CASE STUDY: CANADA VEHICLE USE STUDY

Patrick Boily[1,2,3]

Abstract

The aim of the Canadian Vehicle Use Study (CVUS) was to measure various vehicle-related quantities (such as vehicle-km traveled, passenger-km traveled, fuel consumption, speed, fuel consumption ratio, etc.) at different national, provincial and rural/urban levels, and to provide estimates of these quantities to the public, analysts and policy makers.

In this chapter, we present some of the highlights of the data collection and estimation procedures used in the early stages of the CVUS (more information can be found in [1]).

Keywords
Data collection, web scraping, automatic data collection, sampling methods, CVUS, case study.

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[1]Department of Mathematics and Statistics, University of Ottawa, Ottawa
[2]Data Action Lab, Ottawa
[3]Idlewyld Analytics and Consulting Services, Wakefield, Canada
Email: pboily@uottawa.ca

Contents

1 Introduction **16**
2 Obtaining the Data **17**
2.1 Survey Frame . . . 17
2.2 Sampling Design and Data Collection . . . 18
2.3 Stratification . . . 18
3 Data Processing **19**
3.1 Importing and Editing Data . . . 20
3.2 Creating Daily Summaries . . . 20
3.3 Rural/Urban Classification . . . 21
3.4 Basic and Derived Characteristics . . . 22
3.5 Observations, Accuracy, Precision, Measurement Error . . . 22
4 Estimation and Data Analysis **24**
4.1 Vehicle Information at the Stratum Level . . . 24
4.2 Combining the Strata . . . 26
4.3 Combining Quarterly Results . . . 27
5 Results for Ontario (Q1, 2012) **27**
6 Conclusion **27**

1. Introduction

The **Canadian Vehicle Survey** (CVS) was sponsored by **Transport Canada** (TC) and **Natural Resources Canada** between 1999 and 2009. The quarterly survey employed a **two-stage sample design**: a sample of vehicles was selected and then a period of travel within the quarter was selected for each vehicle.

Vehicles were grouped into three categories: **light vehicles** (passenger cars and light trucks/vans) and two types of **heavy vehicles**, based on their **gross vehicle weight** (GVW).

A **paper questionnaire** was then mailed out to the owners of the selected vehicles, requesting that they record the **number of trips**, **distance driven**, and **fuel consumption** during the observation period.

The CVS was hampered by low participant response rates over its duration ($\approx 20\%$), caused in large part by the **burdensome paper collection** methods. The quality of the estimates was also weakened by **significant errors** in the way in which the on-road vehicle fleet was classified due to mistakes in the **Vehicle Identification Number** (VIN) decoding code.

As a result, TC decided to conduct a pilot **Canadian Vehicle Use Study** (CVUS) to validate (or invalidate) the CVS methodology and results. Improvements included

- the use of **electronic data loggers** to reduce reporting burden;
- the introduction of a more **robust** VIN decoder to increase the accuracy of the in-scope fleet, and
- a **modified sampling design** that incorporated additional strata to enhance the ability to carry out more detailed analyses of motor vehicle use.

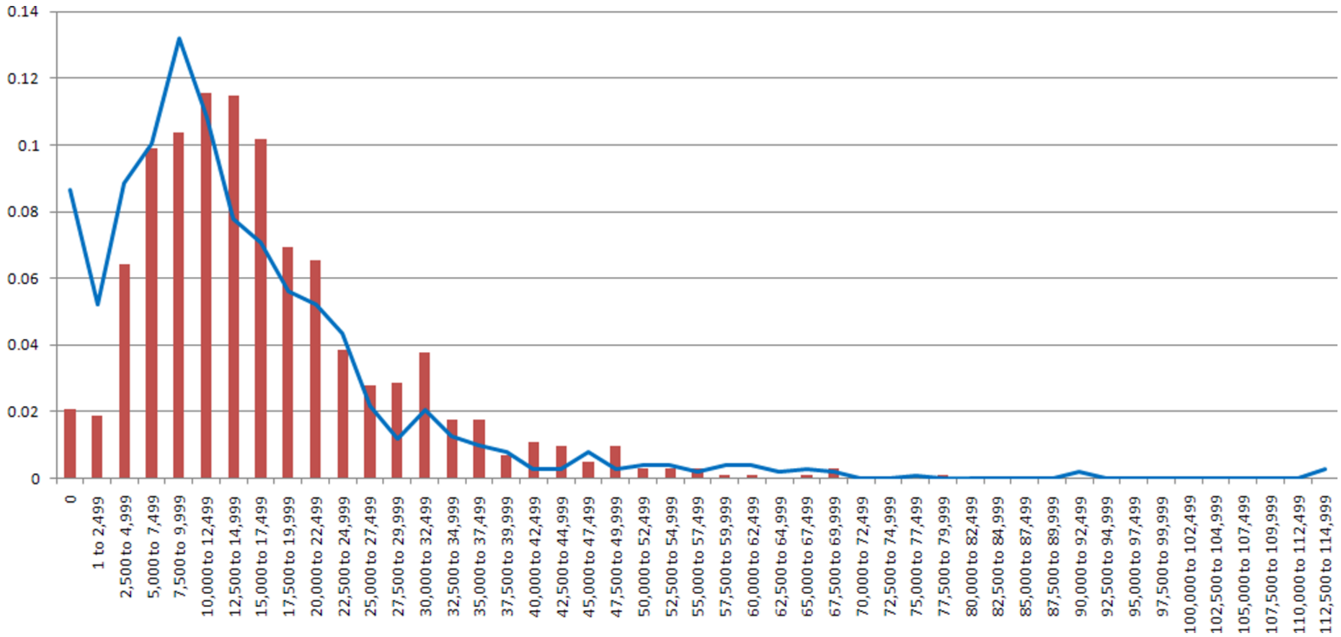


Figure 1. Empirical density charts of estimated yearly distance travelled; CVS in blue, pilot project in red.

The pilot study was carried out in the 4th quarter of 2010 on $n = 1011$ light vehicles, selected via **simple random sampling** (SRS) from a list of vehicles registered with the **Ministry of Transportation of Ontario** (MTO) having an address whose **Forward Sortation Area** (FSA) code was associated with Ottawa and surrounding Ontario areas.

In order to evaluate the performance of the pilot CVUS, **vehicle-km traveled** (VKT) tallies were compared against corresponding CVS observations for the 4th quarter of 2009 ($n = 1016$).

The pilot CVUS was found to have a smaller number of observations at low VKT values than the CVS, whereas that trend was reversed at medium VKT values (see Figure 1).

The empirical means also seemed substantially different, at $\overline{x}_{\text{CVUS}} = 16,716$ km/year vs. $\overline{x}_{\text{CVS}} = 14,237$ km/year, although the high standard deviations $s_{\text{CVUS}} = 11,616$ km/year vs. $s_{\text{CVS}} = 13,844$ km/year made for inconclusive point comparisons.

Perhaps more importantly, the proportion of non-active vehicle in the fleet was much higher for 2009 in the CVS (8.7%) than it was for 2010 in the pilot CVUS (2.1%), and the distribution ranges are quite dissimilar: down to 79,500 km/year in 2010 from 112,500 km/year in 2009.

In any event, a **Kolmogorov-Smirnov test** rejected the null hypothesis that the two samples were drawn from the same distribution at the 99.9% significance level.

The CVS project management team steadfastly refused to update their survey in the face of this evidence, which gave TC the impetus to go ahead with a full-fledge CVUS survey.

2. Obtaining the Data

The logger device records vehicle activity at one-second intervals (e.g. distance, time, speed, fuel, etc.) directly from the vehicle's engine, while the touchscreen captures the remaining trip questions:

> Driver Age/Sex, # Passengers, Trip Purpose, Fuel Information (see Figure 2).

2.1 Survey Frame

The **survey frame** consisted of motor vehicle registration files provided by each jurisdiction, before the beginning of a quarter in order to minimize changes of address and maximize the accuracy of the fleet information.

All the cars and trucks with GVW below 4.5 metric tons were used to define the CVUS survey frame, which excluded some **out-of-scope** (OOS) vehicles:

> motorcycles, trailers, cranes, buses, ambulances, fire trucks, farm equipment, motorhomes, police cars, etc.

OOS vehicles were identified via the **Polk VIN Decoder** (the company has since been acquired by **IHS Markit**) and other information in the registration file (vehicle type, model year and gross vehicle weight rating).

The VIN consists of a 17 character alpha-numeric code for all vehicles whose model year is 1981 or newer (pre-1981 vehicles use a different standard). The first eleven characters define the make, model and other characteristics of the vehicle while the last six digits uniquely identify each vehicle.

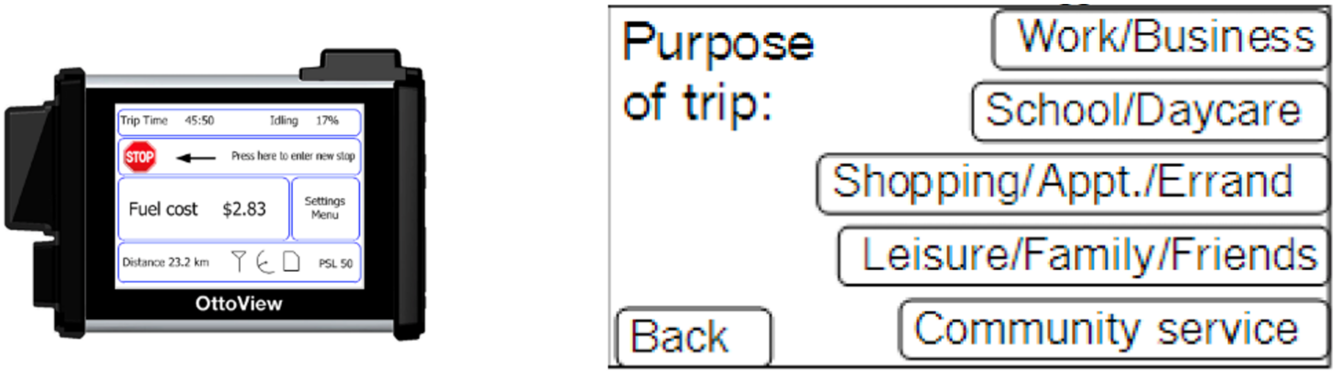


Figure 2. Main screen of electronic logger device [1].

2.2 Sampling Design and Data Collection

At the earliest stage of the CVUS, only 4 provinces were participating, and 6,000 vehicles were selected per year, allocated as follows:

- 2,000 each for Québec and Ontario, and
- 1,000 each for Manitoba and Saskatchewan.

The sample in each province was stratified by **type of vehicle** and **age category**; the allocation was **proportional to the square root** of the vehicle fleet size in the jurisdiction.

At the Canadian level, the estimated quarterly **sample size** (after non-response) was roughly 1,000, which produced a global **confidence level** of 95% and a 3% **coefficient of variation**, but this was not the case for each stratum in a jurisdiction (although most small strata reached satisfactory levels on an annual basis).

For each jurisdiction, the data collection process started with an agreement with a province and the vehicle registration service. Once the sample was selected, the list of the selected vehicles was sent to the province to get the contact information of the vehicle's owner.

Logistical Aspects A third party was hired to manage all the communications with the selected vehicle owners. Quarterly samples were spread randomly in 13 batches to cover vehicle activities over the quarter.

The owners of selected vehicles were sent an official letter from TC inviting them to participate in the survey, and to respond via the TC website, by mail or through a toll-free number in order to provide some basic information about the **vehicle** and their **drivers**.

When it was impossible to contact the owner by mail, a **telephone matching** procedure was used. Overall matching rates were approximately 85%.

The third party sent the logger and cables to those vehicle owners who agreed to participate, together with an information kit and the start and end dates of their specific data collection period.

From the initiation of a first contact with a vehicle owner, it took an **average of roughly 60 days** (including the 21 survey days) to complete the data collection cycle.

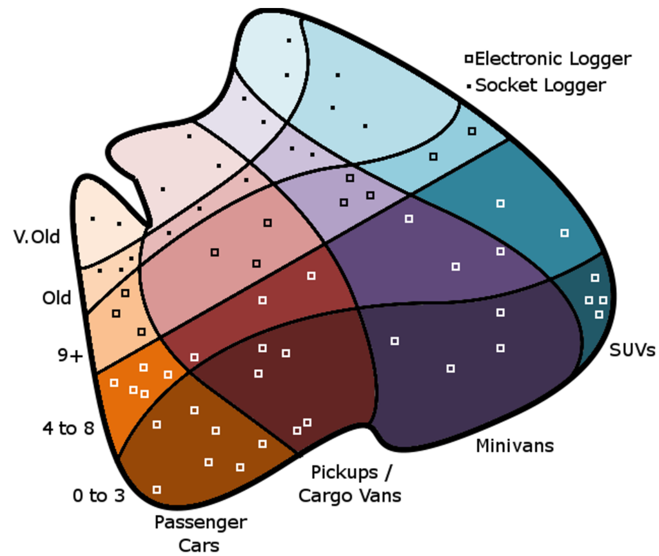


Figure 3. Stratification structure.

Incentives were provided to guarantee the return of the logger, including a detailed vehicle use report (compared to other drivers) and the chance of a monetary rewards in the form of monthly draws of $CDN1000 among those participants who had returned their electronic loggers to TC. In spite of this, a handful of loggers were lost each quarter.

2.3 Stratification

The sampling design was that of a **nested stratified sample survey**. The stratification variables were selected from:

- **Jurisdiction**
- **Urban/Rural** [census metropolitan area, non-CMA]
- **Vehicle Type** [passenger car (PC), light truck (LT)]
- **Vehicle Style** [PC, pick-up truck/cargo van (PT/CV), minivan (MV), sports utility vehichle (SUV)]
- **Vehicle Age** [electronic loggers for newer vehicles, socket loggers for older vehicles].

Schematically, the stratification in a given jurisdiction was structured as in Figure 3. Within each stratum, the allocation was **proportional** to the vehicle fleet size. This design allows for **stratum aggregation** (see Figure 4).

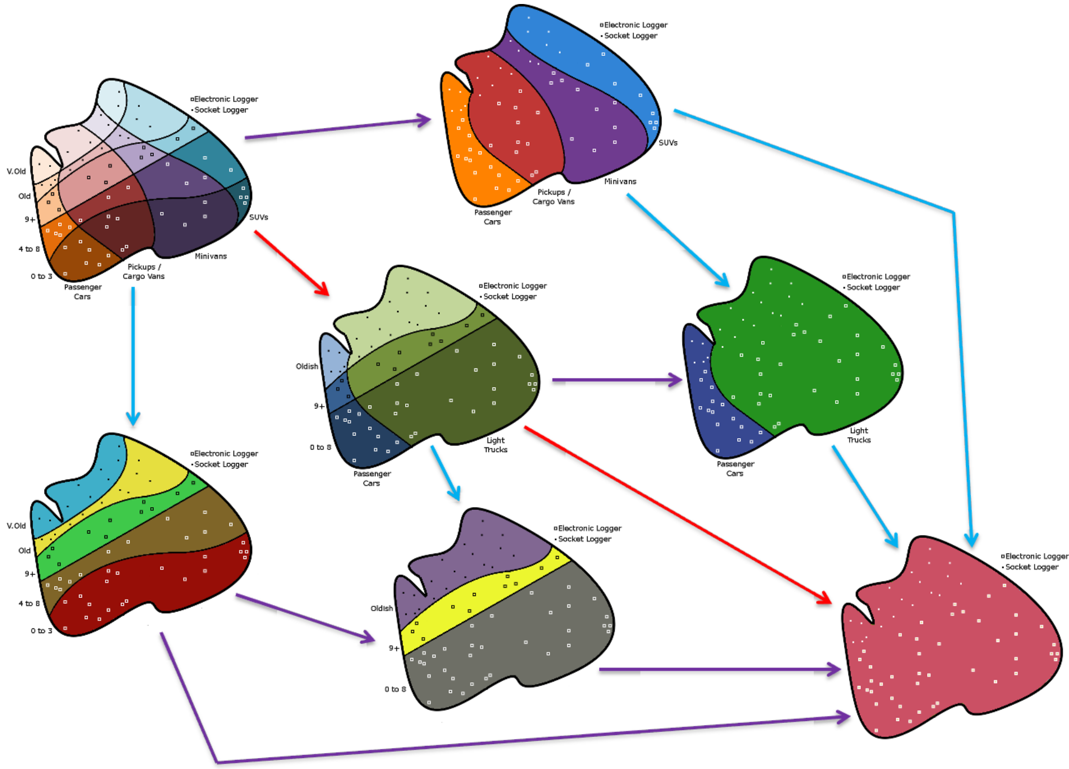


Figure 4. Hierarchical strata can be aggregated to report on various combinations of variable levels. In this stratification tree, blue arrows represent aggregation of vehicle styles, purple arrows represent aggregation of vehicle age categories, and red arrows represent combined vehicle style and age aggregation.

3. Data Processing

Ultimately, the goal of the CVUS was to reach a quantitative understanding of various characteristics for all vehicles in the population.

The true population parameters (the mean μ, the variance σ^2, the quantiles q^α, say) for a given characteristic x are unknown, but they can be estimated by judiciously selecting units from the population, observing a value of x for these units and using statistical sampling theory to provide estimates.

In the context of the CVUS, the **basic characteristics** of a vehicle's activity for a given day were:

- **nTrips** – the number of trips;
- **VKT** – vehicle-kilometres of travel or distance traveled by each vehicle in km;
- **PKT** – passenger-kilometres (the product of VKT and the number of individuals in the vehicle);
- **Use** – the number of hours for which the engine was turned on;
- **UseNI** – the number of hours for which the engine was turned on and not idling;
- **Fuel** – the fuel consumed in litres.

Vehicles presented themselves as natural sampling units since we had access to a good sampling frame consisting of registered vehicles; households or drivers could also have been used as units, but it was harder to obtain quality sampling frames in those cases.

In the CVUS, the **characteristics of interest** were thus observed for sampled vehicles.

At the rawest level, **observations** for x consisted of a measurement of x for a specific vehicle over an interval of roughly one second. Over such a small interval, it seemed safe to assume that the observation is quite precise, (barring a possible malfunction of the recording equipment).

Such precision comes at a price, however: 3 hours of travelling corresponds to roughly 10,800 observations. For a large number of vehicles, studied over weeks, the total size of the observations quickly became prohibitive.

The obvious solution was to consider averages: for instance, a vehicle travelling 200km over 10,000 seconds travelled at the average speed of 0.02 km/sec.

Small scales can prove useful if we want to determine which proportion of a trip was undertaken at speeds between two given thresholds, for instance (more on this later).

Yet the scale of these observations undeniably leaves something to be desired: a conversion table can easily show

Vehicle Age	Vehicle Style	Vehicle Type
0 TO 3	PASSENGER CAR	PASSENGER CAR
4 TO 8	MINIVAN	LIGHT TRUCK
9+	PICKUP/CARGO	
OLD	SUV	
V.OLD		

VEHICLE characteristics (strata)

Length Characteristics	Basic Characteristics	Derived Characteristics
Number of Study Days	Daily Number of Trips	Fuel Consumption Ratio (L/100km)
Number of Active Days	Daily Vehicle km Traveled	Idling Ratio
	Daily Passenger km Traveled	Average Vehicle Occupancy
	Daily Fuel Consumption (L)	Average Speed (km/h)
	Daily Driving Time (h)	Average Trip Length (km)
		Average Trip Duration (min)

MEASURED and **DERIVED** characteristics

TRIP characteristics

Purpose	Driver Gender	Driver Age	Number of Passengers	Trip Length	Type of Day
UNKNOWN	UNKNOWN	UNKNOWN	DRIVER ONLY	0 km	WORKDAY
WORK/BUSINESS	FEMALE	16-24	DRIVER & 1 PASSENGER	1 km TO 5 km	WEEKEND
SCHOOL/DAYCARE	MALE	25-44	DRIVER & 2+ PASSENGERS	6 km TO 10 km	
SHOP/APP/ERRAND		45-64		11 km TO 15 km	
LEISURE/FAMILY/FRIENDS		65+		16 km TO 20 km	
COMMUNITY SERVICE				21 km TO 30 km	
				31 km TO 50 km	
				51 km TO 100 km	
				100+ km	

SUB-TRIP characteristics

Speed	Idling Type	Time of Day	Engine Temperature
IDLING	NOT IDLING	EARLY (06:00-08:59)	COLD (< 50°C)
1 km/h TO 24 km/h	IDLING DURING TRIP	MORNING (09:00-11:59)	WARM (50°C to 80°C)
25 km/h TO 49 km/h	TRIP START IDLING	MIDDAY (12:00-14:59)	HOT (> 80°C)
50 km/h TO 79 km/h	TRIP END IDLING	AFTERNOON (15:00-17:59)	NO DATA
80 km/h TO 99 km/h		EVENING (18:00-20:59)	
100 km/h TO 119 km/h		NIGHT (21:00-05:59)	
120+ km/h			

Table 1. Measured and derived characteristics collected by the logger. Characteristics at the vehicle, trip, and sub-trip levels are categorical; measured and derived characteristics are numerical.

that the average speed of a vehicle which travelled 12.1m/s is 43.56 km/h, but the two quantities do not have the same power of evocation.

The permeating nature of the periodic day/night cycle in human affairs suggested that aggregating the raw observations at the daily level would provide a good balance between preciseness and ease of interpretation, at least for the basic characteristics, for both **actual study days** and **active days of observation**.

The rest of this section tackles the process of **aggregation**; the problem of transforming daily observations into a single measurement for a given vehicle is described in the last sub-section.

3.1 Importing and Editing Data

Observations were first collated at the **trip-level**. Each record consisted of

- **vehicle identifiers:** vehicle id, trip id, logger id;
- **stratum identifiers:** province, vehicle type, vehicle age, forward sortation area;
- **trip parameters:** trip year, trip month, trip day, trip start time, trip end time;
- **travel characteristics:** purpose, driver age and gender, number of occupants, trip length, type of day;
- **basic trip characteristics:** VKT, PKT, Use, UseNI, Fuel, and
- **basic sub-trip characteristics:** VKT, PKT, Use, UseNI and Fuel, cross-tabulated by engine temperature, vehicle speed and period of day.

The allowed values of these characteristics are shown in Table 1. Within the study period for each vehicle, days for which it was not in use (non-active days) were added to the dataset, under the assumption that all basic trip and sub-trip characteristics took on the value 0 on these days.

3.2 Creating Daily Summaries

A problem arose for the first and last days of each study period: as we do not know exactly when the electronic logger was installed/uninstalled, we cannot *a priori* assume that the basic trip characteristics recorded on these days are complete. For instance, if the logger was installed at 10am on a Monday, any driving occurring before 10am would not have been recorded.

The first and last days of the study period should thus not be weighed in the same manner as the other days.

The **daily weight** for vehicle i on a regular day was set to $w^i_{\text{reg}} = 1$ (because a full day's worth of observations on these days was worth one regular day of observations).

In order to determine the daily weights of the first and last days, we proceeded as follows. For any vehicle i, let b^i_{min} (resp. b^i_{max}) be the earliest start time (resp. latest end time) amongst all trips by that vehicle (as a fraction of a single day) over all days in the study period. The **base driving day** for vehicle i is the interval

$$[b^i_{\text{min}}, b^i_{\text{max}}] \subseteq [0,1].$$

In practice, we allowed for the possibility that $b^i_{\text{max}} > 1$: a trip which started on a given calendar day but ended on the following day had to be classified as occurring on a single day. It was arbitrarily decided that the entire trip would be recorded as having taken place on the start date. In that case, the latest end time would actually be 1 + length of the trip in the early morning of the second day.

Let α_i (resp. ω_i) be the earliest (resp. latest) recorded time on the first (resp. last) day of the study.

The **daily weight** w^i_{first} (resp. w^i_{last}) is the proportion of the base driving day occurring after α_i on the first day (resp. before ω_i on the last day), that is

$$w^i_{\text{first}} = \frac{b^i_{\text{max}} - \alpha_i}{b^i_{\text{max}} - b^i_{\text{min}}} \quad \text{and} \quad w^i_{\text{last}} = \frac{\omega^i - b^i_{\text{min}}}{b^i_{\text{max}} - b^i_{\text{min}}}.$$

For instance, if, amongst all trips, the earliest start time was 0.3 and the latest end time was 0.9, and if the earliest start time on the first day was 0.5 and the latest end time on the last day was 0.6, then

$$w^i_{\text{first}} = \frac{0.9-0.5}{0.9-0.3} = \frac{2}{3} \quad \text{and} \quad w^i_{\text{last}} = \frac{0.6-0.3}{0.9-0.3} = \frac{1}{2},$$

meaning that the observations on the first (resp. last) day were weighed 2/3 (resp. 1/2) as heavily as observations on regular days.

The observations were then aggregated at the **day-level**, along the trip id's. Each record consisted of:

- **vehicle identifier:** vehicle id;
- **stratum identifiers:** province, vehicle type, vehicle age, forward sortation area;
- **trip parameters:** year, quarter, month, day, numerical date, weekday, active day flag;
- **travel characteristics:** purpose, driver age and gender, number of occupants, trip length, type of day;
- **basic characteristics:** daily weight, nTrips, VKT, PKT, Use, UseNI, Fuel, and
- **basic sub-trip characteristics:** VKT, PKT, Use, UseNI and Fuel, cross-tabulated by engine temperature, vehicle speed and period of day

The observations could have looked like those shown in Table 2, for instance. Note the presence of **non-active days** (those rows for which the number of trips is 0), as well the daily weights on the first and last days for a given vehicle.

3.3 Rural/Urban Classification

The classification of a vehicle as belonging to either an urban or rural setting was done using the **Forward Sortation Area** (FSA) portion of the postal code found in the registration file.[1]

[1]For privacy reasons, the full address was not available before a vehicle has been selected.

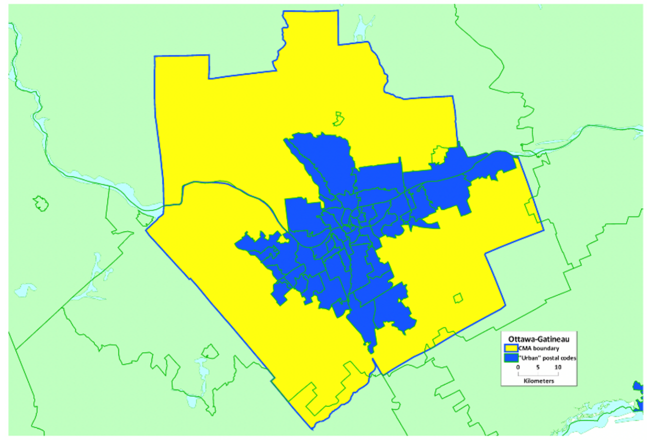


Figure 5. Map of Ottawa-Gatineau with overlapping FSAs.

The most convenient way to do so was to use the **Canada Post** system: an FSA is defined as **rural** if the digit in the second position is a "0", and as **urban** otherwise. There are some issues with this approach, however.

For instance, New Brunswick changed its FSA codes so that none of the province's sortation areas would ever be classified as rural, in spite of the obvious fact that New Brunswick is not made up of urban areas.

Furthermore, FSA codes may change fairly frequently, according to some arbitrary (at least, with respect to CVUS aims) internal logic at Canada Post. There is a chance that after such a change, a vehicle which would have been considered rural one day would suddenly be considered urban the next yet be used in the same area in both instances.

Lastly, as we are were not privy to the internal logic that allows the classification of FSAs, the possibility remained that what would be considered rural in one jurisdiction may prove to be urban in another, cancelling any effort to provide estimates across jurisdictions.

An eventual solution to this conundrum could be to use **population** and **population density** data in order to classify the FSA: any FSA with a given population above a certain threshold and with a population density above a certain threshold would be considered "urban", all other FSA, "rural".

This approach had the obvious advantage of being a uniform definition across all jurisdictions and sub-regions, and it avoided the pitfalls of random FSA classification changes by Canada Post.

Another solution could have been to manually select those FSA that intersect the boundaries of **Census Metropolitan Areas** (CMA) or some other municipal regroupings. The map displayed in Figure 5 showing the FSAs overlayed over the CMA boundaries for Ottawa-Gatineau illustrates some of the problems associated with this approach: the overlap of FSAs with the CMAs boundary is not exact.

v id	prov	type	age	fsa	year	qtr	month	day	date	week day	day type	active day flag	purpose cd	daily weight	nTrips	VKT	PKT	Use / 24	UseNI / 24	Fuel
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	0	0.963	1	0	0	0.0006	0	0.046
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	1	0.963	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	2	0.963	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	3	0.963	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	4	0.963	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	14	18853	Sun	WeekEnd	1	5	0.963	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	0	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	1	1	1	6.266	6.266	0.0083	0.0065	0.798
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	2	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	3	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	4	1	7	299.131	588.919	0.2124	0.1981	27.610
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	15	18854	Mon	WorkDay	1	5	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	0	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	1	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	2	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	3	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	4	1	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	8	16	18855	Tue	WorkDay	0	5	1	0	0	0	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮			⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	0	0.698	2	44.076	44.076	0.0323	0.0302	3.954
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	1	0.698	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	2	0.698	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	3	0.698	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	4	0.698	0	0	0	0	0	0
2	35_ON	02_LT	02_NEW	K8N	2011	3	9	4	18874	Sun	WeekEnd	1	5	0.698	0	0	0	0	0	0
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	0	0.985	0	0	0	0	0	0
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	1	0.985	0	0	0	0	0	0
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	2	0.985	0	0	0	0	0	0
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	3	0.985	1	11.058	11.058	0.0158	0.0098	1.394
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	4	0.985	2	15.022	30.044	0.0219	0.0144	1.759
3	35_ON	01_PC	02_NEW	K1C	2011	3	8	15	18854	Mon	WorkDay	1	5	0.985	0	0	0	0	0	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮			⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 2. Summarized data at the daily level (in order to make the table more easily readable, "purpose" is the only retained trip identifier retained, and the basic sub-trip characteristics are not shown).

Given that the thresholds mentioned in the approach above would have needed to depend on how many (and which) jurisdictions would join the CVUS line-up before it started, it was decided that using Canada Post's classification was the most advantageous approach, in spite of its flaws.

3.4 Basic and Derived Characteristics

In the CVUS context, a derived characteristic was defined as a characteristic obtained by multiplying or dividing two or more basic characteristics. There was some ambiguity: PKT could be considered a derived characteristic, as it is obtained by multiplying VKT and the number of passengers; however, given that the number of passengers was not a basic characteristics, PKT was classified as a basic characteristic instead.

The **derived characteristics** of a vehicle for a given day are ratios of basic trip characteristics. Some of these derived characteristics are more commonly recognizable under their common names: distance per hour of use is simply the **average vehicle speed**, whereas distance per litre consumed is the **average fuel consumption ratio** (after an appropriate re-scaling).

The following convention was used: the derived characteristic obtained by dividing the basic characteristic a by the basic characteristic b is denoted by a_b.

Each derived characteristic had an **associated daily characteristic weight**, which is simply the denominator in the computation of the ratio (which would be b, above).

When the computation of a derived characteristic involved a division by 0 (i.e., when the associated weight was 0), we set the derived characteristic to 0. For instance, if on a given day the engine was started but the vehicle was not driven, the daily fuel consumption per km travelled is set to 0.

From 6 basic characteristics, 30 core derived characteristics can be built. They are presented in Table 3. At the subtrip-level, each of the variables was treated as a basic characteristic. Strictly speaking, there was nothing to forbid us from creating derived characteristics for these variables, but it was deemed impractical to do so due to their sheer quantity.

3.5 Observations, Accuracy, Precision, Meas. Error

Following the previous sub-sections, let us assume that for a given vehicle j we had a series of i_j daily observations of the characteristic $x_{j,1},\ldots,x_{j,i_j}$, with accompanying weights $w_{j,1},\ldots,w_{j,i_j}\neq 0$ and daily weights $v_{j,1},\ldots,v_{j,i_j}$.[2]

[2]For basic characteristics, the daily weights and accompanying weights are identical; for derived characteristics, they may not be.

Ratio of Column to Row	nTrips	VKT (km)	PKT (km)	Use (hr)	UseNI (hr)	Fuel (L)
nTrips		distance per trip (km)	passenger km per trip (km)	hours per trip (h)	non-idling hours per trip (h)	fuel consumption per trip (L)
VKT (km)	trips per km travelled (km^{-1})		passenger km per km travelled	hours per km travelled (h/km)	non-idling hours per km travelled (h/km)	fuel consumption per km travelled (L/km)
PKT (km)	trips per passenger km travelled (km^{-1})	distance per passenger km		hours per passenger km (h/km)	non-idling hours per passenger km (h/km)	fuel consumption per passenger km (L/km)
Use (h)	trips per hour of use (h^{-1})	distance per hour of use (km/h)	passenger km per hour of use (km/h)		ratio of non-idling use to use	fuel consumption per hour of use (L/h)
UseNI (h)	trips per hour of non-idling use (h^{-1})	distance per hour of non-idling use (km/h)	passenger km per hour of non-idling use (km/h)	ratio of use to non-idling use		fuel consumption per non-idling hour of use (L/h)
Fuel (L)	trips per litre consumed (L^{-1})	distance per litre consumed (km/L)	passenger km per litre consumed (km/L)	hours per litre consumed (h/L)	non-idling hours per litre consumed (h/L)	

Table 3. Derived characteristics.

Write

$$z_j = \sum_{k=1}^{i_j} w_{j,k}, \quad \xi_j = \sum_{k=1}^{i_j} w_{j,k}^2, \quad d_j = \sum_{k=1}^{i_j} v_{j,k},$$

$$\varphi_j = \sum_{k=1}^{i_j} w_{j,k} x_{j,k}, \quad \zeta_j = \sum_{k=1}^{i_j} w_{j,k} x_{j,k}^2.$$

The **(weighted) sample mean** of the daily observations is thus

$$y_j = \frac{1}{z_j}\varphi_j,$$

while their **(weighted) sample variance** is

$$s_j^2 = \frac{z_j}{z_j^2 - \xi_j} \sum_{k=1}^{i_j} w_{j,k}(x_{j,k} - y_j)^2 = \frac{z_j}{z_j^2 - \xi_j}(\zeta_j - z_j y_j^2).$$

Obviously, this is only well-defined for vehicles and characteristics for which $z_j^2 \neq \xi_j$.[3]

We used the sample mean as the observation (or **measurement**) of the characteristic x for vehicle j.

Clearly, the number of observations affects the **accuracy** (how near the estimate is to the true value) and the **precision** (how small the variance of the estimate is) of the sample mean as an estimate of the true mean.

If daily observations were available for every day in the time period of interest (a quarter, say), we would be reasonably certain that the sample mean is both very accurate and very precise: in fact, the sample mean would be the true mean of x for vehicle j in that case (assuming that all **measurement errors** are nil).

[3]When some of the weights are not integers, z_j is a generalization of the number of observations in the computation of the sample mean, d_j is a generalization of the number of sampling days, while

$$\frac{z_j^2 - \xi_j}{z_j}$$

is a generalization of the degrees of freedom in the computation of the unbiased sample variance.

At the other extreme, with a sole daily observation there would have been no way to determine the accuracy and precision of the sample mean as an estimate of the true mean: the sample mean and the true mean could have matched, but we would not have had enough information to qualify (let alone quantify) that statement.

Theoretical Framework If n daily observations of the characteristic x for vehicle j, each with weight $w_{j,k} = 1$, were drawn independently from an infinite population following a distribution $\mathscr{M}_j$ with mean μ_j and variance σ_j^2, then the accuracy of the sample mean y_j would be given by

$$A_j = y_j - \mu_j,$$

while its precision would be measured by its variance

$$V(y_j) \approx \frac{\sigma_j^2}{n}, \quad \text{for large } n.$$

The **Central Limit Theorem** guarantees that $A_j, V(y_j) \to 0$ as $n \to \infty$. In practice, however, the number of daily observations is limited by the number of available days: the variance must include a **finite population correction** (FPC) factor $1 - \frac{n}{N}$.

This generalizes to the CVUS context as follows. Let N be the number of days on which observations could have been made. If i_j daily observations of the characteristic x for vehicle j, with accompanying weights $w_{j,k}$ and daily weights $v_{j,k}$, for $k = 1, \ldots, i_j$, are drawn independently and **without replacement** from a finite population following a distribution $\mathscr{M}_j$ with estimated mean $\hat{\mu}_j$ and estimated variance s_j^2, then the **precision of the sample mean** $y_j = \hat{\mu}_j$ is estimated by

$$e_j^2 = \frac{s_j^2}{d_j}\left(1 - \frac{d_j}{N}\right), \quad \text{if } d_j < N,$$

and 0 otherwise. Note that for basic characteristics with integer weights equal to their daily weights, the expression above indeed collapsed to the classical result. [4]

No measure of **accuracy of the sample mean** was provided as the only estimate of the true mean μ_j available was the sample mean y_j itself, leading to $\hat{A}_j = 0$ no matter the sample size.[5]

[4]In practice, the assumption of independence was unlikely to be satisfied given that the sampling days necessarily occurred consecutively and were thus liable to be positively correlated on some level.

However, over a longer collection period, and perhaps due to the nature of the presumed dimorphism of driving behaviour between weekends and weekdays, it was hoped that the assumption held at least approximately.

[5]Furthermore, we note that accuracy was more easily affected by faulty or misused equipment than precision: constantly overshooting or undershooting the true daily observations by the same additive factor, for instance, would have introduced a bias in the accuracy, but not in the precision.

Consequently, the observation of the characteristic x for a given vehicle j consisted of the **sample mean** y_j, the **vehicle-characteristic weight** z_j, and the **within-vehicle error** e_j^2.

Thus, for each vehicle, there were 6 basic trip characteristics × 2 (days, active days) + 30 derived trip characteristics, for a total of 42 **trip characteristics.**

Sub-Trip Characteristics Similarly, the basic sub-trip characteristics were simply the basic trip characteristics (except for nTrips), tabulated across

- 4 **engine temperature** categories
  - COLD: less than 80°C
  - WARM: 80°C to 100°C
  - HOT: more than 100°C
  - UNK: unknown
- 6 **period of the day**
  - before morning traffic
  - during morning traffic
  - between morning and afternoon traffic
  - during afternoon traffic
  - after afternoon traffic
  - overnight
- 10 **instantaneous speed** categories
  - idle
  - 0 km/h to 5 km/h
  - 5 km/h to 10 km/h
  - 10 km/h to 20 km/h
  - 20km/h to 30 km/h
  - 30 km/h to 50 km/h
  - 50 km/h to 80 km/h
  - 80 km/h to 100 km/h
  - 100 km/h to 120 km/h
  - more than 120 km/h

There were thus 384 basic sub-trip characteristics for each of the 5 basic trip characteristics other than nTrips, hence **1920 basic sub-trip characteristics in total**.

The **vehicle-level** observations could have looked like those shown in Table 4, for instance.

4. Estimation and Data Analysis

The schematics of the estimation and aggregation process used by the CVUS team is shown in Figure 6: from the raw observations, we built trip summaries, which were then compiled into daily measurements, from which we extracted vehicle-level data, which were combined to provide information at the stratum level, which were then further aggregated into a jurisdiction estimate.

At each level, an observation consisted of a triple (y, z, e^2) corresponding to a **point estimate**, a **weight**, and a **precision**. How were those used to go up/down the **stratification tree**, such as in Figure 7, for instance?

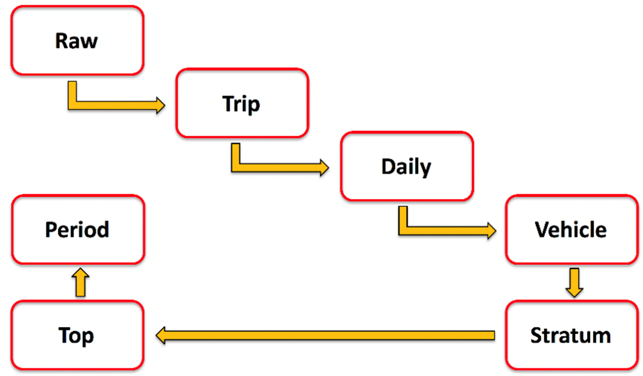


Figure 6. Estimation schematics for the CVUS.

4.1 Vehicle Information at the Stratum Level

For the given characteristic x, let us assume that m vehicles were sampled in a given stratum with overall vehicle population M. We then had a series of observations

$$(y_1, z_1, e_1^2), \ldots, (y_m, z_m, e_m^2),$$

as described in Section 3.5.

In a manner reminiscent of that of Section 3.5, write

$$z = \sum_{j=1}^m z_j, \quad \xi = \sum_{j=1}^m z_j^2, \quad \delta = \sum_{j=1}^m z_j e_j^2,$$

$$\varphi = \sum_{j=1}^m z_j y_j, \quad \zeta = \sum_{j=1}^m z_j y_j^2.$$

The **estimate of the mean** of x in the stratum is given by the (weighted) sample mean of the observations y_j:

$$\overline{y} = \frac{1}{z}\varphi.$$

The **estimate for the variance** of x in the stratum is slightly more complex than it was in Section 3.4: with perfect precision for each observation, only the (weighted) sample variance in y_j between the sampled vehicles would contribute to the variance:

$$\hat{V}_b = \frac{z}{z^2-\xi}\sum_{j=1}^m z_j(y_j - \overline{y}_j)^2 = \frac{z}{z^2-\xi}(\zeta - z\overline{y}^2).$$

Obviously, this is only well-defined for vehicles and characteristics for which $z^2 \neq \xi$.

This **between-vehicle** contribution does not tell the whole variance-story, however, as each of the measurements y_j comes with a measure e_j^2 of its own **within-vehicle** uncertainty:

$$hatV_w = \frac{z}{z^2-\xi}\sum_{j=1}^m z_j e_j^2 = \frac{z}{z^2-\xi}\delta.$$

It was reasonable to further assume that precision errors are independent of one another from vehicle to vehicle.

v id	prov	type	age	urbrural	fsa	week day	day type	purpose cd	data type	nTrips daily wt	nTrips daily	nTrips daily e2	VKT daily wt	VKT daily	VKT daily e2		Fuel UseNI wt	Fuel UseNI	Fuel UseNI e2
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	999	16	21.618	3.806	0.271	21.618	60.620	279.483	...	19.803	6.856	0.134
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	999	16	24.572	6.743	0.353	24.572	72.417	45.269	...	34.718	4.791	0.009
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	0	17	21.618	3.436	0.261	21.618	46.493	174.464	...	14.893	7.209	0.204
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	1	17	21.618	0.046	0.002	21.618	0.290	0.065	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	2	17	21.618	0.000	0.000	21.618	0.000	0.000	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	3	17	21.618	0.000	0.000	21.618	0.000	0.000	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	4	17	21.618	0.324	0.081	21.618	13.837	148.002	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	999999_ALL	5	17	21.618	0.000	0.000	21.618	0.000	0.000	...	0.000	0.000	0.000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	0	17	24.572	0.857	0.032	24.572	2.561	0.733	...	1.424	5.592	0.840
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	1	17	24.572	3.744	0.204	24.572	43.541	30.654	...	19.568	5.064	0.014
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	2	17	24.572	0.000	0.000	24.572	0.000	0.000	...	0.000	0.000	0.000
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	3	17	24.572	0.615	0.078	24.572	3.947	4.402	...	2.744	4.021	0.063
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	4	17	24.572	1.486	0.108	24.572	21.948	32.880	...	10.753	4.393	0.038
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	999999_ALL	5	17	24.572	0.041	0.001	24.572	0.420	0.131	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	01_WorkDay	999	20	15.000	3.933	0.414	15.000	59.516	455.729	...	14.077	6.488	0.175
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	02_WeekEnd	999	20	6.618	3.516	0.927	6.618	63.124	810.123	...	5.726	7.762	0.582
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	01_WorkDay	999	20	17.053	6.454	0.599	17.053	69.336	68.974	...	22.296	4.936	0.011
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	02_WeekEnd	999	20	7.519	7.399	0.807	7.519	79.404	147.010	...	12.422	4.530	0.037
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	01_WorkDay	0	21	15.000	3.400	0.395	15.000	39.156	219.846	...	9.166	6.864	0.360
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	02_WeekEnd	0	21	6.618	3.516	0.927	6.618	63.124	810.123	...	5.726	7.762	0.582
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	01_WorkDay	5	21	15.000	0.000	0.000	15.000	0.000	0.000	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	99_ALL	02_WeekEnd	5	21	6.618	0.000	0.000	6.618	0.000	0.000	...	0.000	0.000	0.000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	01_WorkDay	0	21	17.053	0.707	0.043	17.053	3.069	1.335	...	1.198	5.773	1.082
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	02_WeekEnd	0	21	7.519	1.197	0.123	7.519	1.408	1.098	...	0.227	4.637	1.577
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	01_WorkDay	5	21	17.053	0.000	0.000	17.053	0.000	0.000	...	0.000	0.000	0.000
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	99_ALL	02_WeekEnd	5	21	7.519	0.133	0.013	7.519	1.374	1.388	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	01_Mon	999999_ALL	999	24	3.000	6.667	0.370	3.000	112.679	7738.282	...	5.886	5.510	0.187
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	07_Sun	999999_ALL	999	24	3.618	2.009	0.158	3.618	14.719	63.106	...	1.325	4.989	0.270
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	01_Mon	999999_ALL	999	24	4.000	6.750	5.797	4.000	89.292	689.010	...	6.580	4.771	0.016
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	07_Sun	999999_ALL	999	24	4.000	6.500	1.688	4.000	71.602	329.549	...	6.091	4.129	0.010
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	01_Mon	999999_ALL	0	25	3.000	4.000	3.333	3.000	10.880	25.424	...	0.976	4.124	0.005
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	02_Tue	999999_ALL	0	25	3.000	1.667	1.204	3.000	29.891	744.269	...	1.378	6.158	1.026
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	06_Sat	999999_ALL	5	25	3.000	0.000	0.000	3.000	0.000	0.000	...	0.000	0.000	0.000
2	35_ON	02_LT	02_NEW	02_URBAN	K8N	07_Sun	999999_ALL	5	25	3.618	0.000	0.000	3.618	0.000	0.000	...	0.000	0.000	0.000
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	01_Mon	999999_ALL	0	25	4.000	0.500	0.063	4.000	0.008	0.000	...	0.007	5.616	29.448
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	02_Tue	999999_ALL	0	25	4.000	0.750	0.172	4.000	3.270	3.388	...	0.332	4.410	0.043
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	06_Sat	999999_ALL	5	25	3.519	0.284	0.062	3.519	2.935	6.619	...	0.000	0.000	0.000
210	35_ON	01_PC	01_NEWEST	02_URBAN	K2M	07_Sun	999999_ALL	5	25	4.000	0.000	0.000	4.000	0.000	0.000	...	0.000	0.000	0.000

Table 4. Summarized data at the vehicle level (in order to make the table more easily readable, "purpose" is the only retained trip identifier retained, and the basic sub-trip characteristics are not shown).

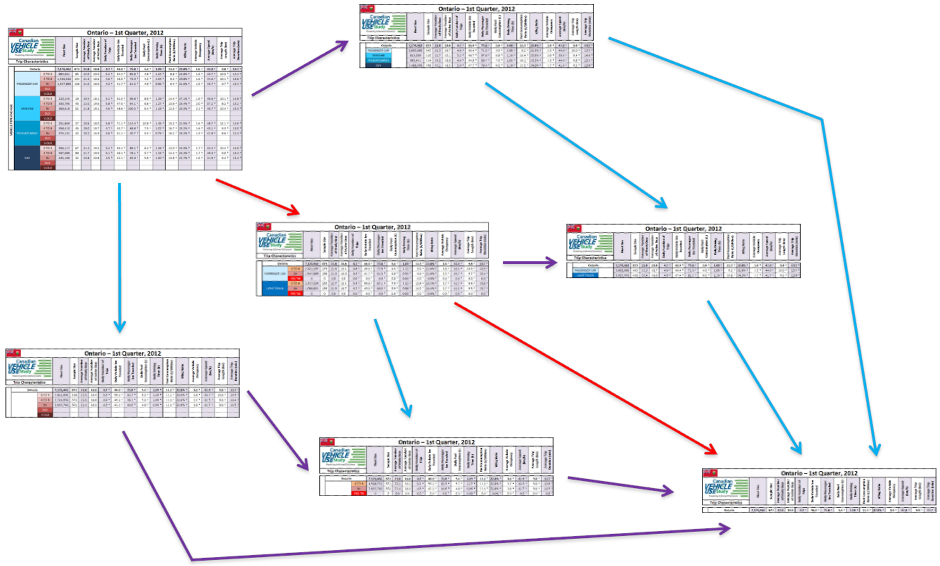


Figure 7. Hierarchical results of the CVUS. Strata can be aggregated to report on various combinations of variable levels (compare with Figure 4).

The total (weighted) sample variance of the observations over the stratum was then estimated by

$$s_Y^2 = \hat{V}_b + \hat{V}_w = \frac{z}{z^2 - \xi}(\zeta - z\overline{y}^2 + \delta).$$

In order to provide an estimate for $s_{\overline{Y}}^2$ (the sample variance of the mean $\overline{y}$ over the stratum), we keep in mind that both the number of sampled vehicles and the precision of their respective estimate affected the accuracy and precision of the sample mean $\overline{y}$ as an estimate of the true mean for the characteristic x at the stratum level.

Following the Central Limit Theorem argument presented in Section 3.5, we estimated the stratum variance for the sample mean $\overline{y}$ in the stratum by

$$s_{\overline{Y}}^2 \approx \frac{\hat{V}_b}{m}\left(1+\frac{m}{M}\right) + \frac{\hat{V}_w}{m} \approx \frac{s_Y^2}{m}\left(1+\frac{m}{M}\right), \quad \text{when } m \ll M.$$

When observations are available for each of the stratum vehicles, the precision of the sample mean as an estimate of the true mean is precisely that of the individual observations, which explains the finite population correction term in the "between" component of $s_{\overline{Y}}^2$.

There is no such factor for the "within" component since its uncertainty goes to 0 with the number of sampling days, not with the number of sampled vehicles. However, the FPC is approximately equal to 1 when $m \ll M$, and so we assumed that $s_{\overline{Y}}^2$ took the classical form in our case.

In the ℓ^{th} stratum, the characteristic x was thus described by the **stratum mean** $\overline{x}_\ell = \overline{y}$, the **estimated variance of the stratum mean** $s_{\overline{X}_\ell}^2 = s_{\overline{Y}}^2$ and the **stratum weight** $M_\ell = M$.

In each stratum, the **coefficient of variation** $\text{cv}(\mu_\ell)$ was obtained by dividing the standard deviation of the stratum mean by its mean:

$$\text{cv}(\mu_\ell) = \frac{\sigma_{\mu_\ell}}{\mu_\ell} \approx \frac{s_{\overline{X}_\ell}}{\overline{x}_\ell} = \widehat{\text{cv}}(\mu_\ell).$$

Confidence intervals (CI) were then easy to compute: an $(1-\alpha)\%$ confidence interval for μ_ℓ was approximated by

$$\text{CI}_{1-\alpha}(\mu_\ell) = \overline{x}_\ell \pm z_\alpha \overline{x}_\ell \widehat{\text{cv}}(\mu_\ell),$$

where z_α represents the $(1-\alpha/2)$th percentile of the standard normal distribution.

4.2 Combining the Strata

For the characteristic of interest x, let us assume that vehicles were selected in k strata with stratum statistics

$$(\overline{x}_1, s_{\overline{X}_1}^2, M_1), \ldots, (\overline{x}_k, s_{\overline{X}_k}^2, M_k),$$

as described in Section 4.1. Write

$$M = \sum_{\ell=1}^k M_\ell, \quad \phi = \sum_{\ell=1}^k M_\ell \overline{x}_\ell, \quad \text{and} \quad S = \sum_{\ell=1}^k M_\ell^2 s_{\overline{X}_\ell}^2.$$

The **estimate of the true mean** of x over all strata was given by the **(weighted) sample mean of the stratum means** $\overline{x}_\ell$:

$$x = \frac{1}{M}\phi,$$

and **the estimate for the variance** in x over all strata was then obtained using the formulas of stratified sampling [4]:

$$s_{\overline{X}}^2 = \frac{1}{M^2}\sum_{\ell=1}^k M_\ell^2 s_{\overline{X}_\ell}^2 = \frac{1}{M^2}S.$$

4.3 Combining Quarterly Results

Observations were gathered at the **quarter** level; in order to be able to say something about longer time periods was to pool the results of available quarters, as CVUS end users did not have access to raw/daily results (had they had access, they could simply have re-run the estimation procedure of Section 3.5 with a modified N to account for custom time periods).

For the characteristic of interest x, let us assume that estimates were available in b distinct quarters with quarter statistics

$$(\overline{x}_1, s^2_{\overline{X}_1}, \partial_1), \ldots, (\overline{x}_b, s^2_{\overline{X}_b}, \partial_b),$$

as described in Section 4.1, with ∂_β being the number of days in quarter β. Write

$$\Delta = \sum_{\beta=1}^{b} \partial_\beta, \quad \eta = \sum_{\beta=1}^{b} \partial_\beta \overline{x}_\beta, \quad \text{and} \quad \rho = \sum_{\beta=1}^{b} (\partial_\beta - 1).$$

The **estimate of the true mean** of x over all quarters was given by the **(weighted) sample mean of the quarter means** $\overline{x}_\beta$:

$$\overline{x} = \frac{1}{\Delta}\eta,$$

and **the estimate for the pooled variance** in x over all quarters was then:

$$s^2_{\overline{X}} = \frac{1}{\rho}\sum_{\beta=1}^{b} (\partial_\beta - 1) s^2_{\overline{X}_\beta}.$$

5. Results for Ontario (Q1, 2012)

The (unofficial) results for Ontario during the first quarter of 2012 are shown in Tables 5 to 9.

Vehicle and trip characteristics are provided in Table 5, a stratification tree in Table 6, and sub-trip characteristics in Table 7.[6]

Various charts (of middling quality, see the Data Visualization chapter for remedial measures) are available in Tables 7 and 9.

The **quality of the estimates** was qualified with the help of the coefficient of variation, using the Statistics Canada standard [4]:

- a: less than 5% (excellent)
- b: between 5% and 10% (good)
- c: between 10% and 15% (acceptable)
- d: between 15% and 20% (use with caution)
- e: between 20% and 35% (unreliable)
- f: more than 35% (unusable)

[6] Values in columns may not add up or average (weighted) exactly to the corresponding column header due to to round-off errors.

The **vehicle age** stratification levels corresponded to

- 0 TO 3: 3 years old and younger
- 4 TO 8: between 4 and 8 years old
- 9+: 9 years old and older with model year post-1995
- OLD: model year between 1981 and 1995
- V.OLD: model year pre-1981

The estimates provided in the driver **age** and **gender** categories are **vehicle** characteristics, not **driver** characteristics.

Without further information on the distribution of drivers in a given jurisdiction (by age and gender), the estimates of the basic characteristics (nTrips, VKT, PKT, Fuel, Use, UseNI) cannot be used to predict the average driving behaviour of various combinations of driver age and gender for that jurisdiction.

6. Conclusion

The CVUS ran for 3 years, from 2012 to 2014. A sister study, the **Heavy Duty Vehicle Use Study** also ran in 2014. Official results can be found in [2].

Consulting Post-Mortem The original CVS management team was **steadfast** in its refusal to update their survey methodology, dismissing TC's technical abilities and domain expertise; consequently, a fair amount of "anger" and organizational strife was directed at TC for not renewing the CVS. TC suspected that this lead to only a fraction of the 13 Canadian provinces and territories joining the CVUS.

A number of sampled drivers had **privacy concerns** related to electronic recording devices, in regards to recorded data being used to establish speeding or liability in the event of a collision [3]; consequently, there were doubts, internally, about the representativeness of the sample.

A small number of electronic loggers were **not returned**, which added to the unexpected costs of running a large-scale study. Additionally, the local post office had not been warned and was **not prepared to handle the high volume** of loggers being sent and returned on a monthly basis.

Finally, there was a high turnover in third party telephone agents who were tasked with contacting the sampled drivers. The cost of continually training inexperienced agents was another unexpected expense.

References

[1] Allie, E. [2014], Canadian Vehicle Use Study: Electronic Data Collection, in *Proceedings of Statistics Canada Symposium 2014*, Beyond traditional survey taking: adapting to a changing world.

[2] CVUS Results, 2012-2014, Transport Canada.

[3] CVUS Privacy Statement, Transport Canada.

[4] *Survey Methods and Practices*, Statistics Canada, Catalogue no.12-587-X.

Ontario – 1st Quarter, 2012

Canadian VEHICLE USE Study – Powering Informed Decisions

Trip Characteristics			Fleet Size	Sample Size	Average Number of Study Days	Average Number of Active Days	Daily Number of Trips	Daily Vehicle km Traveled	Daily Passenger km Traveled	Daily Fuel Consumption (L)	Daily Driving Time (h)	Fuel Consumption Ratio (L/100km)	Idling Ratio	Average Vehicle Occupancy	Average Speed (km/h)	Average Trip Length (km)	Average Trip Duration (min)
VEHICLE TYPE AND AGE	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
		0 TO 3	1,812,892	198	21.5	19.4	5.3 [a]	56.2 [a]	91.7 [b]	6.3 [a]	1.28 [a]	11.1 [a]	23.4% [a]	1.6 [a]	43.7 [a]	10.6 [a]	14.5 [a]
		4 TO 8	2,725,830	373	22.5	18.9	4.9 [a]	46.2 [a]	76.1 [a]	5.3 [a]	1.09 [a]	11.4 [a]	22.5% [a]	1.7 [a]	42.5 [a]	9.5 [a]	13.4 [a]
		9+	2,637,740	302	21.4	18.3	4.3 [a]	41.2 [a]	64.6 [b]	4.8 [a]	0.96 [a]	11.4 [d]	22.8% [a]	1.6 [a]	42.7 [a]	9.6 [a]	13.5 [a]
		OLD															
		V.OLD															
	PASSENGER CAR		3,869,086	445	21.3	18.7	4.6 [a]	46.4 [a]	71.3 [a]	4.3 [a]	1.05 [a]	9.2 [a]	21.6% [a]	1.5 [a]	44.0 [a]	10.0 [a]	13.7 [a]
	MINIVAN		823,659	116	21.7	19.1	5.2 [b]	48.7 [b]	97.8 [b]	6.8 [b]	1.24 [b]	13.4 [b]	25.6% [a]	2.0 [a]	39.3 [a]	9.4 [b]	14.4 [b]
	PICKUP/CARGO		985,411	114	23.5	18.0	4.6 [b]	45.9 [b]	69.7 [b]	7.5 [b]	1.02 [b]	16.1 [f]	23.5% [a]	1.5 [a]	44.0 [a]	9.8 [b]	13.2 [a]
	SUV		1,498,306	198	22.1	19.5	5.0 [a]	47.7 [b]	79.4 [b]	6.0 [a]	1.16 [a]	12.5 [a]	24.0% [a]	1.7 [a]	41.4 [a]	9.5 [a]	13.8 [a]
	PASSENGER CAR	0 TO 3	884,661	85	22.0	20.0	5.2 [a]	54.4 [b]	85.8 [b]	4.8 [b]	1.24 [b]	8.8 [a]	22.8% [a]	1.6 [a]	43.7 [a]	10.5 [b]	14.4 [a]
		4 TO 8	1,436,536	194	21.3	18.6	4.6 [a]	46.5 [b]	73.0 [b]	4.3 [b]	1.04 [a]	9.2 [a]	20.8% [a]	1.6 [a]	44.6 [a]	10.1 [b]	13.6 [a]
		9+	1,547,889	166	21.0	18.0	4.3 [a]	41.7 [b]	61.5 [b]	4.0 [b]	0.95 [b]	9.4 [a]	21.6% [a]	1.5 [a]	43.7 [a]	9.7 [b]	13.4 [a]
		OLD															
		V.OLD															
	MINIVAN	0 TO 3	120,245	19	20.4	18.1	5.2 [e]	52.3 [e]	99.8 [e]	8.0 [e]	1.29 [e]	14.4 [e]	27.1% [e]	1.9 [e]	40.6 [e]	10.1 [e]	14.9 [e]
		4 TO 8	333,795	45	22.0	19.5	5.8 [b]	47.5 [c]	94.1 [c]	6.8 [c]	1.27 [d]	13.9 [a]	25.4% [b]	2.0 [b]	37.2 [b]	8.2 [b]	13.2 [c]
		9+	369,619	52	21.8	19.1	4.6 [b]	48.6 [c]	100.5 [d]	6.4 [b]	1.19 [b]	12.5 [c]	25.3% [b]	2.1 [b]	40.7 [b]	10.4 [c]	15.3 [b]
		OLD															
		V.OLD															
	PICKUP/CARGO	0 TO 3	251,869	27	20.6	18.0	5.8 [d]	71.1 [d]	114.4 [e]	10.8 [d]	1.45 [d]	15.2 [d]	21.5% [d]	1.6 [d]	48.7 [d]	12.1 [d]	14.9 [d]
		4 TO 8	358,410	45	29.0	19.7	4.7 [c]	43.7 [c]	68.8 [b]	7.5 [c]	1.02 [b]	16.7 [a]	23.2% [a]	1.6 [b]	43.1 [a]	9.3 [b]	13.0 [b]
		9+	375,132	42	20.2	16.3	3.6 [b]	31.1 [c]	40.7 [d]	5.3 [c]	0.75 [c]	16.2 [f]	25.2% [b]	1.3 [a]	41.8 [a]	8.6 [c]	12.4 [b]
		OLD															
		V.OLD															
	SUV	0 TO 3	556,117	67	21.4	19.2	5.2 [a]	53.1 [b]	89.1 [b]	6.4 [b]	1.26 [b]	12.0 [a]	24.3% [b]	1.7 [a]	42.2 [a]	10.2 [b]	14.5 [b]
		4 TO 8	597,089	89	21.7	19.0	5.1 [b]	46.1 [b]	78.1 [b]	5.7 [b]	1.15 [b]	12.2 [a]	24.4% [b]	1.7 [a]	40.3 [a]	9.0 [b]	13.4 [a]
		9+	345,100	42	23.8	20.8	4.5 [b]	42.1 [c]	65.9 [c]	5.9 [c]	1.00 [b]	13.8 [a]	22.7% [b]	1.6 [a]	41.9 [a]	9.4 [b]	13.4 [b]
		OLD															
		V.OLD															
PURPOSE	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	UNKNOWN					11.1	0.7 [b]	3.0 [c]	3.0 [c]	0.4 [c]	0.09 [c]	12.4 [f]	31.0% [a]	1.0 [a]	32.3 [a]	3.9 [a]	7.1 [a]
	WORK/BUSINESS					14.0	1.3 [a]	18.4 [a]	24.3 [b]	2.1 [a]	0.40 [a]	11.1 [b]	21.6% [a]	1.3 [a]	46.4 [a]	14.3 [a]	18.5 [a]
	SCHOOL/DAYCARE					9.0	0.2 [b]	1.3 [b]	2.5 [b]	0.2 [b]	0.04 [b]	13.2 [a]	28.3% [a]	1.9 [a]	32.1 [a]	6.9 [b]	13.0 [b]
	SHOP/APP/ERRAND					11.6	1.3 [a]	8.5 [a]	14.4 [a]	1.0 [a]	0.23 [a]	12.1 [e]	24.2% [a]	1.7 [a]	36.2 [a]	6.5 [a]	10.7 [a]
	LEISURE/FAMILY/FRIENDS					11.8	1.1 [a]	14.7 [a]	29.8 [b]	1.6 [a]	0.30 [a]	10.8 [a]	19.9% [a]	2.0 [a]	48.5 [a]	13.2 [a]	16.3 [a]
	COMMUNITY SERVICE					6.2	0.1 [b]	0.9 [c]	1.7 [d]	0.1 [c]	0.02 [c]	12.2 [f]	25.0% [a]	1.8 [a]	36.4 [a]	7.9 [b]	12.8 [b]
GENDER***	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	UNKNOWN					11.9	0.9 [b]	5.0 [c]	6.8 [c]	0.7 [c]	0.14 [c]	11.8 [f]	27.8% [a]	1.3 [a]	35.8 [a]	5.3 [a]	8.8 [a]
	FEMALE					16.0	1.6 [a]	15.8 [b]	25.9 [b]	1.7 [b]	0.38 [a]	11.6 [a]	23.0% [a]	1.6 [a]	42.5 [a]	10.3 [a]	14.5 [a]
	MALE					16.9	2.3 [a]	26.1 [a]	43.1 [a]	3.0 [a]	0.57 [a]	11.2 [b]	21.4% [a]	1.7 [a]	45.2 [a]	11.5 [a]	15.3 [a]
DRIVER AGE***	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	UNKNOWN					11.6	0.9 [b]	4.5 [c]	5.9 [c]	0.6 [c]	0.13 [c]	11.8 [f]	28.8% [a]	1.3 [a]	35.3 [a]	5.0 [a]	8.6 [a]
	16-24					11.9	0.2 [d]	1.9 [d]	2.9 [d]	0.2 [d]	0.04 [d]	8.3 [a]	17.3% [b]	1.2 [a]	33.8 [a]	8.2 [c]	11.3 [b]
	25-44					18.3	1.3 [b]	15.4 [b]	26.7 [b]	1.7 [b]	0.34 [b]	11.2 [a]	23.0% [a]	1.8 [a]	44.7 [a]	11.7 [a]	15.6 [a]
	45-64					17.8	1.8 [a]	19.1 [b]	30.8 [b]	2.2 [b]	0.44 [a]	11.3 [c]	21.8% [a]	1.6 [a]	43.5 [a]	10.8 [a]	14.9 [a]
	65+					16.7	0.6 [b]	5.9 [c]	9.5 [c]	0.7 [c]	0.14 [b]	11.5 [a]	20.5% [a]	1.6 [a]	42.5 [a]	9.4 [b]	13.2 [a]
OCCUPANTS	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	DRIVER ONLY					17.2	3.1 [a]	27.4 [a]	27.4 [a]	3.1 [a]	0.65 [a]	11.4 [b]	23.2% [a]	1.0 [a]	42.1 [a]	8.8 [a]	12.5 [a]
	DRIVER & 1 PASSENGER					13.5	1.5 [a]	17.1 [a]	37.7 [a]	2.0 [a]	0.39 [a]	11.3 [a]	22.1% [a]	2.2 [a]	43.7 [a]	11.5 [a]	15.8 [a]
	DRIVER & 2+ PASSENGERS					6.4	0.2 [b]	2.4 [c]	10.7 [c]	0.3 [c]	0.05 [b]	10.3 [a]	22.9% [a]	4.2 [a]	42.3 [a]	13.2 [b]	17.4 [a]
TRIP LENGTH	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	0 km					4.6	0.1 [b]	0.0 [f]	0.1 [f]	0.0 [f]	0.01 [d]	0.0	96.0% [a]	0.0	2.2 [d]	0.8 [f]	5.5 [f]
	1 km TO 5 km					16.5	2.6 [a]	5.3 [a]	8.0 [a]	0.9 [a]	0.25 [a]	16.7 [a]	33.4% [a]	1.5 [a]	21.1 [a]	2.0 [a]	5.7 [a]
	6 km TO 10 km					12.3	0.8 [a]	5.8 [a]	8.9 [a]	0.8 [a]	0.18 [a]	13.2 [a]	26.1% [a]	1.5 [a]	31.4 [a]	7.2 [a]	13.7 [a]
	11 km TO 15 km					9.7	0.4 [a]	4.9 [a]	7.8 [a]	0.6 [a]	0.13 [a]	11.6 [a]	23.3% [a]	1.6 [a]	38.3 [a]	12.3 [a]	19.3 [a]
	16 km TO 20 km					8.6	0.2 [b]	4.0 [b]	6.2 [a]	0.4 [b]	0.09 [b]	11.0 [a]	19.9% [a]	1.5 [a]	44.6 [a]	17.3 [a]	23.4 [a]
	21 km TO 30 km					9.2	0.3 [b]	6.2 [b]	9.7 [b]	0.7 [b]	0.12 [b]	10.5 [a]	18.6% [a]	1.5 [a]	50.5 [a]	24.5 [a]	29.2 [a]
	31 km TO 50 km					10.0	0.2 [b]	8.0 [b]	12.5 [b]	0.8 [b]	0.14 [b]	10.0 [a]	15.1% [a]	1.5 [a]	58.0 [a]	38.1 [a]	39.7 [a]
	51 km TO 100 km					8.1	0.1 [b]	7.2 [b]	11.8 [b]	0.7 [b]	0.10 [b]	9.5 [a]	11.5% [a]	1.6 [a]	70.1 [a]	66.3 [a]	57.1 [a]
	100+ km					3.4	0.0 [c]	5.5 [c]	10.8 [c]	0.5 [c]	0.06 [c]	9.6 [a]	6.4% [b]	1.9 [b]	87.7 [a]	160.1 [a]	109.7 [a]
DAY TYPE	Ontario		7,176,462	873	21.8	18.8	4.7 [a]	46.9 [a]	75.8 [a]	5.4 [a]	1.09 [a]	11.3 [b]	22.8% [a]	1.6 [a]	42.9 [a]	9.8 [a]	13.7 [a]
	WORKDAY			873	15.7	14.0	5.0 [a]	48.9 [a]	73.2 [a]	5.6 [a]	1.16 [a]	11.3 [a]	22.9% [a]	1.5 [a]	42.3 [a]	9.7 [a]	13.8 [a]
	WEEKEND			866	6.2	5.3	4.1 [a]	41.8 [a]	82.4 [b]	4.7 [a]	0.93 [a]	11.3 [b]	22.6% [a]	1.9 [a]	45.0 [a]	10.2 [a]	13.6 [a]

Table 5. Results for Ontario (Q1, 2012), part I.

Ontario – 1st Quarter, 2012

Canadian Vehicle Use Study – Powering Informed Decisions

Trip Characteristics

Grouping	Vehicle Type	Age	Fleet Size	Sample Size	Average Number of Study Days	Average Number of Active Days	Daily Number of Trips	Daily Vehicle km Traveled	Daily Passenger km Traveled	Daily Fuel Consumption (L)	Daily Driving Time (h)	Fuel Consumption Ratio (L/100km)	Idling Ratio	Average Vehicle Occupancy	Average Speed (km/h)	Average Trip Length (km)	Average Trip Duration (min)
VEHICLE TYPE AND AGE (NRCan & TC)	**Ontario**		**7,176,462**	**873**	**21.8**	**18.8**	**4.7 [a]**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**1.09 [a]**	**11.3 [b]**	**22.8% [a]**	**1.6 [a]**	**42.9 [a]**	**9.8 [a]**	**13.7 [a]**
		0 TO 8	4,538,722	571	22.1	19.1	5.1 [a]	50.2 [a]	82.3 [a]	5.7 [a]	1.17 [a]	11.3 [a]	22.8% [a]	1.7 [a]	43.0 [a]	9.9 [a]	13.8 [a]
		9+	2,637,740	302	21.4	18.3	4.3 [a]	41.2 [a]	64.6 [b]	4.8 [a]	0.96 [a]	11.4 [d]	22.8% [a]	1.6 [a]	42.7 [a]	9.6 [a]	13.5 [a]
		PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	PASSENGER CAR		3,869,086	445	21.3	18.7	4.6 [a]	46.4 [a]	71.3 [a]	4.3 [a]	1.05 [a]	9.2 [a]	21.6% [a]	1.5 [a]	44.0 [a]	10.0 [a]	13.7 [a]
	MINIVAN		823,659	116	21.7	19.1	5.2 [b]	48.7 [b]	97.8 [b]	6.8 [b]	1.24 [b]	13.4 [b]	25.6% [a]	2.0 [a]	39.3 [a]	9.4 [b]	14.4 [b]
	PICKUP/CARGO		985,411	114	23.5	18.0	4.6 [b]	45.9 [b]	69.7 [b]	7.5 [b]	1.02 [b]	16.1 [f]	23.5% [a]	1.5 [a]	44.0 [a]	9.8 [b]	13.2 [a]
	SUV		1,498,306	198	22.1	19.5	5.0 [a]	47.7 [b]	79.4 [b]	6.0 [a]	1.16 [a]	12.5 [a]	24.0% [a]	1.7 [a]	41.4 [a]	9.5 [a]	13.8 [a]
	PASSENGER CAR	0 TO 8	2,321,197	279	21.6	19.1	4.8 [a]	49.5 [a]	77.9 [b]	4.5 [a]	1.12 [a]	9.0 [a]	21.6% [a]	1.6 [a]	44.3 [a]	10.3 [a]	13.9 [a]
	PASSENGER CAR	9+	1,547,889	166	21.0	18.0	4.3 [a]	41.7 [b]	61.5 [b]	4.0 [b]	0.95 [b]	9.4 [a]	21.6% [a]	1.5 [a]	43.7 [a]	9.7 [b]	13.4 [a]
	PASSENGER CAR	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	MINIVAN	0 TO 8	454,040	64	21.6	19.1	5.6 [b]	48.8 [c]	95.6 [b]	7.1 [c]	1.28 [c]	14.0 [a]	25.9% [a]	2.0 [a]	38.1 [a]	8.7 [b]	13.7 [b]
	MINIVAN	9+	369,619	52	21.8	19.1	4.6 [b]	48.6 [c]	100.5 [d]	6.4 [b]	1.19 [b]	12.5 [c]	25.3% [b]	2.1 [b]	40.7 [b]	10.4 [c]	15.3 [b]
	MINIVAN	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	PICKUP/CARGO	0 TO 8	610,279	72	25.5	19.0	5.2 [b]	55.0 [b]	87.6 [c]	8.9 [b]	1.20 [b]	16.1 [a]	22.5% [a]	1.6 [a]	45.4 [a]	10.5 [b]	13.8 [b]
	PICKUP/CARGO	9+	375,132	42	20.2	16.3	3.6 [b]	31.1 [c]	40.7 [d]	5.3 [c]	0.75 [c]	16.2 [f]	25.2% [b]	1.3 [a]	41.8 [a]	8.6 [c]	12.4 [b]
	PICKUP/CARGO	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	SUV	0 TO 8	1,153,206	156	21.6	19.1	5.1 [a]	49.5 [b]	83.4 [b]	6.0 [b]	1.20 [a]	12.1 [a]	24.3% [a]	1.7 [a]	41.2 [a]	9.6 [b]	13.9 [a]
	SUV	9+	345,100	42	23.8	20.8	4.5 [b]	42.1 [c]	65.9 [c]	5.9 [c]	1.00 [b]	13.8 [a]	22.7% [b]	1.6 [a]	41.9 [a]	9.4 [b]	13.4 [b]
	SUV	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
VEHICLE TYPE AND AGE (EC)	**Ontario**		**7,176,462**	**873**	**21.8**	**18.8**	**4.7 [a]**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**1.09 [a]**	**11.3 [b]**	**22.8% [a]**	**1.6 [a]**	**42.9 [a]**	**9.8 [a]**	**13.7 [a]**
		0 TO 3	1,812,892	198	21.5	19.4	5.3 [a]	56.2 [b]	91.7 [b]	6.3 [a]	1.28 [a]	11.1 [a]	23.4% [a]	1.6 [a]	43.7 [a]	10.6 [a]	14.5 [a]
		4 TO 8	2,725,830	373	22.5	18.9	4.9 [a]	46.2 [a]	76.1 [b]	5.3 [a]	1.09 [a]	11.4 [a]	22.5% [a]	1.7 [a]	42.5 [a]	9.5 [a]	13.4 [a]
		9+	2,637,740	302	21.4	18.3	4.3 [a]	41.2 [a]	64.6 [b]	4.8 [a]	0.96 [a]	11.4 [d]	22.8% [a]	1.6 [a]	42.7 [a]	9.6 [a]	13.5 [a]
		OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
		V.OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	PASSENGER CAR		3,869,086	445	21.3	18.7	4.6 [a]	46.4 [a]	71.3 [a]	4.3 [a]	1.05 [a]	9.2 [a]	21.6% [a]	1.5 [a]	44.0 [a]	10.0 [a]	13.7 [a]
	LIGHT TRUCK		3,307,376	428	22.4	19.0	4.9 [a]	47.4 [a]	81.1 [a]	6.6 [a]	1.14 [a]	13.8 [c]	24.2% [a]	1.7 [a]	41.7 [a]	9.6 [a]	13.8 [a]
	PASSENGER CAR	0 TO 3	884,661	85	22.0	20.0	5.2 [a]	54.4 [b]	85.8 [b]	4.8 [b]	1.24 [b]	8.8 [a]	22.8% [a]	1.6 [a]	43.7 [a]	10.5 [b]	14.4 [a]
	PASSENGER CAR	4 TO 8	1,436,536	194	21.3	18.6	4.6 [a]	46.5 [b]	73.0 [b]	4.3 [b]	1.04 [a]	9.2 [a]	20.8% [a]	1.6 [a]	44.6 [a]	10.1 [b]	13.6 [a]
	PASSENGER CAR	9+	1,547,889	166	21.0	18.0	4.3 [a]	41.7 [b]	61.5 [b]	4.0 [b]	0.95 [b]	9.4 [a]	21.6% [a]	1.5 [a]	43.7 [a]	9.7 [b]	13.4 [a]
	PASSENGER CAR	OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	PASSENGER CAR	V.OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	LIGHT TRUCK	0 TO 3	928,231	113	21.1	18.7	5.4 [a]	57.9 [b]	97.4 [b]	7.8 [b]	1.32 [b]	13.2 [a]	23.9% [a]	1.7 [a]	43.8 [a]	10.7 [b]	14.7 [a]
	LIGHT TRUCK	4 TO 8	1,289,294	179	23.8	19.3	5.2 [a]	45.8 [b]	79.7 [b]	6.5 [b]	1.14 [b]	13.9 [a]	24.3% [a]	1.7 [a]	40.3 [a]	8.9 [a]	13.2 [a]
	LIGHT TRUCK	9+	1,089,851	136	21.9	18.7	4.2 [a]	40.5 [b]	69.0 [c]	5.9 [b]	0.98 [b]	14.2 [f]	24.4% [a]	1.7 [a]	41.5 [a]	9.5 [b]	13.7 [a]
	LIGHT TRUCK	OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	LIGHT TRUCK	V.OLD	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
VEHICLE TYPE AND AGE	**Ontario**		**7,176,462**	**873**	**21.8**	**18.8**	**4.7 [a]**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**1.09 [a]**	**11.3 [b]**	**22.8% [a]**	**1.6 [a]**	**42.9 [a]**	**9.8 [a]**	**13.7 [a]**
		0 TO 8	4,538,722	571	22.1	19.1	5.1 [a]	50.2 [a]	82.3 [a]	5.7 [a]	1.17 [a]	11.3 [a]	22.8% [a]	1.7 [a]	43.0 [a]	9.9 [a]	13.8 [a]
		9+	2,637,740	302	21.4	18.3	4.3 [a]	41.2 [a]	64.6 [b]	4.8 [a]	0.96 [a]	11.4 [d]	22.8% [a]	1.6 [a]	42.7 [a]	9.6 [a]	13.5 [a]
		PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	PASSENGER CAR		3,869,086	445	21.3	18.7	4.6 [a]	46.4 [a]	71.3 [a]	4.3 [a]	1.05 [a]	9.2 [a]	21.6% [a]	1.5 [a]	44.0 [a]	10.0 [a]	13.7 [a]
	LIGHT TRUCK		3,307,376	428	22.4	19.0	4.9 [a]	47.4 [a]	81.1 [a]	6.6 [a]	1.14 [a]	13.8 [c]	24.2% [a]	1.7 [a]	41.7 [a]	9.6 [a]	13.8 [a]
	PASSENGER CAR	0 TO 8	2,321,197	279	21.6	19.1	4.8 [a]	49.5 [a]	77.9 [b]	4.5 [a]	1.12 [a]	9.0 [a]	21.6% [a]	1.6 [a]	44.3 [a]	10.3 [a]	13.9 [a]
	PASSENGER CAR	9+	1,547,889	166	21.0	18.0	4.3 [a]	41.7 [b]	61.5 [b]	4.0 [b]	0.95 [b]	9.4 [a]	21.6% [a]	1.5 [a]	43.7 [a]	9.7 [b]	13.4 [a]
	PASSENGER CAR	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]
	LIGHT TRUCK	0 TO 8	2,217,525	292	22.7	19.1	5.3 [a]	50.9 [a]	87.1 [a]	7.0 [a]	1.22 [a]	13.6 [a]	24.2% [a]	1.7 [a]	41.7 [a]	9.6 [a]	13.8 [a]
	LIGHT TRUCK	9+	1,089,851	136	21.9	18.7	4.2 [a]	40.5 [b]	69.0 [c]	5.9 [b]	0.98 [b]	14.2 [f]	24.4% [a]	1.7 [a]	41.5 [a]	9.5 [b]	13.7 [a]
	LIGHT TRUCK	PRE '96	0	0	0.0	0.0	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.00 [f]	0.0 [f]	0.0% [f]	0.0 [f]	0.0 [f]	0.0 [f]	0.0 [f]

Table 6. Results for Ontario (Q1, 2012), part II.

Ontario – 1st Quarter, 2012

Canadian VEHICLE USE Study — Powering Informed Decisions

Sub-Trip Characteristics	Fleet Size	Sample Size	Average Number of Study Days	Average Number of Active Days	Daily Vehicle km Traveled	Daily Passenger km Traveled	Daily Fuel Consumption (L)	Daily Non-Idling Time (h)	Daily Idling Time (h)
VEHICLE SPEED									
Ontario	**7,176,462**	**873**	**21.8**	**18.8**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**0.84 [a]**	**0.24 [a]**
IDLING					0.0 [a]	0.0 [a]	0.4 [a]	0.00 [c]	0.24 [a]
1 km/h TO 24 km/h					2.1 [a]	3.4 [a]	0.6 [a]	0.18 [a]	0.00 [a]
25 km/h TO 49 km/h					7.6 [a]	11.9 [a]	1.0 [a]	0.20 [a]	0.00 [a]
50 km/h TO 79 km/h					15.2 [a]	24.0 [a]	1.4 [a]	0.24 [a]	0.00 [a]
80 km/h TO 99 km/h					10.3 [a]	16.5 [a]	0.9 [a]	0.12 [a]	0.00 [a]
100 km/h TO 119 km/h					9.7 [b]	16.7 [b]	0.9 [b]	0.09 [b]	0.00 [a]
120+ km/h					2.0 [c]	3.4 [c]	0.2 [c]	0.02 [c]	0.00 [a]
IDLING TYPE									
Ontario	**7,176,462**	**873**	**21.8**	**18.8**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**0.84 [a]**	**0.24 [a]**
NOT IDLING					46.9 [a]	75.8 [a]	5.0 [a]	0.84 [a]	0.00 [a]
IDLING DURING TRIP					0.0 [a]	0.0 [a]	0.2 [a]	0.00 [a]	0.15 [a]
TRIP START IDLING					0.0 [a]	0.0 [a]	0.1 [a]	0.00 [a]	0.07 [a]
TRIP END IDLING					0.0 [a]	0.0 [a]	0.0 [a]	0.00 [a]	0.02 [b]
TIME OF DRIVING									
Ontario	**7,176,462**	**873**	**21.8**	**18.8**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**0.84 [a]**	**0.24 [a]**
EARLY (06:00-08:59)					7.3 [a]	10.1 [a]	0.8 [a]	0.13 [a]	0.04 [a]
MORNING (09:00-11:59)					7.1 [a]	11.8 [a]	0.9 [a]	0.13 [a]	0.04 [a]
MIDDAY (12:00-14:59)					9.0 [a]	15.3 [a]	1.1 [a]	0.17 [a]	0.05 [a]
AFTERNOON (15:00-17:59)					11.6 [a]	18.3 [a]	1.3 [a]	0.21 [a]	0.06 [a]
EVENING (18:00-20:59)					7.1 [a]	12.3 [b]	0.8 [a]	0.12 [a]	0.03 [a]
NIGHT (21:00-05:59)					4.8 [b]	8.0 [b]	0.5 [b]	0.08 [b]	0.02 [b]
ENGINE TEMP.									
Ontario	**7,176,462**	**873**	**21.8**	**18.8**	**46.9 [a]**	**75.8 [a]**	**5.4 [a]**	**0.84 [a]**	**0.24 [a]**
COLD (< 50°C)					1.5 [a]	2.2 [a]	0.4 [a]	0.05 [a]	0.05 [a]
WARM (50°C to 80°C)					7.2 [a]	11.0 [a]	1.0 [a]	0.16 [a]	0.06 [a]
HOT (> 80°C)					38.0 [a]	62.6 [a]	4.0 [a]	0.63 [a]	0.13 [a]
NO DATA					0.1 [f]	0.1 [f]	0.0 [f]	0.00 [f]	0.00 [f]

Quality of Estimates (cv)
a: less than 5% (excellent)
b: between 5% and 10% (good)
c: between 10% and 15% (acceptable)
d: between 15% and 20% (use with caution)
e: between 20% and 35% (unreliable)
f: more than 35% (unusable)

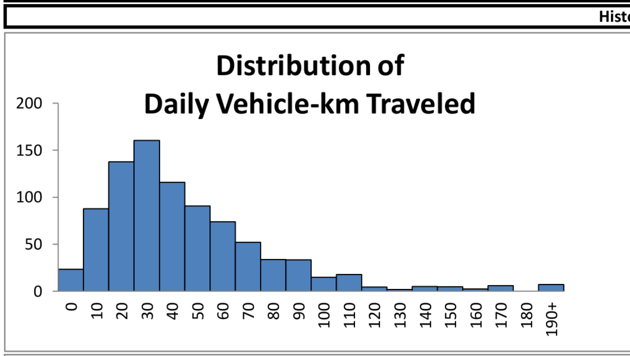
Vehicle Age
0 TO 3: 3 years old and younger
4 TO 8: between 4 and 8 years old
9+: 9 years old and older with model year post-1995
OLD: model year between 1981 and 1995
V.OLD: model year pre-1981

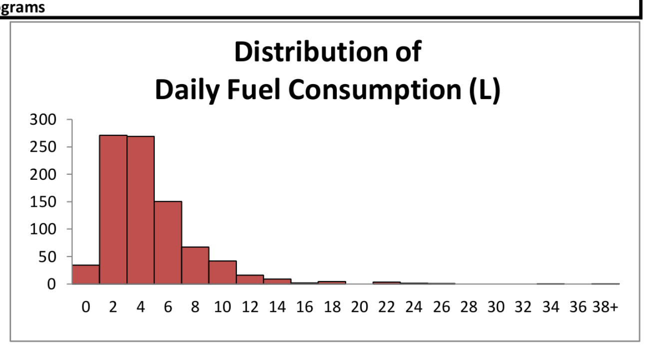
Notes on Driver Age and Gender
The estimates provided in the DRIVER AGE and GENDER category are VEHICLE characteristics, not DRIVER characteristics. Without further information on the distribution of drivers in a given jurisdiction (by AGE and GENDER), the estimates of the basic characteristics (nTrips, VKT, PKT, Fuel, Use, UseNI) cannot be used to predict the average driving behaviour of various combinations of DRIVER AGE and GENDER for that jurisdiction.

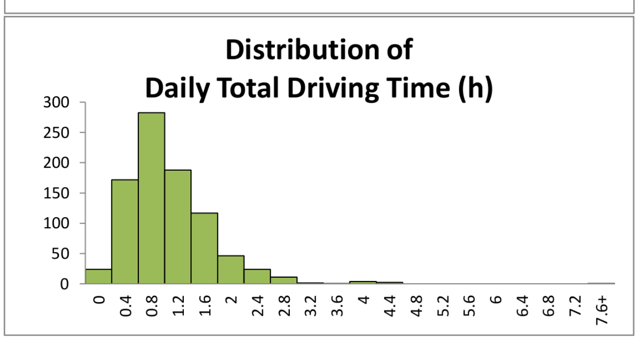
Values in columns may not add up or average (weighted) exactly to the corresponding column header due to to round off errors.

Ontario – 1st Quarter, 2012

Histograms







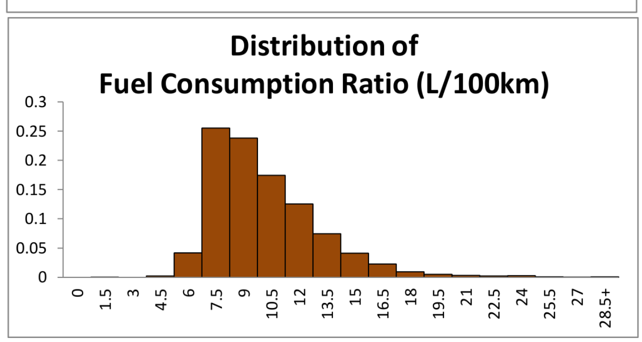


Table 7. Results for Ontario (Q1, 2012), part III.

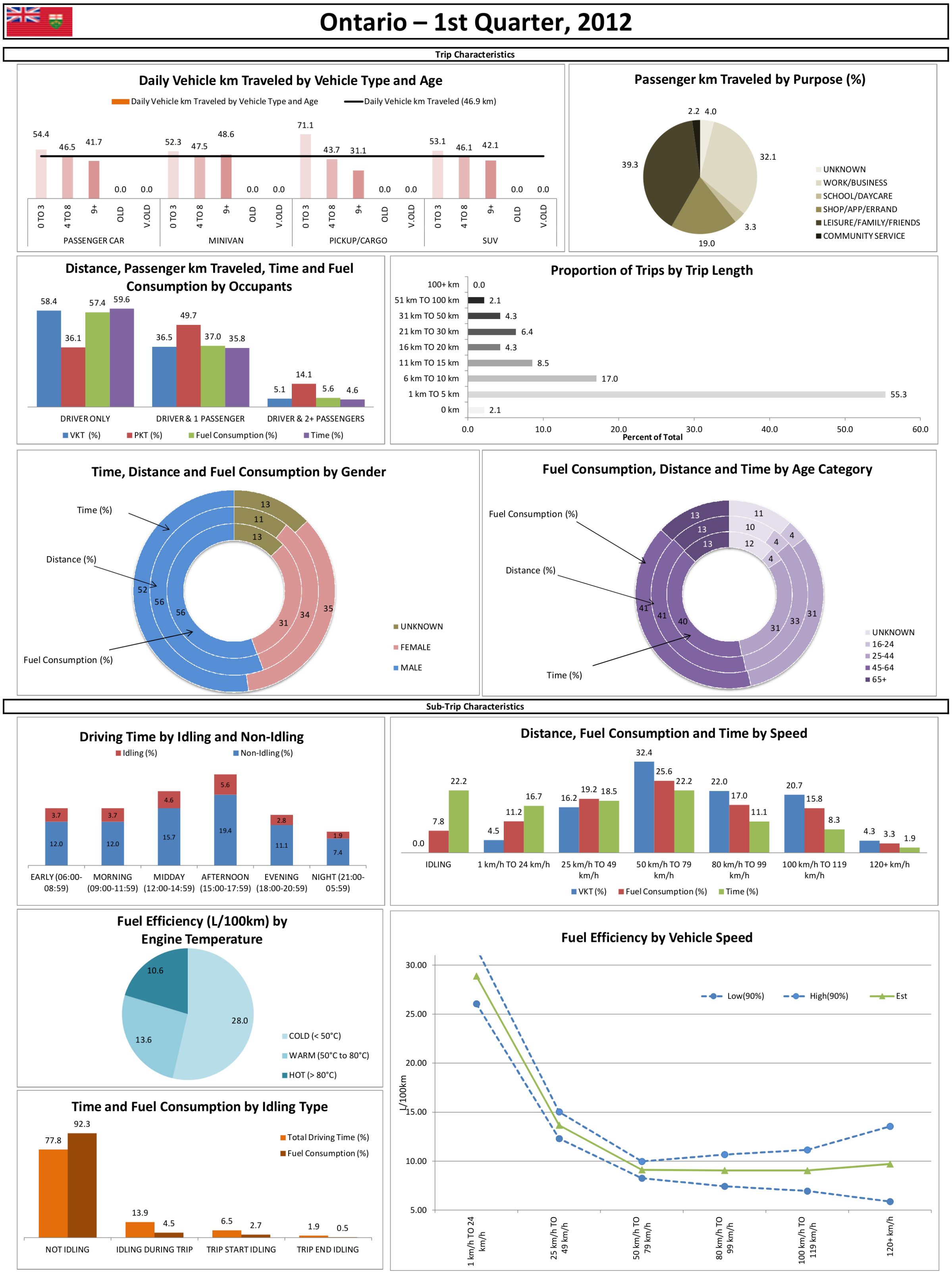


Table 8. Results for Ontario (Q1, 2012), part IV.

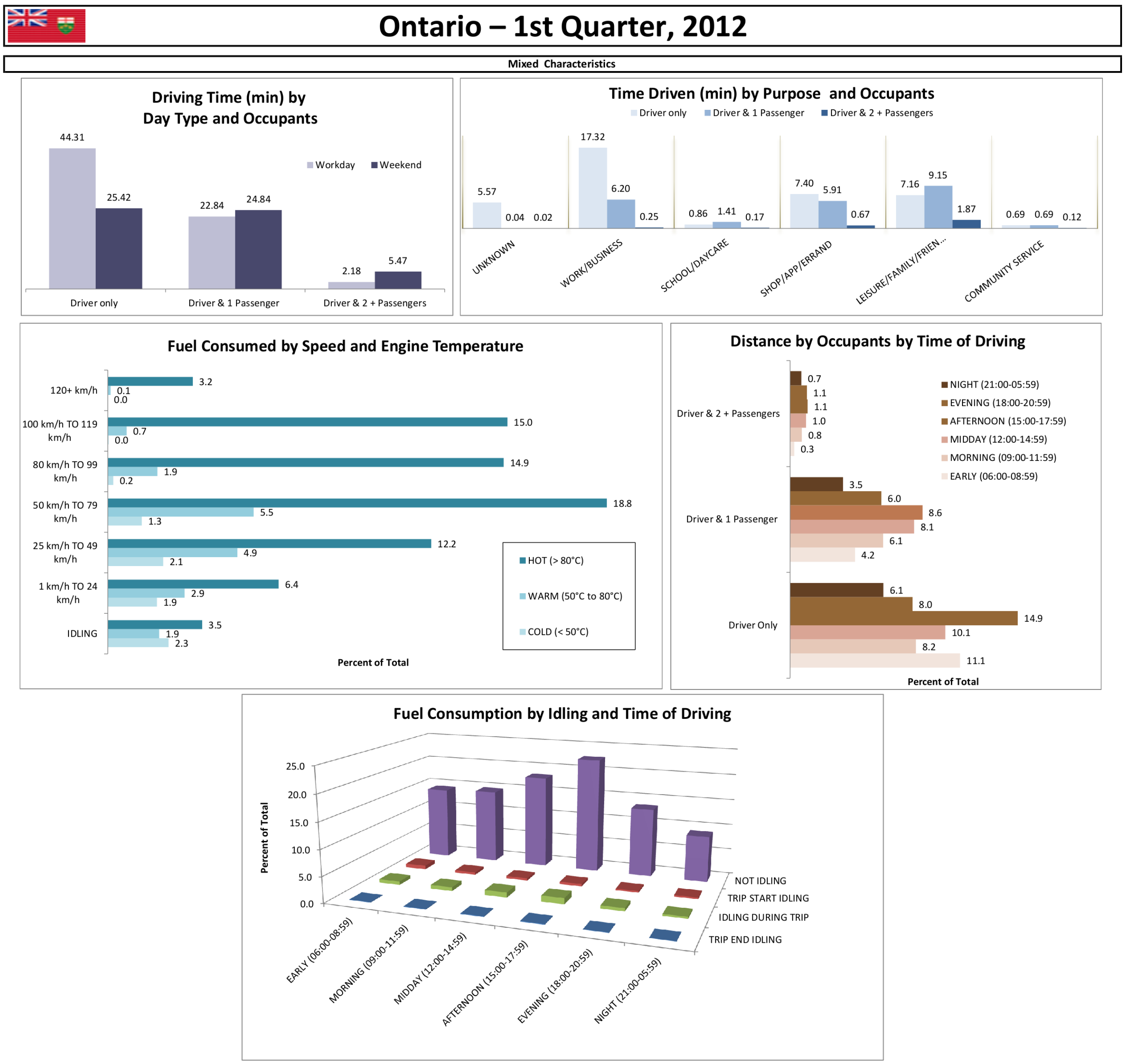


Table 9. Results for Ontario (Q1, 2012), part V.