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A Framework to Quantify Determinants of Electric Fleet Acquisition by Government and Commercial Sectors in Ontario, Canada

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Summary

This paper reports on the framework that is developed to collect stated preference choice data on EV fleet acquisitions by Government and Commercial sectors. A web-based survey is designed to collect information from establishments within the government and commercial sectors in Ontario, Canada. Data about establishment characteristics, details of existing conventional and non-conventional fleets will be collected. Design of the stated preference choice scenarios will be based on four key elements namely: Cost, Incentives, Performance and Fueling/Charging Infrastructure. The collected data will be used to develop behavioral econometric models to assess the determinants for EV adoption by Canadian fleets.

Keywords: Electric Vehicles (EV), Fleets, Commercial, Stated Preference, Willingness-to-pay

1 Introduction

Technological advancements in the manufacturing of key Electric Vehicle (EV) components, especially the battery components, and the heightened climate change awareness have renewed public's interest in EV adoption. These advancements have been focused on extending the trip range, lessening the charging time and lowering the capital cost to own an EV. Governments around the globe are supporting policies that encourage the public as well as commercial entities to consider EV adoption on a more substantial scale. As such, governments and the private sector are responsible for the majority of global EV purchases as reported by Sierczula [1]. The demand and sales of EVs to power fleets that engage in urban distribution functions have started to gain traction. Typically, fleets in an urban setting operate on predictable depot-based routes. Since the trip range provided by the EVs is sufficient (150-250 km for payloads up to 7.5 tonnes) for most route operations in mid-size urban jurisdictions, these fleet are ideal candidates for early EV adoption.

The primary objective of this research is to develop a clear understanding of the costs and benefits of adopting EVs in Canada. More specifically, the objective is to characterize the preferences and motivations of commercial

firms/government entities and vehicle rental companies as they contemplate replacing their automobile and light truck fleets with EVs. The collected data and analysis will help identify the circumstances that will lead to higher adoption rates of EVs by firms and government agencies. Related to the primary objective is the important goal of better engaging the general public with the concept of EV mobility and enhancing its understanding of all the implications, including the external costs that each gasoline-powered vehicle imposes on society. For this, a stated preference survey for fleets will be designed to understand the attitudes of government agencies and commercial establishments towards EV deployment.

The research will help the automotive sector prepare for a very different future where electric mobility assumes a leading role at the expense of the internal combustion engine. Also, the research will make Canadians better aware of the contributions of gasoline-powered vehicles to global warming and negative health outcomes through vehicle emissions. It will also demonstrate how a clean electricity generation profile in Canada can be leveraged through EV adoption for the benefit of all Canadians.

2. Review of Stated Preference Methods

Stated Preference (SP) technique is frequently used to assess how decision makers react to a change in levels of service of an alternative or to the introduction of an additional hypothetical alternative in the choice set [2]. The contemporary design of SP methods in transportation research is catered for the development of discrete choice models. In the latter, alternatives can be described in terms of their characteristics and attributes rather than their whole value. This allows the individual making the choice (i.e. decision-maker) to compare multiple alternatives encased within a single scenario, each described in terms of varying attributes, and requiring an elicited response from the decision maker. The behavioral data acquired through this method can be used to evaluate the WTP estimates of the modeled decision makers for choosing a specific alternative.

The review of the relevant academic literature suggests that the use of this particular approach is in ascendency as it provides a close replication of the situations decision makers normally face in everyday life while choosing a single option from a set of choices. Our literature review suggests that most of the earlier SP studies undertaken to assess the adoption of Electric vehicles (EVs) were conducted in response to an event or act that had transpired in recent past. For example, the efforts by Beggs et al. [3] and Calfee [4] were in response to the 1970's oil crisis. Low market representation of EV and limited trip range anxiety were the two most important concerns reported in the results by these studies.

During the early 1990s, the introduction of the zero-emission vehicle mandate by the State of California (as first enacted in 1991) inspired many researchers to conduct work to predict the potential EV demand in this American state. Some of these studies include the work of Bunch et al. [5]; Golob et al. [6]; Brownstone and Train [7] and Brownstone et al. [8]. Later on, the work by Ewing and Sarigollu [9] and Dagsvike et al. [10] identified various key factors that affect the adoption of EVs, which included reliability, limited trip range, longer charging hours, high purchase and maintenance cost. The results from these studies also pointed to a low probability of EV adoption among conventional gasoline vehicle users.

The focus on using more energy efficient transport technologies and reducing the dependence of fossil fuel in the new millennium has led to another wave of studies on the adoption of Alternate Fuel Vehicles (AFV). These studies also estimated the willingness-to-pay (WTP) for specific types of AFVs by relying on SP data; see for example: Mau et al. [11]; Potoglou and Kanaroglou [12] and Train [13]. The results from these studies suggested that the limited availability of fueling stations will have a strong negative effect on the choice of AFVs. Potoglou and Kanaroglou [12] and Hidrue et al. [2] reported that the WTP for emission reduction is noticeably high when it comes to selecting AFVs. On the other hand, results from the study by Dimitropoulos et al. [14] pointed to the existence of significant heterogeneity among decision makers in the WTP estimates for EV trip range.

Given the infancy of the EV market penetration around the globe in general and in Canada in particular, there is ample of room for research to explore the potential social and economic implications of marketing EVs. This

paper contributes to this area of transportation research by outlining a framework for collecting attribute-based stated preference data on the acquisition of EVs by Canadian governmental and commercial fleet operators. The collected data will serve as an input to advanced discrete choice models that will be used to quantify the determinants of EV fleet vehicle purchases. The WTP estimates for the EV adoption by Canadian fleets could assist stakeholders in their efforts to evaluate the circumstances that will lead to higher adoption rates of EVs, as well as identify the social and economic benefits of introducing and using EVs in various Canadian markets.

2. Canadian Fleet Characteristics

To assess the determinants of Electric Vehicle (EV) adoption by business fleets it is important to identify key features of the existing fleet operations including fleet sectors, types of vehicles acquired by these sectors, types of fuels these fleets run on and the jurisdiction they are acquired in. The following subsections highlight the characteristics of the Canadian fleet as reported in the 2015 Canadian Automotive Fleet (CMA) annual fleet fact-book [15]. The reported registrations are based on the 2014 POLK data [16]. All figures are adapted from the aforementioned fact-book.

2.1 Fleet Registration by Province/Territories

The breakdown of total fleet registrations (Car and Light Truck) for the year 2014 by jurisdiction is provided in Fig. 1. Ontario has the largest share of 37.23% of fleet registration among all jurisdictions followed by Alberta and Quebec with shares of 21.71% and 16.94%, respectively. Fleet registrations in the province of British Columbia account for 11.31% of total fleet registrations. The Maritime Provinces (i.e. New Brunswick, Nova Scotia and Prince Edward Island) account for nearly 6% of total fleet registrations.

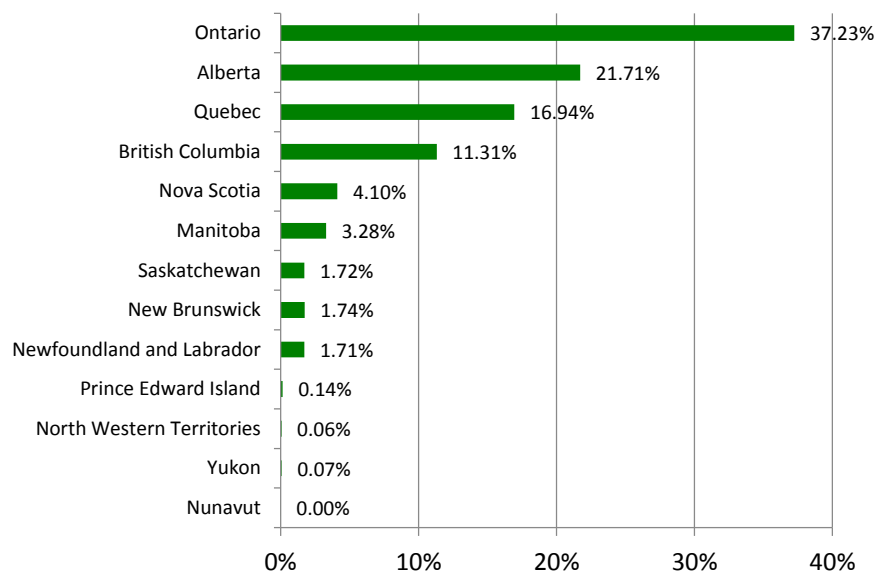


Figure 1: Fleet Registration by Province and Territories (Car and Light Truck)

2.2 Fleet Registration by Sector Type

The 2014 fleet vehicles registrations consist of two main categories: Cars and Light Trucks. The breakdown of fleet registrations by sector type is presented in Fig.2.

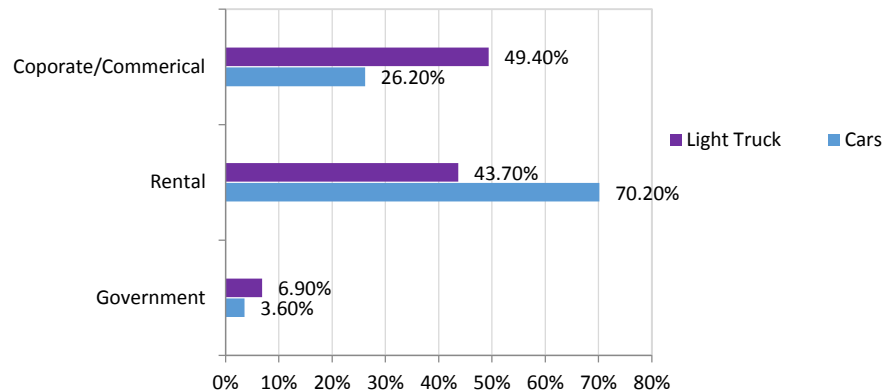


Figure 2: 2014 Fleet Registration by Sector Type

In the case of cars, the rental industry accounts for nearly 70.20% of all car fleet registrations followed by the Corporate/Commercial sector with 26.10% of the total car registrations reported in 2014. The government sector only accounts for a small fraction of the reported car registrations (3.60%). On the other hand, the corporate/commercial sector has the highest representation of a nearly half of the total 2014 truck fleet registrations (49.40%) followed by the rental sector with a share of 43.70% market share. Consistent with the low shares observed for car registrations, only 6.9% of the total light truck registrations were reported for the Government sector. The present reach is focused on government and corporate/commercial sectors as these two sectors, unlike the rental sector have some similarities in the underlying fleet acquisition processes.

2.3 Fleet Registration by Fuel Type

Conventional fuels dominate the 2014 car fleet registrations, as shown in Fig.3. Gasoline cars accounts for 84.10% of all car registrations. Cars running on flexible fuels account for 12% of the total registrations. Electric cars are only a handful of 0.01%. Gasoline based light truck registrations account for 53.50% market share. However, an interesting observation is the share of light trucks running on flexible fuels which amounts to nearly 39% of the total truck registrations. Light trucks running on more conventional fuels such as diesel account for 7.40% of total truck registrations reported in 2014.

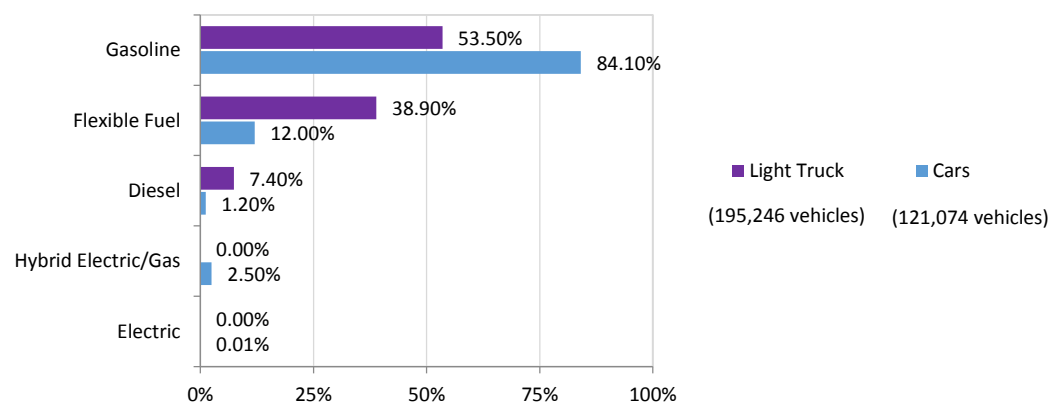


Figure 3: 2014 Fleet Registration by Fuel Type

2.4 Fleet Registration by Vehicle Type

The breakdown of car registrations based on its sub-categories is presented in Fig. 4a. Compact cars account for nearly 37.20% of the total registrations followed by Intermediate and subcompact types with registration shares of 36.60% and 14.90% respectively.

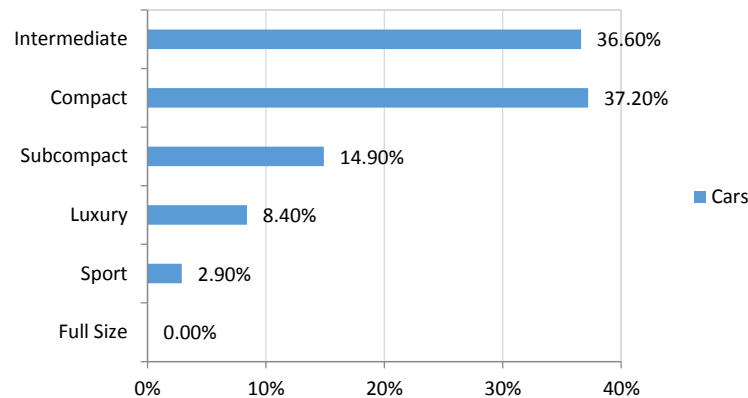


Figure 4a: 2014 Fleet Registration by Vehicle Type - Cars

Fleet registrations for different categories of Light Truck are presented in Fig. 4b. The “All Pickups” category accounts for 37.10% while the SUV category (including Compact and All other SUV) accounts for nearly 42.20% of total registrations. The registration shares of small and large vans are 12.20% and 8.5% respectively.

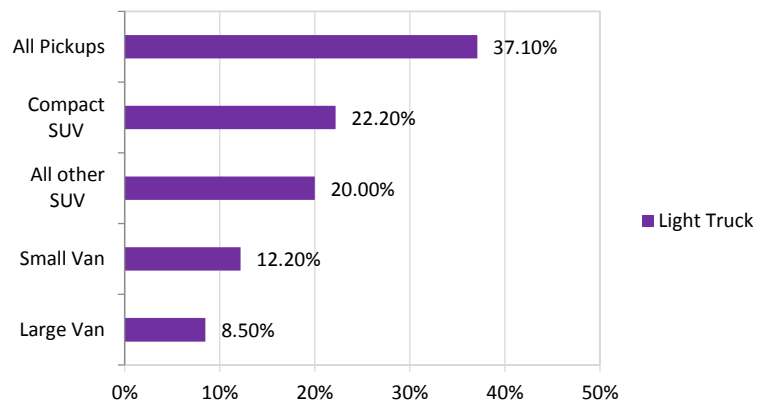


Figure 4b: 2014 Fleet Registration by Vehicle Type – Light Truck

3. Method

The literature review provides details of various statistically techniques that could be used to design stated preference scenarios. For instance, in a Full Factorial stated preference design, all combinations of the attributes levels are enumerated. Mathematically, for J alternatives with K_j number of attributes, with each k_j has I_{jk}

attribute levels, the total number of combination S in a factorial design is represented by the following expression [17]:

$$S = \prod_{j=1}^J \prod_{k=1}^{K_j} I_{jk}$$

To illustrate the design process, consider the example of three alternatives (A, B And C) with two attributes (x and y) having three levels each (Levels 1, Level 2 and Level 3) as shown in Fig.5 below. In this case, the possible number of choice combinations amount up 729. Presenting all these choice situations to a respondent in a survey is not feasible. As a remedy, Fractional Factorial design (FFD) is used to generate fewer number of choice scenarios while minimizing the correlation among attributes levels [18]. The FFD is based on the consideration of interaction effects among attributes and their levels. The main effects in FFD are considered as effect of one of the attribute on the dependent variable, ignoring the effects of all other factors and typically account for 70-90 % of explained variance [18]. On the other hand, the interaction effects pertain to the effect of one level of an attribute on the levels of another attribute and account for 5 -15 % of explained variance [18].

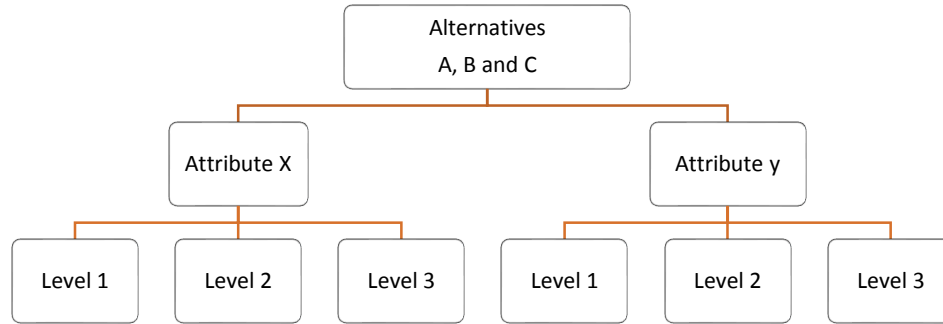


Figure 5: Example of a three alternatives choice set

The choice scenarios can be presented to the respondent either in a random fashion by selecting a subsets from the full design or in a sequential selection where the 1st subset is assigned to the 1st respondent, 2nd subset to the 2nd respondent. Alternately, a systematically structured subset can be used such that attribute level balance is achieved by avoiding over exposure and under exposure. A Simultaneous Fractional Factorial (SFFD) assumes that orthogonality among attributes not only holds within each alternatives, but also across all alternatives. In other words, an orthogonal design enforce statistical independence among the attributes [18].

This research, using Ngene software [17], will employ orthogonal FFD technique to developed stated choice scenarios that will be presented to survey participants. An orthogonal FFD deigns will ensures that that the attribute levels are not correlated both within and across the alternatives. More specially, the orthogonal FFD will contains 144 choice sets generated via Negne and 4 randomly selected choice scenarios will be presented to each respondents. The respondents will be recruited by Research Now Inc. [19] a market research company that owns panel of fleet managers responsible for operating commercial fleets. For the government sector, the contacts of fleet managers in major municipalities in different Canadian jurisdictions have been contacted to invite them to participate in this study.

3.1 Sated Preference Survey Development

An on-line survey is developed to collect data on the EV adoption of commercial and government agencies. The survey starts with a welcome message informing the participant the background of the research. A preliminary screening question before the start of the survey ensures that the survey will be completed by an employee who is managing his/her establishment's fleet and/or involved in the decision-making process pertaining to fleet acquisition. The survey will be administered in seven distinct sections as follow:

1. Existing Fleet Characteristics
2. Fleet Industry Insights
3. EV Fleet Prospects
4. Fleet Replacement Choices
5. Stated Preference Scenarios
6. Establishment General Characteristics
7. Attitudinal Statements

Questions in section 1 are designed to help understand the nature of the establishment and its associated transportation needs in a geographical context. Fleet characteristics will be acquired in this section. Section 2 will seek key industry insights from the survey participants. Section 3 will ask participant's views on the success and growth prospects of EV fleet by governmental/commercial entities. Section 4, will offer participants vehicle choices with which they can replace their existing fleets. Stated preference scenarios will be presented in Section 5. Section 6 will collect information pertaining to establishment's general characteristics. Finally, in Section 7 participants will express their opinion on attitudinal statements pertaining to the key considerations of fleet operations and acquisitions.

Based on the relevant literature review, four broad categories of attributes are identified to be included in the survey design. These are 1)- Cost, 2)- Incentives, 3)- Performance and 4)- Fuelling/charging Time and Infrastructure. The description of variables forming the stated preference experiment is provided in Table 1. The cost category is considered to be the most important factor for owning and operating a fleet [6]. The variable included contained in this category are: purchase price, annual maintenance cost and annual fueling/charging cost. Incentives, both monetary and non-monetary have been widely used in studies that model the demand of Alternative Fuel Vehicles (AFVs). The variables under the Performance category include, range per refuel/recharge, depreciation rate, extended battery warranty and tail pipe emission reduction. The last category, Fuelling/Charging Time and Infrastructure, comprises of three variables that pertain to fueling/recharging time and availability of both public and on-site fueling/recharging charging station.

Three main categories of vehicles are included in the survey namely: 1)- Cars, 2)- Light Trucks and 3)- Utility Trucks are included in the choice set. Cars are further divided into three classes i.e. compact, intermediate and full sedan. On the other hand, Light truck category features: small, intermediate and large pickup truck. Lastly, the Utility Truck category, features utility van, bucket truck and large walk-in truck. As for the choice set of alternatives, the stated preference scenarios will feature the following vehicle technologies to choose from:

- 1- **Internal Combustion Engine Vehicles (ICEVs)** - are the most common type of vehicles, usually powered by fossil fuels such as gasoline or diesel fuel
- 2- **Hybrid Electric Vehicles (HEVs)** - are more fuel-efficient than ICEVs, especially within city driving. No charging or plugging-in is required. While idling or travelling at low speeds, HEVs are powered by battery and do not generate tailpipe emissions
- 3- **Plug-in Hybrid Electric Vehicles (PHEVs)** – run on both battery and petroleum. The battery allows short range travel without emissions, while the conventional engine could be used for longer distance traveling
- 4- **Battery Electric Vehicles (BEVs)** - are powered only by a large battery, resulting in zero tailpipe emission. BEVs can be recharged at home or other designated recharging stations

Prior to the start of the Stated Preference Scenarios section, respondent will be presented with a screen showing 9 vehicle types belonging to the three main vehicle categories i.e. Cars, Light Trucks and Utility Trucks. The respondents will be asked to select a vehicle type among the 9 available types that his/her establishment/agency would most likely acquire for its fleet of vehicles. More specifically, the respondents will be asked to replace their company's fleet by assigning a specific fleet usage to the desired types of vehicles technologies. Three

types of fleet usages namely: 1) Delivering Goods, 2)- Providing Services, and 3)- Transporting Employees, will be included in each of the 4 stated preference scenarios that will be presented to the respondent. This design is inspired by the approach followed by Golob et al. [6]. An example of the stated preference scenario is presented in Table 2

Table 1: Description of Stated Preference Attributes.

Stated Preference Attributes	Description
Cost	
<i>Catalogue Price/Purchase Price (\$)</i>	pertains to total vehicle cost including all taxes minus any applicable discounts/subsidies/government monetary incentives
<i>Annual Maintenance Cost(\$)</i>	includes cost pertaining to maintaining the vehicle. Based on the type of vehicle, this cost is expected to vary in estimate. For example, as oppose to Internal Combustion Engine Vehicles (ICE), the BEV does not require an oil change
<i>Annual Fueling/Charging Cost(\$)</i>	includes cost pertaining to operating the vehicle. For ICE and Hybrid Electric Vehicle (HEV) there is no cost for electricity. On the other hand there is no gasoline cost for the Battery Electric Vehicle (BEV). For Plug-in in Hybrid Electric Vehicle (PHEV) the annual furl cost comprises of gasoline and electricity
Incentives	
<i>Monetary Incentives (\$)</i>	pertain to the various incentives offered when acquiring a BEV HEV or PHEV. For example, government rebates, tax credits
<i>Non-Monetary Incentives</i>	pertain to accessing High Occupancy Vehicle (HOV) lanes, bus lanes, and free municipal parking
Performance	
<i>Range per Refuel/Recharge(km)</i>	pertains to the maximum distance (trip range) that can be travelled on a fully charged battery
<i>Depreciation Rate (\$ per year)</i>	pertains to a decline in the value of the vehicle over vehicle's useful life. Depending on vehicle technology, depreciation rate may vary among different vehicle types
<i>Extended Battery Warranty (No. of years)</i>	pertains to warranty above and beyond manufacturers' warranty and is specific to battery
<i>Tail pipe Emission Reduction</i>	pertains to the reduction of toxic emissions that are released into the environment while operating ICE and PHEV
Fuelling/Charging Time and Infrastructure	
<i>Fueling/Recharging Time</i>	pertains to the time required to refuel (in the case of ICE,PHEV) and recharge (in the case of BEV) per occurrence on monthly basis (hours per month)
<i>Number of Public Fuelling/ Charging Stations in a 5 km Radius</i>	pertains to the number of available charging stations in public places
<i>On-site Fuelling / Charging Stations</i>	pertains to the availability of on-site fuelling / charging stations

Table2: Example of a Stated Preference Scenario

Features	Alternatives				
	Vehicle 1 (ICEV)- Base	Vehicle 2 (HEV)	Vehicle 3 (PHEV)	Vehicle 4 (BEV)	
Cost					
Catalogue Price/Purchase Price (\$)	25,000	30,000	35,000	40,000	
Annual Maintenance Cost (\$)	5,000	3,500	2,500	1,500	
Annual Fueling/Charging Cost (\$)	1,800	2,000	1,500	800	
Incentives					
Monetary	N.A	Government Rebate-1	Government Rebate -2	Manufacturer Discounts	
Non- monetary	N.A	Access to Bus Lanes	Access to HOV Lanes	Free Municipal Parking	
Performance					
Range per Refuel/Recharge(km)	300	500	700	400	
Depreciation Rate (\$ per year)	Base	8% of Base	6% of Base	4% of Base	
Extended Battery Warranty	N.A	2 years	5 years	8 years	
Reduction in Tail pipe Emissions	Base	20% of Base	80% of Base	100% of Base	
Fuelling/Charging Time and Infrastructure					
Fueling/Recharging Time	10 min	10 min	4 hrs	8 hrs	
Number of Public Fuelling/ Charging stations in a 5 km Radius	3	5	1	5	
On-Site Fuelling / Charging Stations	N.A	N.A.	Available	Available	
Fleet Replacement					
Fleet Usage: Select Applicable Type in Each Case	None	ICEV	HEV	PHEV	BEV
Deliver Goods	☐	☐	☐	☐	☐
Deliver Services	☐	☐	☐	☐	☐
Transport Employees	☐	☐	☐	☐	☐

4 Excepted Results

The execution of the proposed framework will result in the collection of a unique and high quality dataset reflecting the true decision making process involved in the acquisition of vehicle fleets by government and commercial sectors in Canada. The collected data will allow researchers to develop behavioral model to assess the determinants of the Electric Vehicle (EV) adoption by these two fleet sectors. More specifically, the models will identify the most relevant vehicle attributes and functions pertaining to the fleet acquisition processes. Such information is currently lacking. Advanced statistical and econometric techniques will be employed to estimate the willingness-to-pay (WTP) measures for the adoption of EVs by Canadian fleet operators.

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