make corrections manually. This approach is used because the proper corrective action often cannot be determined without referring to the diary itself. The screening questionnaires are edited in a similar manner, except that the edits are much simpler. The edited diaries and screening questionnaires are then linked together prior to imputation and weighting.

Imputation is used at two points in processing. During the editing of the individual purchase records, if only the amount paid is present, the price is imputed as the average price for that type of fuel in that province in that month. The imputed price is then used to calculate the volume of fuel purchased. This procedure is used in less than one percent of all purchases. Imputation is also used after the screening questionnaire and the diary are linked. If the diary did not contain a pair of fillups sufficiently far apart

to calculate the amount of fuel consumed, but the data are otherwise valid, the amount of fuel consumed is imputed from a regression model. The coefficients are calculated from the complete records for vehicles in the same quarter, with the predictor variables being distance travelled and vehicle weight. This procedure is used in 10 to 12 percent of all cases. The imputed records are identified on microdata and users are cautioned to omit these records when doing regression analysis involving fuel consumption.

Weighting of the data is straightforward. A final weight for each vehicle on the clean, edited file is obtained by multiplying together four factors:

- 1) the inverse of the first-phase probability of selection,
- 2) the inverse of the second-phase probability of selection,
- 3) the inverse of the response rate to the telephone interview, and
- 4) the inverse of the response rate to the diary.

Weights are calculated separately within each stratum. When the number of diaries within a stratum is small, or the response rates to the telephone interview or the diary are low, the stratum is collapsed with a neighbouring stratum before the weights are computed.

Although variance estimation would, ideally, allow for two phases of sampling, this would have required the design and programming of a customized computer system. Instead, it was decided to make the simplifying assumption that the sample had been drawn in one phase rather than two. As well, it was assumed that the sample was drawn by simple random sampling rather than systematically within each stratum. With these assumptions, it was possible to use MINICARP, a system already available in Statistics Canada, to carry out the calculation of sampling error estimates. Some modifications to the MINICARP system were made to allow it to handle large tables, and to improve the system's efficiency by eliminating calculations not needed by the survey.

2.4 Sources of Error

As in any survey, there are numerous sources of error, both sampling and non-

sampling, which affect the data. This section discusses a few of the more important sources of non-sampling errors which are known or suspected to exist.

2.4.1 Coverage Errors

Because the sampling frame used for the survey is constructed from provincial files, the coverage of vehicles is highly dependent on the accuracy of these files. Experience has shown that the files can fluctuate considerably from quarter to quarter, as older vehicles are dropped or new vehicles are registered. Such fluctuations often, but not always, are reflected in the estimates of total vehicles, distance travelled and fuel consumption. Such fluctuations indicate that problems with coverage may exist. Some sources of under-coverage are known, such as those provinces which do not forward records with errors in them, but no method of adjusting for those sources has been developed.

When figures from this survey are compared directly to estimates of vehicle registrations (e.g., Statistics Canada 53-219), the survey estimates appear to be low. However, the concepts involved are quite different. The survey counts include only personal use passenger cars of certain model years which happen to be operated during a specific month, while the registration data refer to the number of vehicle registrations over a twelve-month period. As well, the same vehicle may be registered in more than one province when a person moves. Some attempts have been made to adjust for such differences and compare these two data sources, but the results have been inconclusive. In some provinces, the two sets of data appear very similar, while in other provinces the figures are far apart. Further work would be needed to develop methods for more accurate estimation of the level of coverage error. In the meantime, users are cautioned that estimates of level are subject to such errors.

2.4.2 Telephone Interview Non-response

Non-response to the telephone interview is another potential source of bias. A study conducted in early 1982 did show a mild, but not statistically signi-

ficant, tendency for older cars to have higher non-response rates. Refusals by leasing companies to provide the name of the lessee occur more frequently than refusals by private individuals. A significant cause of non-response to the telephone interview is unlisted numbers, which tend to belong to persons in higher socio-economic classes. Exactly how potential sources of non-response bias affect the data is unknown, however. Ideally one would wish to follow up a sample of non-respondents to study their characteristics further.

2.4.3 Diary Non-response

As in the case of the telephone interview, very little is yet known of non-respondents to the diary. Comparisons of response rates for different sub-groups of the population have occasionally indicated that response does vary between provinces and between urban and rural areas. Again, however, one would have to conduct much more intensive follow up of non-respondents to make more precise statements on the nature of possible biases.

When the non-response rates to the telephone interview and the diary are taken together, it is evident that the overall response rate to the survey (not counting vehicles ineligible for the survey) is of the order of 50%. While this figure is comparable to many other surveys using a diary, it does leave considerable room for doubt about the reliability of the data. The problems with coverage and low response rates are a consequence of the methodology used, but at the same time any other approach would be prohibitively expensive. As often happens, then, the choice of a methodology is subject to considerations of both cost and data quality.

3. SOME RESULTS FROM THE SURVEY

Analysis of results from the survey to date has concentrated on a description of the vehicle fleet in operation, the distances travelled, the fuel consumed, and the fuel consumption ratio (fuel consumed per unit of distance travelled). These variables have been analyzed by vehicle characteristics such as model year, vehicle weight, number of cylinders and type of transmis-

sion, as well as by province and quarter.

One of the most interesting results is that the vehicle population in use is much younger than previously believed (Table 2). This table also shows the trend to greater use of newer vehicles, with average kilometres per vehicle declining with increasing age. Over 45% of vehicles operated and 50% of total kilometres driven are accounted for by the four most recent model years. About 90% of both vehicles operated and kilometres driven are accounted for by the nine most recent model years.

TABLE 2. Vehicles Operated, Kilometres per Vehicle, and Total
Kilometres Driven, by Model Year
(Reference Period October 1980 - September 1981)

| Model Year | Vehicles Operated | Kilometres per Vehicle | Total Kilometres Driven (millions) |
|-------------------|-------------------|------------------------|------------------------------------|
| 1980 | 574,300 | 20,404 | 11,718 |
| 1979 | 825,000 | 18,871 | 15,568 |
| 1978 | 945,900 | 15,735 | 14,884 |
| 1977 | 880,100 | 16,905 | 14,878 |
| 1976 | 891,800 | 17,671 | 15,759 |
| 1975 | 676,300 | 15,414 | 10,425 |
| 1974 | 637,300 | 12,252 | 7,808 |
| 1973 | 473,500 | 12,810 | 6,066 |
| 1972 | 361,700 | 12,569 | 4,547 |
| 1971 and previous | 789,600 | 11,224 | 8,862 |

Turning to seasonal variations, Table 3 shows a peak in vehicle use during the summer quarter. About 33 percent more distance is travelled than in the winter quarter, and about 17 percent more than in the fall quarter. The fuel consumption ratio also changes with the season. On average, vehicles used 17 percent more litres per kilometre during the October to December period compared to the April to June quarter. Much of this difference is undoubtedly due to differences in climate, but the spring and summer months also contain a higher proportion of more fuel-efficient highway travel. The exact contribution of these two factors is unknown.

TABLE 3. Total Kilometres Driven and Fuel Consumption Ratio, by Quarter
(Reference Period, October 1980 to September 1981)

| | Total Kilometres (millions) | Fuel Consumption Ratio | |
|------------------|--------------------------------|------------------------|------|
| | | l/(100 km) | MPG |
| January-March | 23,059 | 17.4 | 16.2 |
| April-June | 30,468 | 15.1 | 18.7 |
| July-September* | 30,716 | 15.5 | 18.2 |
| October-December | 26,273 | 17.7 | 16.0 |

* Estimates for this quarter are based on data for only July and September due to a postal strike which occurred in August 1981. This may account for the Fuel Consumption Ratio being higher in the summer than in the spring.

Table 4 shows the improvements that have taken place in the fuel consumption ratio during the past decade. The ratio rose slightly between 1973 and 1975 with the introduction of stiffer pollution standards in those model years, but since then fuel efficiency has steadily improved.

TABLE 4. Fuel Consumption Ratio, by Model Year
(Reference Period, October 1980 to September 1981)

| Model Year | Fuel Consumption Ratio | |
|-------------------|------------------------|------|
| | l/(100 km) | MPG |
| 1980 | 12.9 | 22.0 |
| 1979 | 14.3 | 19.8 |
| 1978 | 15.2 | 18.6 |
| 1977 | 16.5 | 17.1 |
| 1976 | 17.1 | 16.5 |
| 1975 | 18.7 | 15.1 |
| 1974 | 18.1 | 15.6 |
| 1973 | 18.1 | 15.6 |
| 1972 | 17.5 | 16.1 |
| 1971 and previous | 19.6 | 14.4 |

Of all the factors examined, however, vehicle weight has the greatest impact on fuel consumption. Table 5 illustrates its effect: the heaviest cars consume more than twice as much fuel per kilometre as the lightest cars. In

fact, the recent improvements in fuel efficiency shown in Table 4 have been achieved primarily by reductions in the average vehicle weight.

TABLE 5. Fuel Consumption Ratio, by Vehicle Weight
(Reference Period, October 1980 to September 1981)

| Vehicle Weight | Fuel Consumption Ratio | |
|------------------|------------------------|------|
| | l/(100 km) | MPG |
| Under 1000 kg | 9.7 | 29.2 |
| 1000 to 1271 kg | 13.3 | 21.3 |
| 1272 to 1544 kg | 15.6 | 18.1 |
| 1545 to 1816 kg | 18.1 | 15.6 |
| 1817 kg and over | 20.4 | 13.8 |

Finally, regression analysis was used to look at the effect of vehicle characteristics and distance driven on the fuel consumption rate. Table 6 shows a typical result from the third quarter of 1981. The cumulative R-squared reaffirms the importance of the vehicle weight, but the age of the car and the number of cylinders also enter into the equation. An interesting finding is the negative coefficient for kilometres travelled. One hypothesis is that vehicles travelling longer distances tend to have better fuel efficiency because a higher proportion of their travel is on the highway. The R-squared value for the equation indicates that about 30 percent of the variation in the

TABLE 6. Multiple Regression Analysis of the Fuel Consumption Rate*
(Reference Period, July to September 1981)

| Independent Variable | Regression Coefficient | Standard Error | Cumulative R-squared |
|----------------------|------------------------|----------------|----------------------|
| ln (weight) | 0.646 | 0.038 | 57.2 |
| ln (distance) | -0.132 | 0.008 | 66.4 |
| ln (age) | 0.049 | 0.007 | 67.5 |
| ln (cylinders) | 0.245 | 0.033 | 69.0 |
| Constant Terms | -1.578 | 0.232 | |

* The dependent variable was ln (Fuel Consumption Rate)

the fuel consumption rate remains unexplained.

4. FUTURE DIRECTIONS FOR THE SURVEY

Development of the survey was hindered for several years by its financial arrangements. With Transport Canada providing funding only on a year-to-year basis, personnel and other resources could not be permanently assigned to the project. Early in 1983, however, Transport Canada was able to make a three year commitment to the survey.

One of the first priorities under the new arrangement is to exploit the potential of the registration files as a source of statistics on motor vehicles. Descriptions of the entire motor vehicle fleet will be useful to planners in both governments and private industry. To assist in the analysis of these files, Statistics Canada has purchased the "VINA" system from R.L. Polk and Company. This is a computer system that both verifies the Vehicle Identification Number (or "serial number") and decodes it to give the make, model, weight, engine displacement, and other data. The system will also be useful in conducting the survey. Positive identification of vehicles during the sampling and the automated coding of vehicle data are two potential applications.

A second priority is to expand the coverage of the survey to other categories of vehicles and vehicle use. The major classes not covered by the present survey are commercially-used passenger cars, commercially-used light trucks and vans, and heavy trucks. A study to develop sampling and data collection methods for these vehicles began in the second half of 1983.

Several spin-off studies are also possible. A survey on vehicle maintenance was conducted in August 1983 and will be repeated in February 1984. Another study involves the oversampling of specific makes and models of vehicles. This would allow comparisons between laboratory measurements of fuel efficiency and measurements made under actual conditions of use.

Finally, there is a need for more information on the relationship between fuel

consumption and specific trip characteristics. Very little is known, for example, about how total fuel consumption is split between commuting trips, shopping trips and business/commercial trips. The speed and distance of the trip, the type of roadway used, the weather conditions, and the number of passengers are a few of the other factors affecting fuel use.

Previous surveys, notably the National Driving Survey and the Canadian Travel Survey, have shown the viability of collecting detailed trip data from respondents. Unfortunately, the "fill-refill" method used in the present survey does not permit the measurement of the amount of fuel consumed for an individual trip. In order to do this, a vehicle would have to be equipped with an instrument, similar to an odometer, that accumulates the amount of fuel consumed. Until this happens, surveys of trip making and surveys of fuel consumption will likely continue to develop along separate lines.

The past ten years have seen a rapidly developing awareness of the importance of energy in all sectors of the Canadian economy. Although the world oil situation has changed as a result of the economic times, the need for reliable data on transportation energy use is an established fact. New fuels, new technologies, and new ways in which Canadians view energy use will all make their effects felt. The Fuel Consumption Survey will continue to provide important information for the shaping of future energy policy in Canada.

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