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Modeling the Demand for Electric Vehicles in Canadian Corporate and Government Fleets

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Modeling the Demand for Electric Vehicles in Canadian Corporate and Government Fleets

By

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Modeling the Demand for Electric Vehicles in Canadian Corporate and Government Fleets

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DECLARATION OF CO-AUTHORSHIP / PREVIOUS PUBLICATION

I. Co-Authorship

I hereby declare that this dissertation incorporates material that is the result of joint research, as follows:

Chapter 3 of the dissertation is developed as a book chapter that was co-authored by Dr. Hanna Maoh and Mr. Terence Dimatulac. The chapter is currently under consideration for publication in a new book on the social cost and benefits of electric mobility in Canada that will be published by the University of Toronto Press. Chapter 4 is based on a draft of a journal article that has been submitted to *Transportation Research Part A: Policy and Practice* for publication. Chapter 5 is based on a draft of a journal article that has been submitted to *Transportation Research Part D*: *Transport and Environment*. Lastly, Chapter 6 is based on a draft of a journal article that has been submitted to *Renewable & Sustainable Energy Reviews* for publication consideration.

In Chapters 3 and 5, co-author Terence Dimatulac contributed to the discussions pertaining to the design of the online survey. He also assisted with proof-reading the text in Chapter 5. In each of the Chapters 4, 5 and 6, the research ideas, data analysis, model estimation and writeup was done by the author. The co-author, Dr. Maoh, provided directions in terms of data exploration, brainstorming and input towards answering the research questions. In addition, Dr. Maoh reviewed the text of all the chapters of this dissertation including the manuscripts that are submitted to the various journals for publication.

I am aware of the University of Windsor Senate Policy on Authorship and I certify that I have properly acknowledged the contribution of other researchers to my dissertation and have obtained written permission from each of the co-author(s) to include the above material(s) in my dissertation.

I certify that, with the above qualification, this dissertation, and the research to which it refers, is the product of my own work.

II. Previous Publication

This dissertation includes the following four original papers that have been submitted for publication in peer reviewed journals:

Dissertation Chapter	Publication title/full citation	Publication status
Chapter 3	Khan, S., Maoh, H., Dimatulac, T. (2020). Prospects of electric vehicle acquisition in Canadian fleet markets – insights from a recent survey. Under consideration for a chapter in a book relating to the social cost and benefits of Eclectic Mobility in Canada - to be published by the *University of Toronto Press*.	Under Review
Chapter 4	Khan, S., Maoh, H. (2020). Investigating attitudes towards electric vehicle feasibility in Canadian fleets - a factor analysis approach. Submitted to *Transportation Research Part A: Policy and Practice*.	Under Review
Chapter 5	Khan, S., Maoh, H., Dimatulac, T. (2020). The demand for electrification in Canadian fleets: A latent class modeling approach. Submitted to *Transportation Research Part D: Transport and Environment*.	Under Review
Chapter 6	Khan, S., Maoh, H. (2020). Determinants of battery electric vehicle acquisition timeframe in Canadian corporate and government fleets - an ordered logit model approach. Submitted to *Renewable & Sustainable Energy Reviews*.	Under Review

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ABSTRACT

This dissertation investigates factors affecting the acquisition of Electric Vehicles (EVs) in the Canadian fleet market. Data from a random sample of over 1,000 fleet operating entities (FOEs) that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles) in Canadian cities were collected via an online survey titled Canadian Fleet Acquisition Survey (CFAS) in December 2016. The CFAS gathered information about the general characteristics of the surveyed FOEs, their existing fleet characteristics, future acquisition plans and EV fleet prospects. A stated preference (SP) section was introduced in the CFAS to identify the circumstances that will lead to higher adoption rates of EVs for fleet usage. The SP responses were based on six choice scenarios, each featuring four powertrains (Internal-Combustion Engine Vehicles, Hybrid Electric Vehicles, Plug-in Hybrid Electric Vehicles and Battery Electric Vehicles). The CFAS also included attitudinal statements to understand the issues that support or deter EV acquisition in fleets.

Chapters 4, 5 and 6 of the dissertation are dedicated to employing various modeling approaches including Exploratory Factor Analysis (EFA), Analytical Hierarchy Process (AHP), and advanced discrete choice models such as Latent Class (LC) and Ordered Logit (OL) models to investigate the feasibility of EVs in fleets from various perspectives. This includes investigating EV adoption with respect to entity type (i.e., corporate vs. government), fleet type (car fleets vs. pickup truck fleets vs. utility vehicles fleets), industry type (transportation and warehousing vs. retail trade) as well as the temporal dimension for fleet electrification (i.e., short run vs. long run).

The estimated EFA models identify latent constructs of behavior on various aspects and attitudes relating to EV adoption and provides evidence of attitudinal heterogeneity in the corporate and government FOEs. The AHP approach validates the logical consistency of the attitudinal responses obtained from the sampled FOEs. The four latent classes of FOEs identified in the estimated LC choice model provide novel results regarding the factors that affect acquisition of EVs in fleets. The willingness-to-pay estimates from the LC model reflect the taste variation among the four latent classes for improvements in certain attributes of EVs. The results from the OL modelling exercise successfully explain the behavior governing the acquisition timeframe for battery electric vehicles in the sampled FOEs and highlight the heterogeneity in the factors affecting the acquisition timeframe.

Finally, evidence-based policy guidelines are proposed to help stakeholders make informed decisions regarding the acquisition of EVs in fleets. Key guidelines include investment in public charging infrastructure, incentivizing on-site charging infrastructure, engaging FOEs with climate action plan, and harvesting positive attitudes towards fleet electrification through various campaigns. The research work described in this dissertation is the first of its kind to collect and analyze revealed and state preference data on the acquisition of EVs in Canadian fleets including the timeframes under which these vehicles will likely be acquired. The work is seminal as it fills an important gap in the current knowledge about the motivations and preferences towards fleet electrification in Canada.

DEDICATION

This research is dedicated to my mother, my true inspiration and to the loving memory of my late father.

ACKNOWLEDGEMENTS

The research presented in this dissertation would not have materialized without the help and contributions of many individuals. First and most importantly, I thank Dr. Hanna Maoh, my supervisor, for his mentorship throughout the course of this research. His vast and in-depth knowledge and expertise in the area of transportation engineering inspired me to seek excellence in the conducted research.

The members of my dissertation committee, through their feedback, contributed to improving the quality of the conducted research. I extend my thanks to Dr. Bill Anderson of Cross-Border Institute (CBI) for serving on my committee. By working at the CBI as a Transportation Research Associate for the past 8 years, I have learnt a great deal from Bill and Hanna, both on professional and personal level. Dr. Chris Lee's detailed feedback on the research proposal, enabled me to improve upon various aspects of the research presented in this dissertation. I also thank Dr. Kemal Tepe for his time on this dissertation committee and Dr. Catherine Morency for serving as the external examiner and providing valuable comments and suggestions to further the explanation and discussion of the research findings.

It is relevant to mention here that this research stems from a major project undertaken by the McMaster University that quantifies the social cost and benefits of electric motility in Canada. Within this context, I would like to acknowledge the support of Dr. Mark Ferguson, Dr. Moataz Mohamed and the late Dr. Pavlos Kanaroglou of the McMaster University in providing timely and insightful feedback during the early phase of this research. Further, I am thankful to the Social Sciences and Humanities Research

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There are a few individuals at the CBI who one way or the other, helped me with my research. I thank Haibin Dong for his efforts in programming the online survey instrument that was used to collect the data for this research. My sincere thanks to Terence Dimatulac and Patricia Simone for being great colleagues of mine for the past so many years.

Finally, I thank my wife and kids for their continuous support throughout this research. I could not have accomplished this milestone without their understanding and unfaltering love. Thank you!

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CHAPTER 1

INTRODUCTION

1.1 Preface

Freight transportation in North America is on the verge of some potentially unsettling, innovatory changes. These changes involve adoption of fuel-saving technologies, use of connected, automated or self-driving commercial vehicles. The changes are primarily a response to the evolution of e-commerce, urbanization and negative environmental impacts of the conventional gasoline-based vehicles. Fleet operating organizations, both in public and private sectors often have large fleets with extensive usage and therefore contribute significantly to the carbon footprint. In fact, in 2017, the transportation sector was the second-largest contributor of greenhouse gasses (GHG) in Canada, representing 28% (approximately 201 Mt CO_2 eq) of the total GHG emissions (ENRC, 2019). The rate of adoption for fuel-saving technologies in freight transportation is on the rise (NACFE, 2018) and the discussions on benefits and costs of adopting such technologies including all-electric powertrains have drawn significant attention by the fleet industry.

Governments around the globe are working on polices that target the adoption of EVs by households and firms. A 'Strategic Outlook of the Global Electric Vehicle Market' reveals that up till 2013, majority of EVs were procured by governments agencies and private companies (IEA, 2015). Canada is part of a 16-member government 'Electric Vehicle Initiative' run by the International Energy Agency. Figure 1-1 shows the growth of electric powertrain vehicles in Canada from 2013 and 2018 along with the other developed countries. It is interesting to note that countries like Norway and Sweden with only a fraction (i.e., about 15% and 25%, respectively) of the population of Canada have significantly higher market shares of EVs.

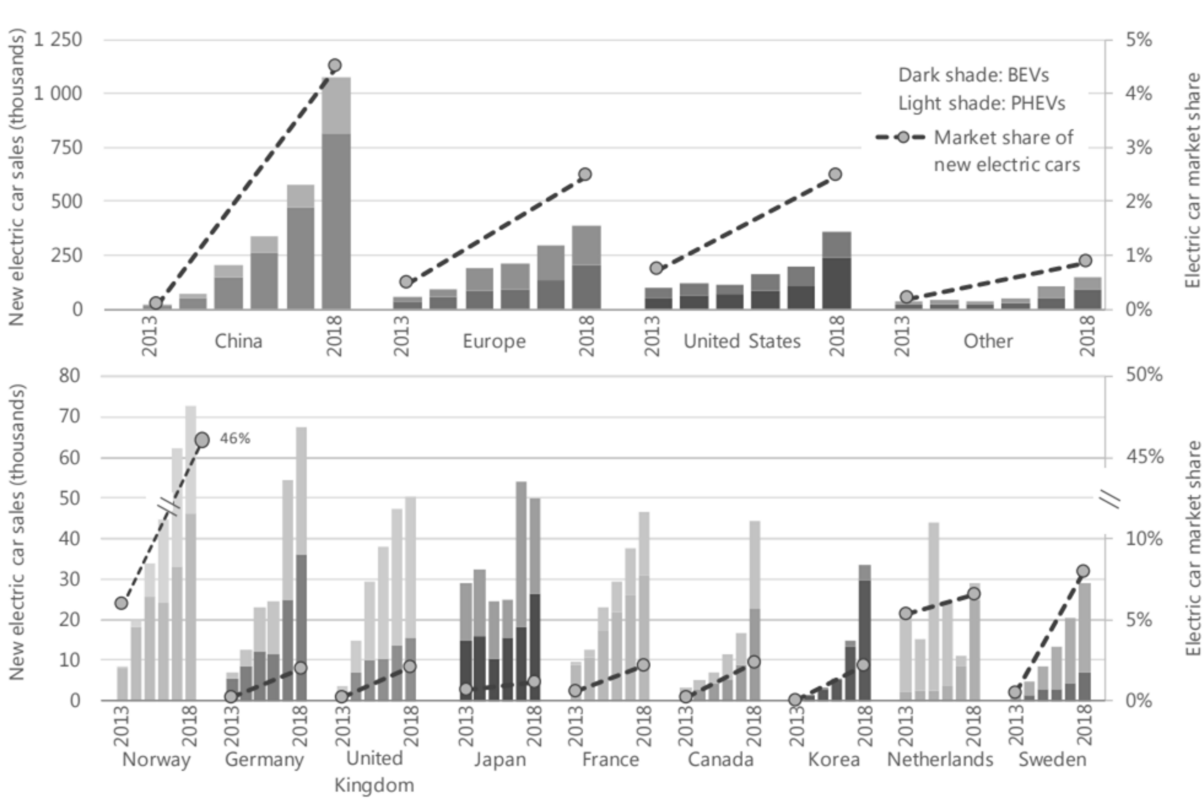

Figure 1-1 Global EV sales and market share
(source: IEA, 2019)

The low demand or acquisition of EVs by Canadian fleets is a pressing issue given the lack of knowledge on the conditions needed to encourage fleet electrification. In this respect, fleets can be considered as ideal candidates for electrification. Many fleets typically operate on predictable depot-based routes where the payload and range provided by commonly available EVs can be sufficient for most route operations in mid-size cities. As such, organizations engaged in depot-based trip activities could expect to have substantial savings from operating EVs in their fleets. The potential benefits of using EVs in fleets could include savings in operating and maintenance costs, improved social image of organizations and, reduction in transportation sector's overall emissions.

The remainder of this chapter provides further context to this research by highlighting various issues and considerations that are relevant to the research questions and objectives.

1.1.1 Cleaner Energy Considerations

Electric vehicles (EVs) powered by coal or gas-based electricity significantly increase the adverse environmental impact compared to conventional vehicles, while EVs running on electricity generated by renewable sources such as hydro, solar and wind, reduce the same by at least 50% (Tessum et al. 2014). In the Canadian context, national electricity generation emission level (about 167 Mt CO_2 eq/GWh) is considerably below the accepted 600 Mt CO_2 eq /GWh threshold, placing Canada as one of the cleanest electric power producers in the world (Kennedy, 2015). According to Figure 1-2, the three largest provinces in Canada (i.e., Ontario, Quebec, and British Columbia) rely on renewable and/or low-carbon sources of energy to produce electricity. This implies that the scarcity of EV ownership in Canada, in general, is due to barriers not related to the source of electricity needed to charge these vehicles. Such observation warrants a more thorough investigation on how a clean electricity generation profile in Canada can be leveraged to increase the adoption of EVs in Canadian fleet operating entities (FOEs).

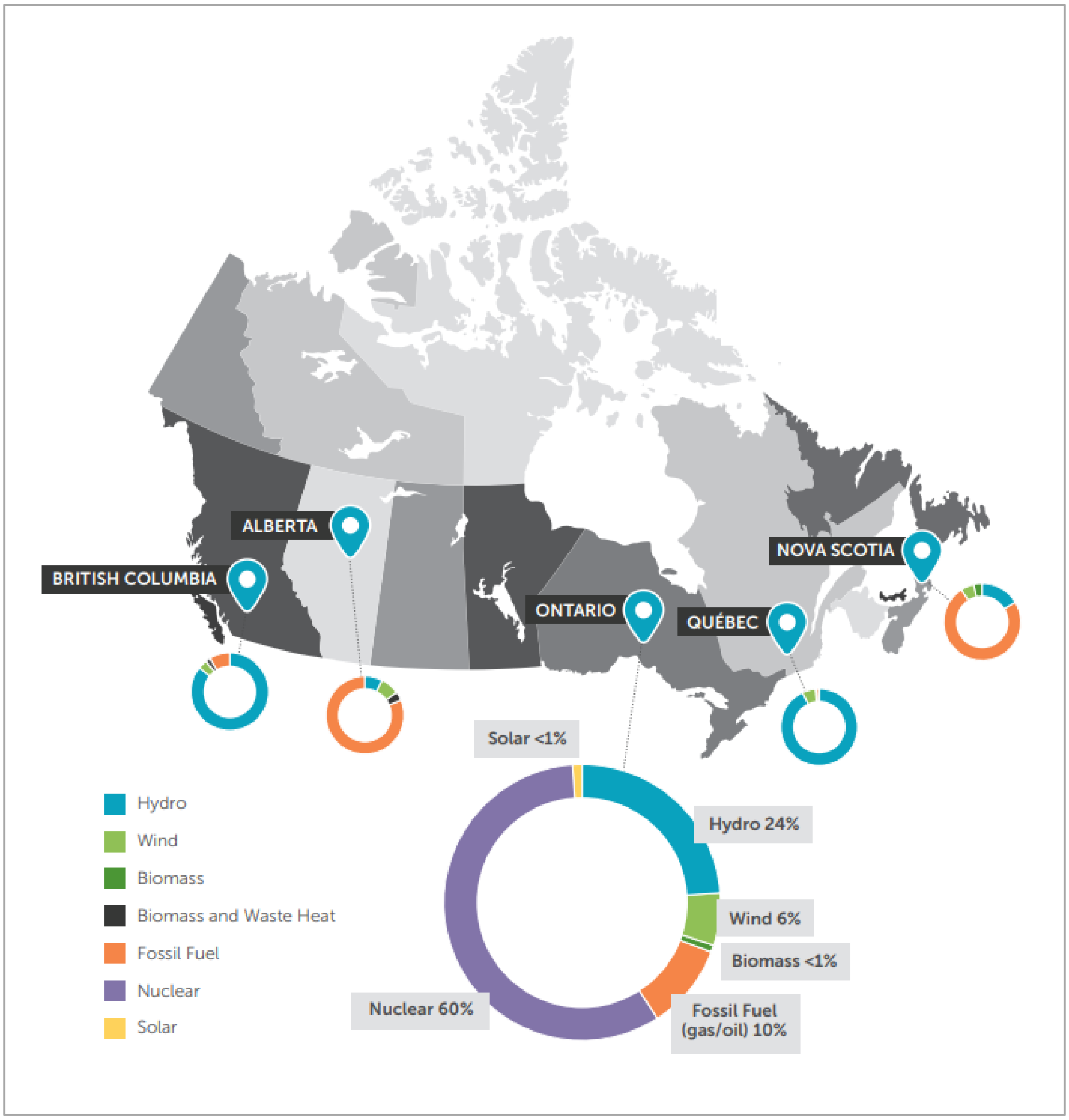

Figure 1-2 Electricity generation by source type across Canada
(source: ElectrcitymapAPI, 2018)

1.1.2 Growth of Canadian Fleets

The overall growth in Canadian fleets in the last 10 years (i.e., from 2009 to 2018) is shown in Figure 1-3. Car fleet registrations have been steady for the past decade or so. On the other hand, light truck registrations have increased significantly during the same period, as much as 90%. Overall, fleet registrations have increased by nearly 62% in the last 10 years from 254,813 in 2009 to 413,212 in 2018. The shares of car and light truck fleets in 2018 were 26% (106,515) and 74% (306,697), respectively (CAF, 2019). Nearly 28% of the total car fleet registrations were reported in the corporate sector while the government sector accounted for 3.3% of the car fleet, as shown in Figure 1-4. For light truck fleets, shares of 44.2% and 6.1% were reported for corporate and government sectors, respectively.

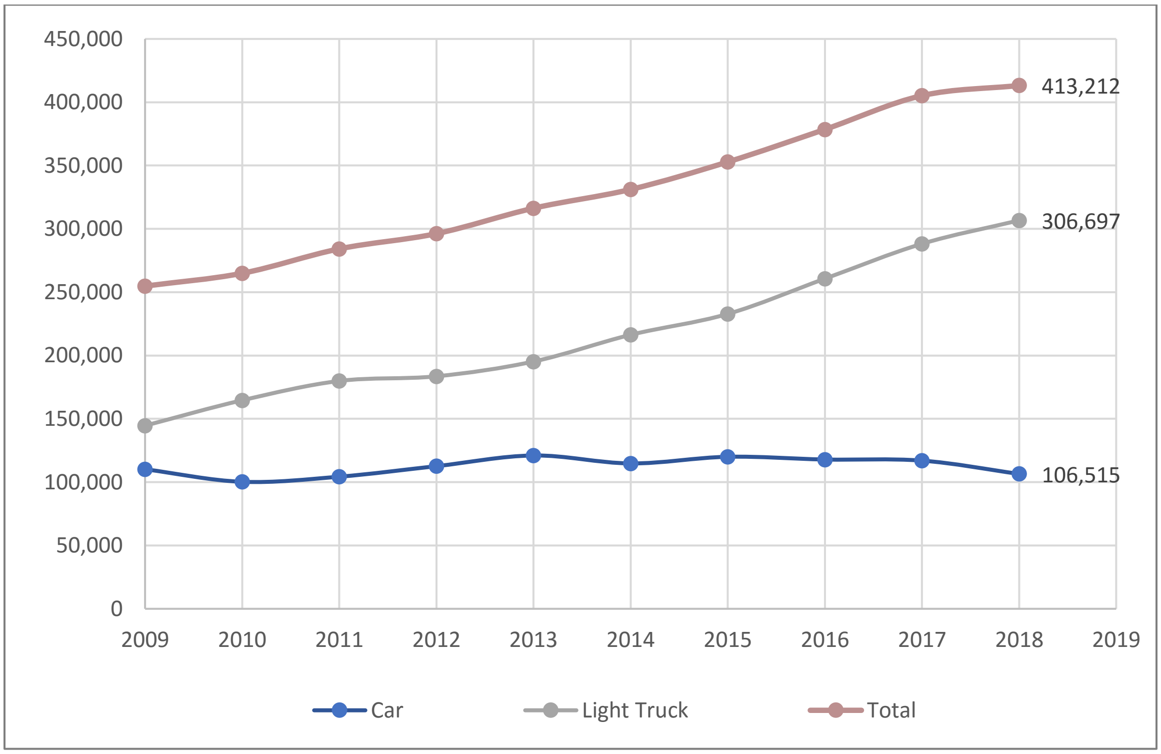

Figure 1-3 Fleet registrations by vehicle type (2009-2018)
(data source: CAF, 2019)

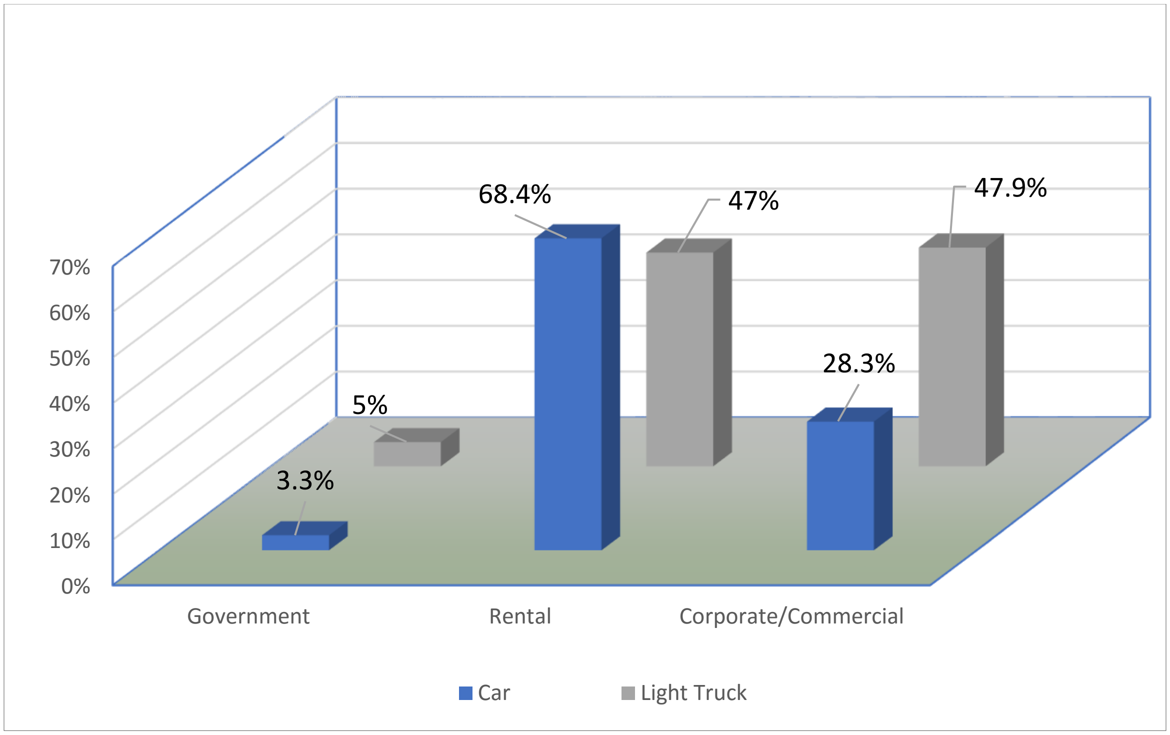

Figure 1-4 Fleet registrations by sector (2018)
(data source: CAF, 2019)

1.1.3 Current Share of EVs in Canadian Fleets

In terms of fleet registration by fuel type, conventional gasoline fuels dominated the landscape with shares of 86.3% and 68.7% for car and light truck fleets in 2018, respectively, as shown in Figure 1-5. Flexible fuels such as Ethanol/Methanol accounted for 9.2% among car fleets and 25.2% among light truck fleets. Interestingly, electric powertrain vehicles had minuscule shares of only 1% in electric car fleets and 0.8% in the hybrid light truck fleet registrations. Such minimal market shares of EVs in Canadian corporate and government fleets warrant the need to explore and investigate the factors that are responsible for the status quo shares and those that could potentially accelerate their adoption in the Canadian fleet market.

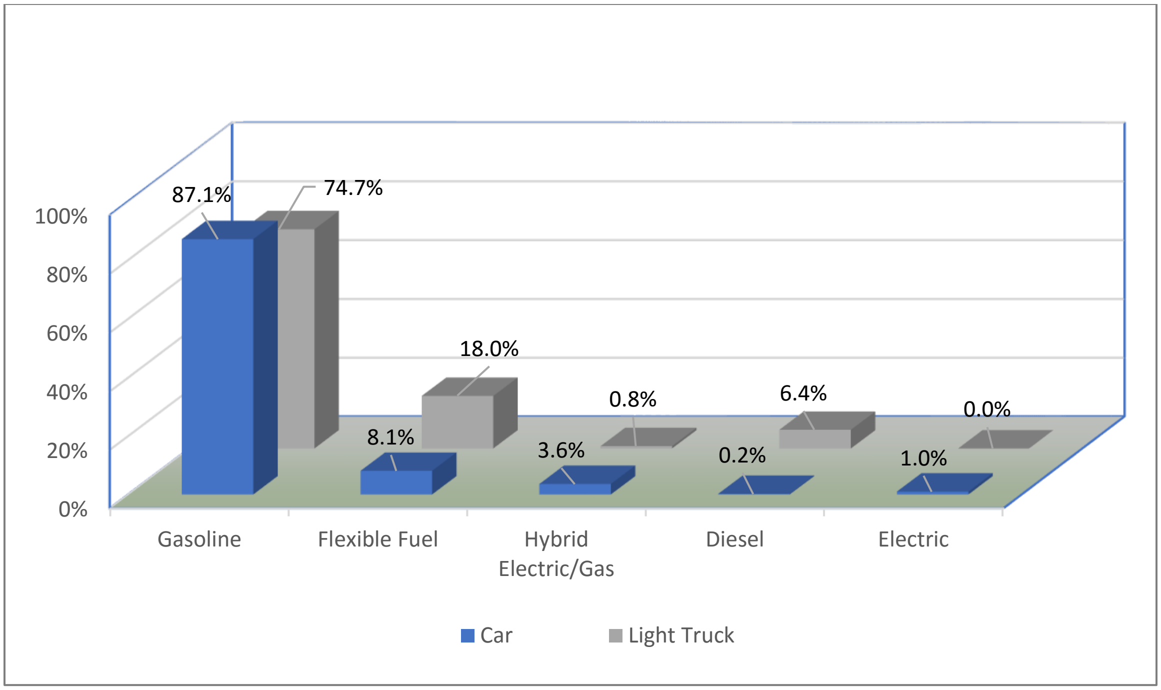

Figure 1-5 Fleet registrations by fuel type (2018)
(data source: CAF, 2019)

1.2 Research Questions and Objectives

While the potential adoption of alternative fuel vehicles (AFVs) including electric vehicles (EVs) among household consumers has been addressed extensively in the literature, there is a clear absence when it comes to the adoption of EVs among fleets. As such, the research in this dissertation will fill the existing gap in knowledge about the broader picture of fleet operations in Canada. It will also examine the factors and conditions that could give rise to fleet electrification among corporate and government entities including investigating the temporal nature of EV adoption. To achieve this main objective, a multitude of challenges are tackled with their description given in the below sub-sections.

1.2.1 Existing State of Fleet Operations in Canada

In order to meet its main objective which is aimed at investigating the viability of

EVs in Canadian fleets, this research seeks to address the following research question:

What do we know about fleet operations in Canada and what are the major fleet sectors? What are the key characteristics of the existing car, light truck and utility vehicle fleets in the major Canadian markets?

The above question addresses the need for new data to investigate the viability of EVs in Canadian fleets. A detailed survey instrument, entitled Canadian Fleet Acquisition Survey (CFAS), is developed to collect data from Canadian FOEs. The design of the survey is based on extensive consultations with the stakeholders and feedback from industry partners and includes data from over 1,000 randomly selected organizations that own and operate light fleets (i.e., cars, pickup trucks and utility vehicles) in Canadian cities. The collected data includes organization's general characteristics, existing fleet characteristics, future acquisition plans and EV fleet prospects.

1.2.2 Underlying Behavioral Constructs in Fleets Towards Electrification

Users' acceptance is one of the most critical factors influencing the success or failure of a new technology (Davis, 1993). To this end, this research poses the following question:

What underlying behavioral constructs exist regarding the acquisition of EVs for fleet usage by Canadian organizations?

An attitudinal section is formulated in CFAS to understand the attitudes and perceptions that influence EV acquisition in fleets. The attitudinal statements are introduced in the last section of CFAS which is divided into three sets of statements to gauge attitudes and perceptions of the participating organizations regarding the adoption of EVs in their fleets. The responses from this section are used in an Exploratory Factor

Analysis exercise to investigate the underlying behavioral constructs that exists in fleets towards various issues regarding EVs.

1.2.3 Determinants of EV Adoption in Fleets

The use of the Stated Preference (SP) method to understand the potential for accepting new technologies when acquiring vehicles is in ascendency in transportation research. Contemporary design of SP methods is catered for the development of discrete choice models, which capture the behavior consumers normally exhibit in everyday life while choosing a single option from a set of alternatives. In the latter, alternatives can be described in terms of their characteristics and attributes (Hidrue et al. 2011). Tied to the main objective of this research, the work here aims to answer the following question in a stated preference setting:

Can fleet operating entities be characterized based on their vehicle powertrain preferences and if so, what are the underlying factors that influence their choices for conventional and electric-based powertrains?

The SP choice scenarios of CFAS are used to collect data pertaining to consumer's evaluation of multi-attributed hypothetical choice alternatives that might become available in the near future. The scenarios focus on the viability of four key powertrains, namely: internal combustion engine vehicles (ICEV), Hybrid electric vehicles (HEV), Plug-in electric hybrid vehicles (PHEV) and Battery electric vehicles (BEV). A latent class choice model is estimated with revealed and stated preference data from CFAS to answer the above research question. More specifically, factors affecting the acquisition of Electric Vehicles (EVs) in Canadian FOEs are identified. The results from the estimated model also provide an assessment of the factors affecting the acquisition of EVs by Canadian FOEs and highlight the underlying factors that vary between corporate and government FOEs.

1.2.4 Determinants of BEV Acquisition Timeframe in Fleets

Large organizations are often at the forefront of embracing new technologies and are willing to invest in such technologies sooner than the smaller organizations (Globisch et al. 2018). This is evident from Amazon Inc.'s recent decision to acquire 100,000 all-electric vans for its delivery operations (CNBC, 2019). Such massive uptakes underline the potential of larger than average FOEs as being the front runners in early EV adoption. Related to the main objective of this research, a key aspect of Battery Electric Vehicle (BEV) acquisition in fleets that needs to be investigated is its acquisition timeframe. To this end, this research seeks to answer the following question:

Will the potential of electrification vary by acquisition timeframe among different fleet sectors and as well as fleet vehicles?

An ordered logit model is estimated using the revealed portion of the CFAS to examine the determinant of the BEV acquisition timeframe in the Canadian fleet market. This research is the first of its kind in Canada to collect and analyze revealed data on the acquisition timeframes of EVs in fleets.

1.2.5 Formulation of Policies Encouraging EV Adoption in Fleets.

Policies and strategies geared towards encouraging EV adoption are needed to help Canadian FOEs prepare for a future where electric mobility is likely to take on a leading role at the expense of the conventional internal combustion engine vehicles. To this end, this research poses the following question.

What type of policy guidelines should be put in place to enable Canadian fleets to move towards adopting EVs in the near future?

The policies proposed in this research will help inform decision-makers and stakeholders of FOEs about the potential benefits of electrification of their existing fleets including the substantial economic savings since electrification will reduce the overall operating cost. Also, the electrification of fleets is expected to result in environmental and economic benefits since EVs can lower global warming and mitigate the negative health outcomes from air pollution through reduced tail-pipe emissions.

1.3 Dissertation Outline

The remainder of this dissertation is organized as follows:

Chapter 2 provides an overview of the design of the CFAS instrument used to collect the data needed in this research (objectives 1.2.1 – 1.2.5). It describes, in details, the different sections of the CFAS and the rationale for including them in the design. It also describes the data collection framework and the tasks undertaken to design the Stated Preference (SP) component of the CFAS. The chapter includes the description of the different powertrain alternatives, their attributes and levels, and details of the SP method used in designing the choice scenarios. Important considerations such as the 'Cognitive Burden' in SP design are also described. The chapter also highlights novel aspects of the CFAS that distinguish it from past efforts on the subject matter.

Chapter 3 investigates the existing attitudes and perceptions towards EVs in the Canadian fleet market. The work is informed by the insights from the CFAS data that pertained to the surveyed corporate and government entities. It does so by dissecting the collected data from various perspectives. The chapter describes the general characteristics of surveyed fleets in terms of their geographical location, operation, usage, average annual mileage and acquisition status using tables and graphs (objectives 1.2.1). Highlights of the SP shares obtained from the CFAS are also presented and discussed in this chapter. The chapter also includes results pertaining to the attitudinal section of the survey.

Chapter 4 investigates the attitudes of the sampled FOEs towards EV adoption using the Exploratory Factor Analysis (EFA) approach. It presents results from a series of EFA models that are estimated to identify latent constructs of behavior on various aspects and attitudes relating to EV adoption (objectives 1.2.2). The chapter also explores the potential variation of attitudes that exists in the corporate and government FOEs towards adopting EVs in their respective fleets. The logical consistency of the attitudinal data obtained from the sampled FOEs is then checked by employing the Analytical Hierarchy Process (AHP) approach.

Chapter 5 investigates the factors governing the choice decision of FOEs to adopt a specific type of vehicle powertrain including plug-in hybrid and battery electric vehicles. A latent class (LC) discrete choice model is estimated using the revealed and stated preference data collected via the CFAS. The LC model can identify latent classes among the modeled FOEs, thus capturing the heterogeneity in the choice behavior of these FOEs (objective 1.2.3). Willingness-to-pay estimates from the LC model are calculated to capture the taste variation among the identified latent classes for improvements in certain attributes of EVs. Informed by the model results, the chapter also provides details of the various policy instruments that can be formulated to entice the acquisition of EVs in corporate and government sectors (objective 1.2.5).

Chapter 6 examines the determinants of the Battery Electric Vehicle (BEV) acquisition timeframe in the Canadian market using revealed EV prospects from the CFAS (objective 1.2.4). Several ordered logit models are estimated to achieve the objective. The determinants include variables representing the characteristics of the surveyed FOEs, attributes of the fleet vehicles they operate, and attitudinal tendencies towards fleet electrification. Results from this chapter provide evidence to help propose policies that could help BEV acquisition in a shorter timeframe (objectives 1.2.5).

Finally, Chapter 7 provides the conclusions to this research by synthesizing the results obtained from the Chapters 3 to 6. It describes the new knowledge generated through this research on the attitudes and perceptions of the FOEs towards adopting EVs in their fleets. The chapter summaries the novel insights, recommends policies, and describes their implications to the decision-making process of EV adoption in corporate and government fleets (objectives 1.2.5). Directions for future research are also provided in this chapter.

With automotive sector's renewed commitment to electric mobility in the 21st century, the type of research conducted in this dissertation is very likely to gain traction in near future. The work also has the potential to pave the way for progress towards a greener and sustainable transportation system in Canada.

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CHAPTER 2

SURVEY DESIGN

2.1 Introduction

Ever since the application of sampling theory in the 1930’s, surveys have become a valuable tool for collecting information to examine human behavior (Vehovar and Lozar, 2008). Surveys are usually used to collect data from sampled respondents with the purpose of generalizing the findings to a much larger population. Similar to their application in the social sciences and marketing research, surveys have been used extensively in the field of transportation to collect data that can be used to address urban planning issues and to help inform future growth policies. There are number of ways in which surveys are administrated, including but not limited to the traditional paper-based mail-in written questionnaire, computer assisted telephone surveys, face-to-face discussions with focus groups, and more popular online surveys.

The focus of present research is on assessing the feasibility of Electric Vehicles (EVs) in Canadian fleets. Organizations operating fleets, in general, are capable of large-scale vehicle acquisitions. That makes them potential candidates for early adoption of fuel-saving technologies such as battery powered EVs. The adoption of EVs in fleets could result in substantial savings since many fleets typically operate on predictable depot-based routes and the payload range provided by commonly available EVs is sufficient for most trip routes in mid-size cities. The growth trends of Canadian fleets presented in Section 1.3

provide evidence of significant potential for the adoption of fuel saving technologies including EVs.

A detailed survey instrument was developed in this research to collect data from fleet operating organizations in both corporate and government sector. The survey, titled the Canadian Fleet Acquisition Survey (CFAS) was launched in December 2016 and collected data from over 1,000 Canadian organizations that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles) across the country.

The collected data includes organization's general characteristics, existing fleet characteristics, future acquisition plans and EV fleet prospects. A key feature of the CFAS was its Stated preference (SP) choice scenarios. These scenarios are used to collect data pertaining to consumer's evaluation of multi-attributed hypothetical choice alternatives that might become available in the near future. SP choice-based surveys are frequently utilized in marketing and transportation planning as they offer the analyst a unique opportunity to quantify the future demand of a certain product and/or alternative. 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 (Hidrue et al. 2011). The SP section of the CFAS focused on the viability of four key powertrains namely: Internal Combustion Engine Vehicles (ICEVs), Hybrid Electric Vehicles (HEVs), Plug-in Electric Hybrid Vehicles (PHEVs) and Battery Electric Vehicles (BEVs). The collected data were used in subsequent analyses to identify the factors and circumstances that could lead to higher adoption rates of EVs for fleet usage. This research is the first of its kind in Canada to collect and analyze SP data on the acquisition of EVs in fleets. Furthermore, the CFAS included a unique set of attitudinal statements to understand the issues that support or deter EV acquisition in fleets. The statements also gauged the attitudes of the surveyed organizations towards certain aspects that could lead to higher adoption of EVs in fleets.

The remainder of this chapter is organized as follows: Section 2 provides an overview of the CFAS and the targeted sample. A description of the important decision-making tasks for developing the structure of the SP part of the survey are provided in Section 3. Next, the details of various methods to design SP scenarios and subsequent results from the pilot and full launch of the CFAS are discussed in Section 4. Finally, Section 5 summarizes the surveys design approach and recommendations for future research concerning use of SP surveys.

2.2 Overview of the CFAS Structure

The CFAS consisted of 6 distinctive sections as shown in Figure 2-1. These sections were carefully drafted after extensive consultations with stakeholder and industry partners. The process took about two years (2014 -2016) from conception to completion. A detailed description of these sections is provided below:

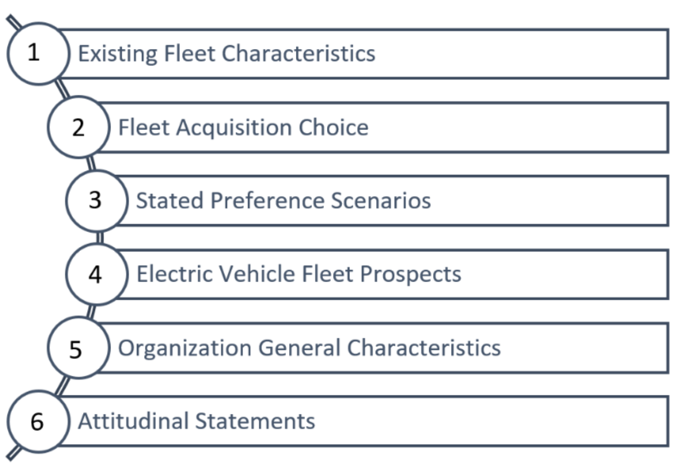


Figure 2-1 Canadian fleet acquisition survey sections

2.2.1 Existing Fleet Characteristics

Section 1 of the survey was dedicated to collect information about the existing fleet characteristics. Here, the respondents (i.e., participating organizations) were asked to provide in-depth details of their existing fleets of cars, pickup trucks and utility vehicles. The collected information pertained to the most dominant vehicle class in the three fleet categories. Information regarding fuel type, acquisition condition and ownership status of the existing fleets was acquired. Furthermore, information pertaining to the geographical coverage (e.g., inter-city, inter-province, intra-province) of fleet operations associated with the indicated fleet type was acquired. Finally, the respondents were asked to provide usage specific information such as annual mileage, replacement cycle and average age of their existing fleet.

Organization general characteristics was introduced in Section 5 of the CFAS. Here, a total of seven questions were asked to identify key characteristics that define the organization and its business needs. This information was collected to understand the nature of the business and its associated transportation needs in a geographical context. Questions pertaining to the best descriptor of the respondent's organization, office location, total number of employees, total fleet locations, total number of Canada-wide employees with daily responsibilities related to the vehicle fleet, and availability of on-site charging infrastructure at its all fleet locations were asked in this section.

2.2.2 Stated Preference Scenarios

Before embarking on the task of completing the SP scenarios, the respondents in Section 2 of the CFAS were presented with nine vehicles types, three pertaining to each of the key fleet categories listed above. For instance, for the car fleet, the three vehicle types included compact sedan, intermediate sedan and full sedan. For pickup truck fleet, the choices included small, intermediate, and large pickup trucks. For the utility fleet, the three vehicle types included utility van, bucket truck and large walk-in truck. The respondents were required to choose only one vehicle type among the nine choices that would most likely be acquired for their organizations' next fleet renewal purchase. We limited the choice to a single vehicle type to keep the cognitive burden of respondents to a minimum while evaluating the SP scenarios. The SP scenarios that were presented to the respondent in Section 3 were customized based on the choice made by the respondents in Section 2.

Section 3 of the CFAS was based on six separate choice scenarios that were presented to the respondent one at a time. Each SP scenario included four powertrain choices with hypothetical, yet realistic, attributes that were categorized by four major categories, namely: cost, incentives, performance, and fueling/charging time and infrastructure. The choice set for each scenario included ICEV, HEV, PHEV and BEV versions of the preferred vehicle size, as shown in Figure 2-2. After evaluating each vehicle powertrain based on its attributes and features, respondents were required to choose a vehicle powertrain that their organization would most likely acquire for its fleet. An illustration of the actual SP scenario is shown in Figure 2-3.

Powertrain	Description
ICE	**Internal Combustion Engine Vehicles (ICEs) -** *are the most common type of vehicles. They are usually powered by gasoline or diesel fuel*
HEV	**Hybrid Electric Vehicles (HEVs)** - *are more fuel-efficient than ICEs, 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. An example of HEV is the Toyota Prius*
PHEV	**Plug-in Hybrid Electric Vehicles (PHEVs)** - *run on both battery and gasoline/diesel. The battery allows short range travel without emissions, while the conventional engine could be used for longer distance traveling. Chevrolet Volt is an example of PHEV*
BEV	**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. An example of BEV is the Tesla Model S*

Figure 2-2 Vehicle powertrains included in the stated preference scenarios

University of Windsor

Social Sciences and Humanities Research Council of Canada

McMaster University

Fleet Acquisition Survey

33%

Scenario 1 of 6

Compact Sedan Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$17,000	$38,300	$29,800	$29,800
Annual Maintenance Cost ($)	$1,000	$600	$500	$800
Annual Fueling/Charging Cost ($)	$2,000	$1,800	$900	$800
Incentives				
Government Cash Incentive ($)	None	None	$3,000	$7,000
Other Monetary Incentives	None	None	No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Parking at Municipal Lots	Access to Bus and HOV Lanes
Performance				
Range per Refuel/Recharge (km)	400	500	700	550
Annual Depreciation Cost ($)	$2,650	$2,920	$2,920	$2,650
Extended Battery Warranty	N/A	N/A	6 Years / 120,000 km	5 Years / 100,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	10% Reduction	50% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	5 mins	10 mins	10 mins	30 mins
Number of Public Fueling/Charging Stations in a Typical 5km Radius	3	5	5	3
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

Cancel << Previous Next >>

Figure 2-3 An illustration of the actual stated preference scenario

Upon completing the SP Scenarios section of the CFAS, the respondent moves on to complete Section 4 of the survey. This section was designed to gauge the success and growth prospects of EVs in corporate and government fleets. At the start of this section, respondents were presented with a policy question about the applicability of any regulatory imperatives in their organization's fleet procurement process. The section also asked respondents about the details regarding future acquisition (if any) of BEVs and PHEVs for their fleets. This included obtaining information pertaining to the number of vehicles to be acquired, time frame, and condition and acquisition strategy for future EV procurement.

2.2.3 Attitudinal Statements

The attitudinal statements are introduced in the last section of the survey (i.e., Section 6). This section was divided into *three sets* of statements to gauge attitudes and perceptions of the participating organizations regarding the adoption of EVs in their fleets. Description of these statements is provided in the results section. In the *first set* of statements, using a 7-point Likert scale, respondents were asked to express their opinion on factors that deter and support the acquisition of plug-in electric vehicles (BEV or PHEV) for their fleets. Some of the key deterring factors include capital cost, battery replacement cost, charging infrastructure cost (i.e., chargers, garage upgrade, etc.), operational reliability due to range limitation and longer charging time, integration with current fleet, cold/hot weather impacts, concerns on the maturity of EV technology, and high risk of being an early adopter of new technologies. On the other hand, the supporting factors that the respondents were asked to express their opinion on included, reduced fuel cost, lower maintenance cost, monetary incentives including municipal and provincial financial support, access to high-occupancy vehicles (HOV) lanes, availability of free parking and factors such as availability of public charging stations. Following that, in the *second set* of statements, the participating organizations were asked to rate their level of agreement with 11 statements that would reflect their confidence in EV adoption. In the final and *third set* of statements, the respondents were presented with six statements and were asked to indicate the relative importance of different aspects of EVs. The CFAS forms are presented in Appendix A.

2.3 CFAS Data collection

2.3.1 Targeted Sample and Screening

The data collection was administered by Research Now Inc. (RNI), a market research company (RNI, 2016). RNI maintains large survey panels with respondents representing Canadian businesses that own and operate fleets. The survey was designed such that it can be completed within 15-20 minutes. The survey started with a preliminary screening page with two screening questions as to whether the individual representing the participating organization had the capacity to influence or make decisions about the acquisition of vehicles for his/her organization and whether the organization operated some combination of at least five vehicles to constitute a fleet. These questions ensured that the survey was completed by a rightful participant and organization.

If the answer provided for the two screening questions was 'Yes', the survey would continue and seek further information regarding the type of organization and the best fitting title of the individual representing the organization (e.g., CEO, President, etc.). On the other hand, if the answer to any of the two-screening questions was 'No', the survey would end. In its entirety, the survey was administrated in six distinct sections.

2.3.2 CFAS Pilot

A pilot of the CFAS was launched in late 2016 from October 08-12. In total, 208 attempts were made at the survey sites. These attempts were classified as, 'Screen out'; Complete'; Over quota' and 'Quantity Check fail' which basically was to rule out the incomplete observations. The final pilot sample consisted of 102 completes with a response rate of 49.0%. The responses from the pilot survey were thoroughly analyzed. It is important to note that the Ngene program (Choice Metrics, 2014) was used for the pilot survey to generate choice scenarios for each of the 9 vehicle classes included in Car, Pickup truck, and Utility vehicle fleets.

2.3.3 CFAS Full Launch

The full launch of the CFAS survey was conducted over a course of 9 days between December 7 and 15, 2016. The sampling outcomes of all respondents who received the survey link from Research Now Inc. are presented in Figure 2-4. A total of 2,426 organizations logged on to the survey site. Nearly 25% (615) of the organizations were screened out on the basis that the person representing the organization was not involved in influencing or making decisions about the acquisition of vehicles for his/her organization. Another 24% (590) of the contacted organizations were also ruled out as they did not operate some combination of at least 5 vehicles in one or more of the vehicle fleet types (i.e., cars, pickup trucks and utility vehicles) featured in the survey.

The remaining 51% (1,254) completed the survey from start to end. However, nearly 20% (246) of these organizations were removed from the survey database later due to inadequate and/or incomplete responses to some of the survey questions resulting in a final sample of 1,008 organizations with complete answers. Overall, inadequate and incomplete responses accounted for nearly 10% of the total 2,426 sample as shown in Figure 2-4. The average recorded time to complete the survey was 17 minutes while the median and mode times were approximately 11 and 8 minutes, respectively.

The representativeness of the data collected through CFAS was checked by comparing it with the POLK 2011 data (IHS Markit, 2019) and the Canadian automotive fleet (CAF) registrations reported in 2016 (CAF, 2017). The POLK datafile for 2011 consists of records of all Canadian registered passenger and commercial vehicles that existed up till that year. Vehicle records are provided at census tract level in the datafile. Each record includes the year when vehicle was manufactured, as well as the make, model and fuel type of the vehicle. The records also include the gross vehicle weight (GVW) ratings. The results are presented in Figure 2-5.

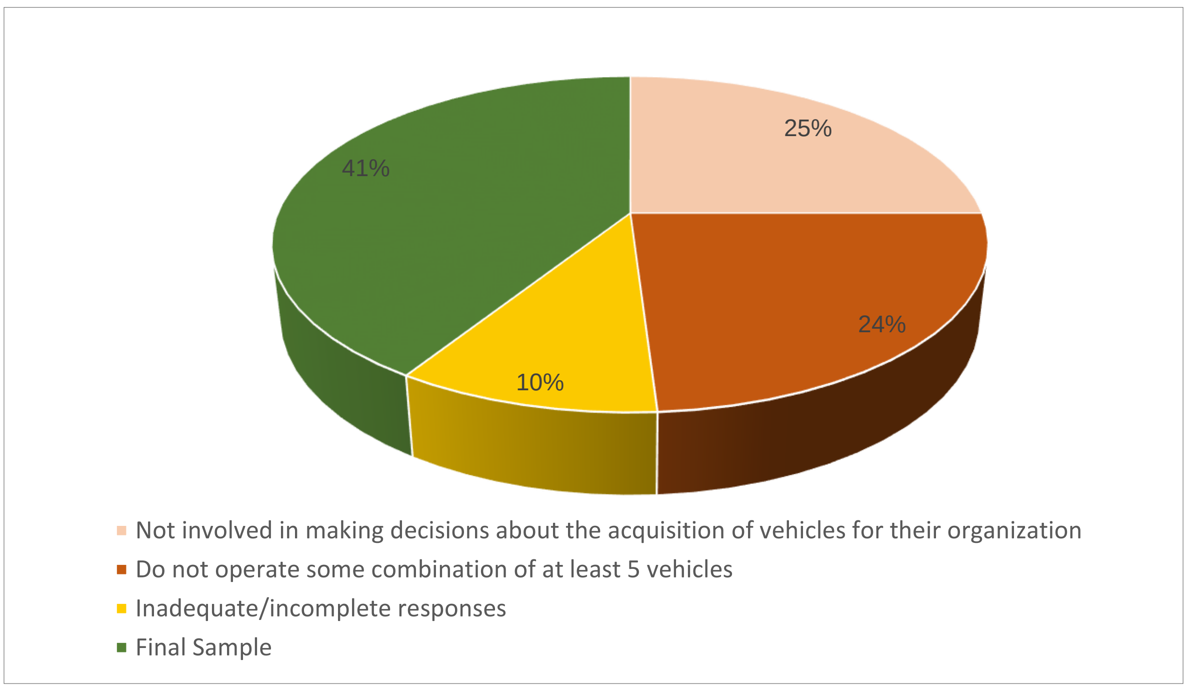


Figure 2-4 Sampling outcomes for all respondents agreeing to participate in CFAS

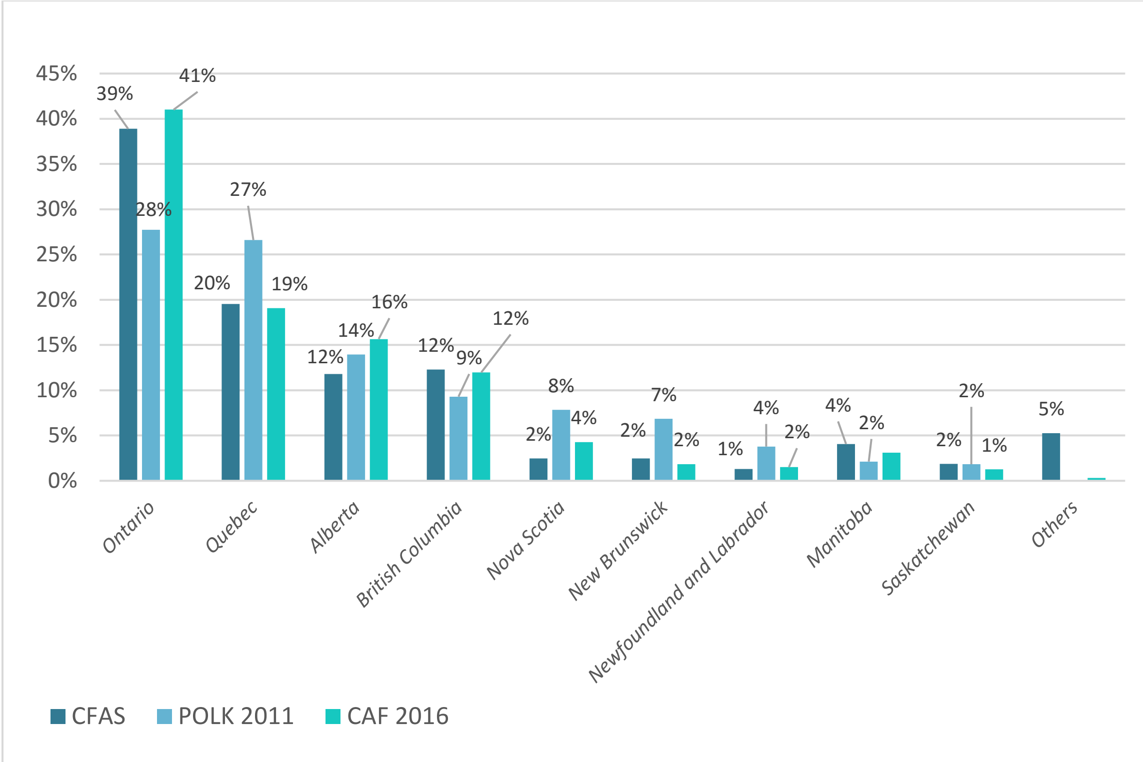


Figure 2-5 Comparison of the spatial distribution of surveyed entities with POLK and CAF data

2.4 Stated Preference Survey Design

Stated Preference (SP) Surveys have been a convenient choice for collecting data on the acceptance of alternative fuel vehicles, including electric powertrain vehicles for household consumers (Mohamed et al. 2016; Abotalebi et al. 2018). In contrast, past studies on the acquisition process of fleets had focused on using restricted data that were made available to researchers by fleet operating entities in private or government sector volunteering to participating in the research. These studies either focused on investigating certain aspect of electric vehicle (EV) adoption or on the viability of a specific vehicle type in fleets (e.g., Correia and Santos, 2014; Feng and Figliozzi, 2013; Haller et al. 2007). The work by Golob et al. (1997) is one of the very few comprehensive efforts that utilized an SP approach to study the adoption of Alternative Fuel Vehicles (AFVs), including EVs, among fleets. More recently, the study by Hoen and Koetse (2014) conducted an SP experiment to collect data on the preferences for AFVs of company car drivers in the Netherlands. Purchases behavior of fleet operating entities or organizations are often based on past experiences and operational considerations. On attitudes and perceptions towards EV adoption in fleets, the study by Nesbitt and Davies (2013) provided useful insights on how the perceived value of the PHEVs varied depending on the employee's responsibilities and role in the organization. A very recent study by Dimatulac et al. (2018) targeted the factors affecting the demand for EVs in the Canadian rental fleet market. However, the study collected SP responses from consumers who rented vehicles within a year from the date they participated in the survey. Our survey, by comparison, focuses on collecting responses from individuals making or influencing the decisions of acquiring vehicles in fleets in their organizations.

2.5 Overview of the Process for Creating SP Scenarios

2.5.1 Sampling for Stated Preference Data

Sampling for Stated Preference (SP) data involves defining the 'sampling frame' which in turn represents the universal but finite set of decision makers (respondents) from whom the choice data will be collected via the data collection instrument (Hensher et al. 2005). The sampling frame which is defined as a function of the objectives of the study should provide operational viability. Once the sampling frame is identified, the next step is to determine the 'sampling strategy' to be employed for data collection. Sampling strategies are broadly categorised into two types: random and non-random sampling. A variety of random sampling strategies are available including but not limited to simple random samples (SRS), stratified random samples, and choice-based samples. The choice data collected through non-random samples often results in unrealistic and dubious demand estimates (Hensher et al. 2005). The present study employed the SRS strategy to collect data from a random sample of 1,000 fleet operating organizations across Canada by engaging a panel maintained by Research Now Inc.

2.5.2 Determinants of Stated Preference Data Quality

Data collected through SP surveys are used as input to estimate models that predict the future choice decisions of the respondents. However, the validity and reliability of the outputs of these models is often a major concern (Louviere et. al 2000). The concern is mainly rooted in quality of the collected SP data, which also embeds in it the fitness of the purpose (Petrik et al. 2015). The latter relates to the degree to which an SP survey instrument meets the objectives of the research (Bliemer and Rose, 2011). Other important aspects of the data quality include but not limited to accuracy, timeliness, accessibility and comparability (Petrik et al. 2015). Data accuracy, which is composed of sampling and non-sampling errors is one of the main issues associated with the quality of the SP data. Sampling errors are dependent on the representativeness of the sample to the population. On the other hand, the non-sampling errors are associated with specification of the SP design, non-response frame, and the data processing errors. In this research, due considerations were given to minimize the sampling error by implementing a robust screening mechanism that targeted only the rightful respondents. Similarly, the attributes and associated levels that were used in the design of the SP scenarios, as well as the method used to generate the scenarios, all ensured that the non-sampling errors are kept to a minimum. The key considerations of the SP design are discussed in the following subsection.

2.5.3 Identification of Attribute and their Levels

Table 2-1 presents the attributes and their levels. The information provided was informed by the existing literature. The number of attribute levels for a given variable largely depend on the model specification (Louviere, 2000). In general, higher number of attribute levels will result in a larger set of choice scenarios. Non-uniformity in the number of levels (i.e., mixed levels of attributes) will also result in a higher number of choice situations (Hensher et al. 2005). However, at the same time, higher number of levels in a design will result in capturing more information in utility space as each level may be mapped to a point that is associated with the utility of that particular attribute as depicted in Figure 2-6.

Table 2-1 Attributes and levels used in the SP scenario design

Attributes	ICEV (Base)	HEV	PHEV	BEV
Cost				
Purchase Price ($)	Base	+50% of base	+50% of base	+50% of base
		+25% of base	+25% of base	+25% of base
		Base	Base	Base
		-25% of base	-25% of base	-25% of base
Annual Maintenance Cost ($)	Base	+25% of base	+25% of base	+25% of base
		Base	Base	Base
		-25% of base	-25% of base	-25% of base
		-50% of base	-50% of base	-50% of base
Annual Fueling/Charging Cost ($)	Base	Base	-15% of base	-30% of base
		-10% of base	-25% of base	-40% of base
		-20% of base	-35% of base	-50% of base
		-30% of base	-45% of base	-60% of base
Incentives				
Government Cash Incentive ($)	None	None	$3,000	$3,000
			$5,000	$5,000
			$7,000	$7,000
			$9,000	$9,000
Other Monetary Incentive	None	Manufacturer rebate	Manufacturer’s rebate	Manufacturer’s rebate
		No purchase tax	No sales tax on purchase price	No sales tax on purchase price
		No annual registration fee	No annual registration fee	No annual registration fee
Non-monetary Incentive	None	None	Free charging station installation	Free charging station installation
		Free parking on municipal lots	Free municipal parking	Free municipal parking
		Access to bus and HOV lanes	Access to Bus and HOV lanes	Access to Bus and HOV lanes

Table 2-1 – continued

Attributes	ICEV (BASE)	HEV	PHEV	BEV
Performance				
Range per Refuel/Recharge (Km)	300	400	550	250
	400	500	600	400
	500	600	650	550
	600	700	700	700
Annual Depreciation Cost ($)	Base	+10% of base	+10% of base	+10% of base
		+7.5% of base	+7.5% of base	+7.5% of base
		+5% of base	+5% of base	+5% of base
		Base	Base	Base
Extended Battery Warranty	None	None	5 Years / 100,000 km	5 Years / 100,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Tailpipe Emission (%)	Base	-10% of base	-50% of base	-100% of base
		-20% of base	-60% of base	
		-30% of base	-70% of base	
		-40% of base	-80% of base	
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time (mins/hrs) (Cars and Light Truck Fleets)	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	4 hrs
	7 mins	7 mins	4 hrs	8 hrs
	10 mins	10 mins	8 hrs	12 hrs
Refueling/Recharging Time for Utility Fleets (mins/hrs) (Utility van, Bucket Truck and Large Walk-in Truck fleets)	7 mins	7 mins	15 mins	4 hrs
	10 mins	10 mins	1 hr	8 hrs
	12 mins	12 mins	6 hrs	12 hrs
	15 mins	15 mins	10 hrs	16 hrs
Number of Public Refueling/Recharging Stations in typical 5 km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

It is clear from Figure 2-6(a) that if only two levels were to be used in the design, the utility relationship for the attribute is linear with a step change in the utility. On the other hand, the analyst could understand the true nature of the utility relationship that exists by varying attributes levels as shown in Figures 2-6(b), 2-6(c), and 2-6(d).

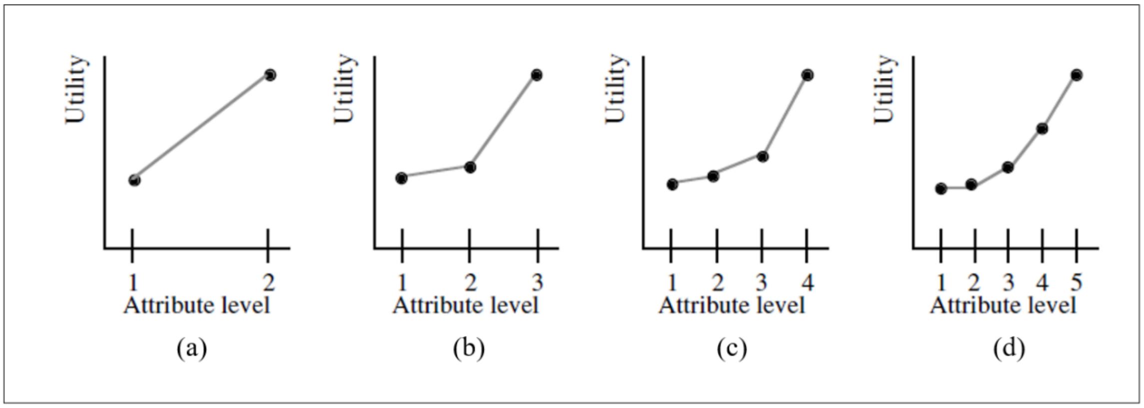


Figure 2-6 Illustration of level of utility of a single attribute at varying levels
(Source: Hensher et al. 2005)

2.5.4 Attribute Level Range

Attribute level range is an important consideration in the design of experimental choice scenarios. If not well specified, the collected data can have serious repercussions for the estimated parameters. More specifically, a wider range could result in choice scenarios with dominated alternatives whereas a narrower range will result in alternatives which are largely indistinguishable (Rose and Bliemer, 2008). The literature on this issue suggests that, in theory, a wide range is statistically preferable to using a narrow range as the former will lead to parameter estimates with smaller standard errors (Louviere et al. 2000). However, for a given SP choice experiment, the range of attribute level should be sensible and intuitive to the respondent. Therefore, the range of attribute levels employed in a given SP experiment will have to be traded-off for statistical significance and practical considerations. In general, the extreme ranges (sometimes also referred to as, endpoints) of the attribute levels can be identified by examining the experiences related to that attribute of the decision maker being targeted (Hensher et al. 2005). These insights to the experiences could be obtained through secondary data or via focus group discussions and are helpful in deriving the endpoints to be used in the design (Hensher et al. 2005). The feedback obtained from several discussions with focus groups and industry partners was pivotal in estimating the endpoints for some of the attributes used in the SP design of CFAS (for example: recharging time and monetary incentives).

2.6 Conception and Implementation of Vehicle Attributes in SP Scenarios

2.6.1 Cost

Purchase Price ($)

The base values for the purchase price pertain to 2016 models of the ICEV powertrain for the 9 vehicles included in the three fleet types. The prices were based on the commonly available non-luxurious domestic and foreign vehicle brands. More specifically, the average purchase prices for compact, intermediate, and full-size vehicles were obtained from *www.autoguide.com* for car fleets.

On the other hand, only popular domestic brands (e.g. Ford, Chevrolet, GMC, and Dodge Ram) for pickup truck fleets were considered since these brands dominate the North American and Canadian pickup truck market. As for the utility vehicles fleets, the base year purchase price for a utility van was obtained from multiple manufacturers while the average prices for bucket truck and walk-in truck were obtained from a single source, i.e., *www.commercialtrucktrader.com*.

The purchase price for the remaining three electric powertrains, namely HEV, PHEV, and BEV, were set relative to the realistic base price of the conventional ICEV powertrain. The prices for all vehicle classes were rounded to the nearest $500. This treatment of the purchase price has been adopted in multiple SP studies in the past (See for example: Potoglou and Kanaroglou, 2007; Ferguson et al. 2018; Dimatulac et al. 2018)

Annual Maintenance Cost ($)

The annual maintenance cost pertains to the total cost incurred in maintaining the vehicle including seasonal maintenance (e.g., oil and tire change) and unexpected repairs. However, annual insurance and registration fees were not included in the maintenance cost. Typically, maintenance cost of a vehicle is dependent on the purpose and annual kilometres driven. That generally increases with the size of the vehicle size. Therefore, large pickup trucks, walk-in trucks and bucket trucks are assumed to cost more to maintain due to their heavy-duty usage (e.g., towing, hauling, and delivery) and retractable equipment (i.e., buckets).

Publications from various reliable sources such as Canadian Automotive Fleet Association (CAF, 2016) and the U.S. Automotive Fleet (USAF, 2015) were used as a reference to estimate the maintenance cost for the vehicles of the three fleet categories. Realistic values were assumed for some of the vehicle classes that were not found in the fleet books. The values were rounded to the nearest $50.

Annual Fueling/Charging Cost ($)

Annual Fueling/Charging Cost represents the total amount spent on gasoline and/or electricity to power the vehicle. Similar to maintenance cost, the annual fuel/charging cost of a vehicle is largely dependent on the purpose and annual kilometres driven. Therefore, it is reasonable to assume that fuel/charging costs increase with vehicle size (i.e., vehicle class) since larger vehicles require more powerful engines, which results in lower fuel economy.

A walk-in truck is assumed to have higher fuel cost than all other vehicle classes in the three fleets since its usage is tied to frequently carrying heavy loads with significant annual mileage. On the other hand, a bucket truck requires excessive power to engage it equipment and as such consumes more fuel. Here, we assumed the annual fuelling cost to be somewhere between the fuel cost of a large pickup truck and a walk-in truck.

The annual charging cost for the plug-in electric powertrains namely, PHEV and BEV were set relative to the fueling cost of their conventional counterpart (i.e., ICEV). Lastly, the charging cost for the HEV is set to zero as HEVs are powered by battery that is charged through regenerative braking and by the internal combustion engine. The maintenance costs for all vehicle classes were rounded to the nearest $100.

2.6.2 Incentives

Government Cash Incentives ($)

Government cash incentives reflect the monetary grants offered at various levels of government including federal and provincial that focus on promoting PHEV and BEV. These incentives could include purchase rebates, tax credits, and waver of annual registration fee. The latter fee tends to vary by province.

Other Monetary Incentives

These incentives pertain to the manufacturers’ cash incentives such as purchase rebates that vary with the brand.

Non-monetary Incentives

These are the incentives that are offered by various levels of governments to encourage specific vehicle type ownership. These include access to bus or HOV lanes, free municipal parking on municipal lots and free installation of charging station at establishment's premises.

2.6.3 Performance

Range per Refuel/Recharge (km)

The range per refuel/recharge accounts for the maximum distance travelled on a full tank of gas and/or on a fully charged battery. Contrary to past studies where no distinction was made for the range, we specify range in terms of the powertrain of the vehicle. For ICVE and HEV the range is specified as the distance travelled on a full tank of gasoline. On the other hand, the ranges for the PHEV and BEV powertrains are specified as the distance travelled on a fully charged battery. However, PHEV is the only powertrain for which the range is specified for both gasoline and battery. The range values for all the powertrains are obtained from reliable sources such as manufacturer's websites and reports published by the various fleet associations.

Annual Depreciation Cost ($)

Annual Depreciation reflects the decline in the value of the vehicle over its useful life in ownership. Fleet replacement life cycles published by various sources including the Canadian Fleet Book (CAF, 2016), U.S. Automotive Fleet (USAF, 2015), and Company Replacement Policy Survey (Milner, 2014) were used as a reference to estimate the base values for annual depreciation cost for ICVE powertrain of each vehicle class of the three fleet types. Typically, vehicles lose around 70% of their original value in the first 6 years of life, as shown in Figure 2-7 (Beirnes, 2012). The total depreciation is divided by the estimated life cycle of each vehicle class. For example, a compact car with a 3-year life cycle will only worth about 53% of its original purchase price. Therefore, the annual depreciation rate is 15.67%. The purchase price for the remaining three electric powertrains (i.e., HEV, PHEV, and BEV) were set relative to the estimated rates of the ICEV powertrain. The depreciation costs for all vehicle classes were rounded to the nearest $50.

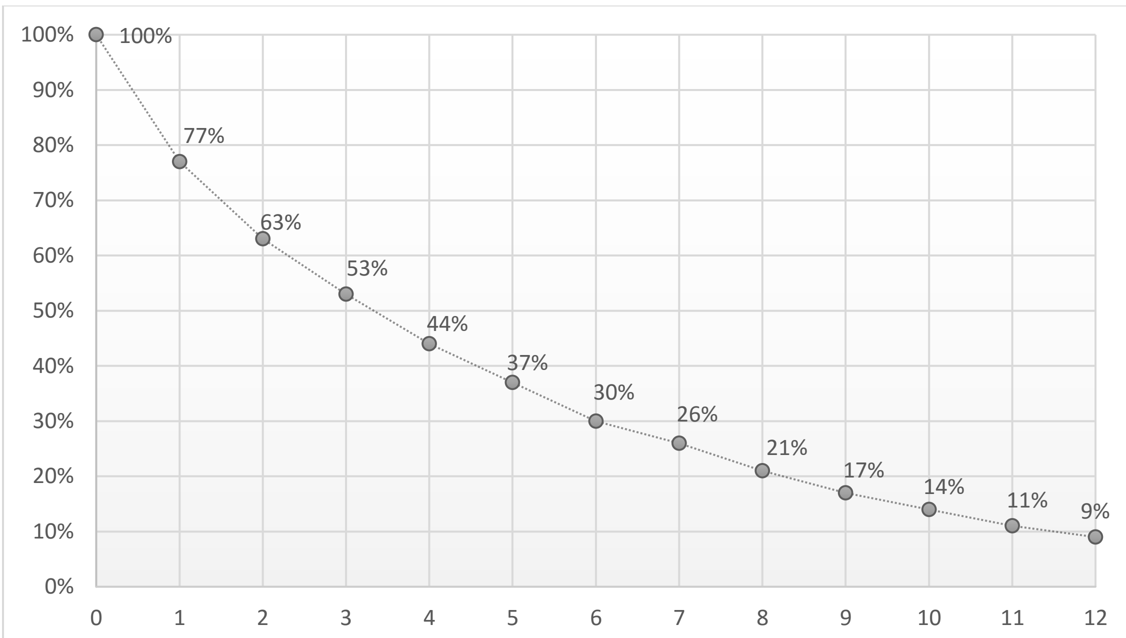


Figure 2-7 Residual value of a typical fleet vehicle by year
(*adapted from Beirnes, 2012*)

Extended Battery Warranty

Extended Battery Warranty is the battery warranty provided above and beyond the manufacturer warranty. These base values were obtained directly from the manufacturer's website. This attribute was specified only for the PHEV and BEV powertrains with realistic improvements to the existing warranties.

Reduction in Tailpipe Emissions (%)

Reduction in tailpipe emissions expressed in percentage, represents the reduction in the quantity of toxic emissions (i.e., HC, CO, NOx, CO_2) that are released into the environment while operating an ICEV compared to an EV (i.e., PHEV and BEV). BEVs have zero tailpipe emissions. It is worth noting that the manufacturing of EVs has consequential greenhouse gas emissions externalities. This involves emissions from the manufacturing process of the vehicle, its usage once produced and its recycling once it becomes unusable. Emissions from the manufacturing process entails the production of the different parts of the vehicle as well as the batteries that are used to power it. Various metrics have been used to assess the environmental performance of EVs including a life cycle or cradle to grave analysis, driving cycle, and the real-life evaluation (Faria et al. 2013; Batista et al. 2015; Huo et al. 2015; Michalek, 2016; Vivanco et al. 2016; Requia et al. 2017). Emission levels of an EV largely depend on the electricity generation profile of the jurisdictions where the vehicle is manufactured, used and recycled. In a broader sense, for global GHG reductions, the entire lifecycle of vehicles would need to be accounted for. However, this type of analysis is beyond the scope of this research. Hence, in our research we only focus on tailpipe emissions for BEV by specifying a 100% reduction as it is imperative for the fleet operating organizations to fully understand the core of the BEV proposition.

2.6.4 Fueling/Charging Time and Infrastructure

Refueling/Recharging Time

Refueling/Recharging Time is the average time to refuel or recharge a vehicle in the fleet. Public charging times represent the following levels or speed of charging:

- Level 2: AC (240V) Charging: 3 to 8 hr for full charge (one-hour charge – 30 km of range)
- Level 3: DC (480V) Charging: 30-45 mins for full charge (one-hour of charge – 250 km of range)

The above charging times assume 80% utilization of the battery. For example, a Level 3 charging station, will recharge battery from empty to 80% in 30-45 minutes.

Number of Public Fueling/Charging Stations

Number of Public Fueling/Charging Stations represent the locational availability of the public fueling/charging facilities within a typical 5 km radius. The number of public charging stations is estimated relative to the existing gasoline infrastructure. This approach has been adopted by past studies to specify this attribute in the SP design (See for example: Brownstone et al. 2000; Tanaka et al. 2014). A base value table and tables with the SP values used in creating the SP choice scenarios for the nine vehicle types are provided in Appendix B of this Chapter.

2.7 Creation of Stated Preference Scenarios

The process to create Stated Preference (SP) scenarios consists of three broad sequential steps as depicted in Figure 2-8. In the first step, the utilities of each alternative to be included in the choice set are formed with generic and alternative specific variables. These variables with their levels are specified after a thorough review to the literature. In the case of the CFAS, the final utility specifications consisted of a multinomial logit model (MNL) with four alternatives namely, ICEV, HEV, PHEV and BEV. It is worth noting that the alternatives are not uniform in their powertrains (e.g., charging time applicable to only PHEV and BEV, while refueling time is associated with only ICEV, HEV and PHEV), and have varying levels. Non-uniformity along with the varying levels makes the organization of the alternatives and their associated attributes a daunting task in the SP environment. The main difficulty arises from the fact that each additional parameter represents an extra degree of freedom. This in turn implies that the experimental design becomes larger and larger with the growing number of scenarios to be presented to the respondents. This problem is further exacerbated when interaction terms are used in the utility specification of the model.

Once the model has been completely specified, the next step involves generating the experimental design. An experimental design results in a set of hypothetical choice scenarios that each respondent will be presented with. The various choice scenarios allow manipulation of attributes and their levels to permit rigorous testing of certain hypothetical situations. The following effects were given due consideration in devising the SP scenarios:

1. *Main Effect:* Main effects pertain to the effect of one of the attributes on the dependent variable, ignoring the effects of all other factors. Main effects typically account for 70-90 % of the explained variance in the design (Louviere et al. 2000).

2. *Interaction Effects:* Interaction effects occur for two attributes if decisionmakers' preferences for levels of one attribute depend on the levels of a second attribute. These effects typically account for 5 -15% of the explained variance (Louviere et al. 2000). Higher-order interactions account for the remaining explained variance.

Model Specification

$$V_{ICEV} = C_{ICEV} + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \dots\dots\dots + \beta_n x_n + \varepsilon_{ri}$$

$$V_{HEV} = C_{HEV} + \beta_1 x_1 + \beta_3 x_3 + \dots\dots\dots\dots\dots\dots + \beta_n x_n + \varepsilon_{ri}$$

$$V_{PHEV} = C_{PHEV} + \beta_2 x_2 + \beta_3 x_3 + \dots\dots\dots\dots\dots\dots + \beta_n x_n + \varepsilon_{ri}$$

$$V_{BEV} = \beta_3 x_3 + \beta_4 x_4 + \dots\dots\dots\dots\dots\dots + \beta_n x_n + \varepsilon_{ri}$$

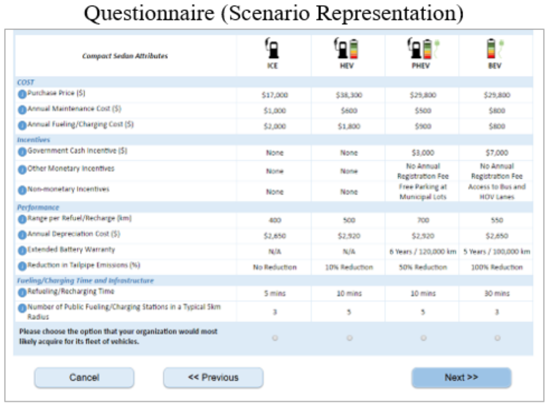
Experimental Design

Scenario	x_1	x_2	x_3	….	x_n
1	-1	-1	-1	….	-1
2	-1	1	-1	….	1
3	-1	-1	1	….	1
4	1	1	1	….	1
….	….	….	….	….	….
n-1	….	….	….	….	….
n	1	-1	1	-1	1

Blocked Fractional Factorial Design

Scenario	x_1	x_2	x_3	….	x_n
1	-1	-1	-1	….	-1
2	-1	1	-1	….	1
3	-1	-1	1	….	1
4	1	1	1	….	1
5	1	-1	-1	….	-1
6	1	1	-1	….	-1

Questionnaire (Scenario Representation)



Compact Sedan Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$17,000	$38,300	$29,800	$29,800
Annual Maintenance Cost ($)	$1,000	$600	$500	$800
Annual Fueling/Charging Cost ($)	$2,000	$1,800	$900	$800
Incentives				
Government Cash Incentive ($)	None	None	$3,000	$7,000
Other Monetary Incentives	None	None	No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Parking at Municipal Lots	Access to Bus and HOV Lanes
Performance				
Range per Refuel/Recharge (km)	400	500	700	550
Annual Depreciation Cost ($)	$2,650	$2,920	$2,920	$2,650
Extended Battery Warranty	N/A	N/A	6 Years / 120,000 km	5 Years / 100,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	10% Reduction	50% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	5 mins	10 mins	10 mins	30 mins
Number of Public Fueling/Charging Stations in a Typical 5km Radius	3	5	5	3
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

Cancel   << Previous   Next >>

Figure 2-8 Overview of the process for creating stated preference scenarios
(*adapted form Choice Metrics, 2014*)

2.7.1 Fractional Factorial Design

There are various methods to develop an ‘experimental design’. A simple way is through a complete factorial design (CFD), where every possible choice situation (i.e., all combination of the attributes and their levels) is presented to the respondent. Following Choice Metrics (2014), if there are a total of J alternatives with K_j number of attributes per alternative j (j=1, 2, …, J) where each attribute k_j (k_j =1_j, 2_j, …, K_j) has I_{jk} attribute levels, then the total number of choice combinations, S^{CF}, in the CFD can be enumerated as:

$$S^{CF} = \prod_{j=1}^{J} \prod_{k=1}^{K_j} I_{jk} \tag{2.1}$$

However, the above formulation would result in an astronomical number of choice scenarios to be evaluated. As a remedy, Fractional Factorial Design (FFD) has been proposed and utilized to constrain the choice scenarios to be presented to each respondent (Louviere et al. 2000). Orthogonality in the FFD design is maintained by negligible correlation among the attributes and their levels and attribute level balance by ensuring equal frequency of all levels of each attribute in the design matrix. Hence, FFD significantly reduces respondents’ fatigue by offering restricted number of choice scenarios to be presented to respondents. However, since the number of choices scenarios in a given design is a function of the number of alternatives including their attributes and levels, then there could be situations when scenarios produced by the FFD are still too large for a respondent to evaluate. In such instances, various techniques have been proposed and used to generate a subset of the FFD. These subsets can be generated by selecting choice scenarios in a random fashion (See for example: Bunch et al. 1993; Golob et al. 1997; Hackbarth and Madlener, 2016; Hoen and Koetse, 2014). While the technique is easy to implement, it could cause the variables to become correlated when the sample size is insufficient.

A more robust technique, called systematic construction, groups the scenarios into small subsets, called blocks (See for example: Ahn et al. 2008; Hess et al. 2011). The block design approach maintains orthogonality and ensures that respondents are presented with the whole range of each attribute's values, and attribute level balance is maintained (Choice Metrics, 2014). Attribute level balance is a desirable property that a valid experimental design should be able to satisfy, though it might lead to a *sub-optimal design* in some cases (Choice Metrics, 2014). Essentially, this property implies that each attribute level appears an equal number of times for each attribute and results in parameters that are estimated on the full range of levels, rather than representing only a certain part of the range.

In this research, a blocked FFD was used to produce 144 unique choice scenarios for each vehicle class/size type. These scenarios were then grouped into 24 blocks, each consisting of 6 scenarios. The decision to limit the number of scenarios to 6 was taken into consideration to reduce respondent's cognitive burden and fatigue when completing the SP section of the CFAS. A variety of coding schemes exists for representing attribute levels in the experimental design. These include a set of predefined rules-based letters, numbers or actual attribute level values. The fractional factorial design of the CFAS employed orthogonal coding to specify levels of the various attributes. Mainly, the orthogonal coding for three levels [-1, 0, 1] and four levels [-3, -1, 1, 3] were used. The blocked FFD was generated in the specialized software program Ngene 1.1.2 (Choice Metrics, 2014). The Ngene code for the SP design is attached in Appendix C.

2.7.2 Labelled vs. Unlabelled Scenarios

The decision to use labelled or unlabelled scenarios in an SP exercise is largely dependent on the model specification. Broadly, the choice scenarios would need to be labelled if the attributes are alternative-specific as in the case of the CFAS else they could be un-labelled (Louvier et al. 2000). As shown in Figure 2-3, the labels (i.e., the names of the alternatives) in the CFAS allowed respondents to infer any information that might have been missed or omitted in the design of the SP.

2.7.3 Cognitive Burden in Stated Preference Scenarios

Cognitive burden, or respondent fatigue is one of the most critical consideration in the design of a stated preference (SP) survey. Cognitive burden arises from the complexity (number of alternatives versus number of attributes versus number of levels) as well as the number of choice scenarios a respondent is subjected to in a given stated preference exercise. Although there is no fix number or rule on determining the optimal number of scenarios, past studies contend that an increase in the number of choice scenarios will affect the reliability of the collected SP data (Swait and Adamowicz, 1996; Brazell and Louviere, 1997). Typically, surveys are pre-tested to inform the choice for the number SP scenarios (Louviere et al. 2000). This consideration was given due attention in the design of the CFAS. In addition to the SP section, the CFAS contained multiple sections that collected data on various characteristics and attitudes of the responding organizations that might result in cumulative burden. The decision on the number of choice scenarios in the CFAS was also informed by the work of Carson et al. (1994) that supports the idea of using reduced number of choice scenarios in case more than ten attributes are used in the design. Higher number of attributes and/or levels increases the complexity of choice scenarios which in turn leads to a higher cognitive effort to understanding and comprehending the information presented to the respondent.

A pilot of the CFAS that collected response from over 100 responding organizations resulted in several changes in the survey forms. These changes were aimed at improving the readability and conciseness of the text, and also reducing the overall cognitive burden of the respondent. However, the six choice scenarios introduced in the pilot were still deemed appropriate in the full survey. The average completion times for the six choice scenarios for the pilot and full launch of the CFAS are presented in Figure 2-9. The two trends are quite similar in the sense that they represent a learning process among the surveyed respondents. On average, the respondents spent relatively more time while completing the first two scenarios, but once they became familiar with the contents in the SP form, their response time improved significantly by more than 50%, in both cases, for the subsequent scenario and largely remained unchanged for the rest of the SP scenarios. Figure 2-10 shows the total time taken to complete the SP exercise for the two versions of the CFAS. The two profiles are almost identical, however, due to higher number of respondents participating in the full launch version (Figure 2-10b), more variation in the completion time range is observed with some respondents taking as much as 28 minutes to complete the SP section. Overall, the average completion times for the pilot and full launch SP section were 2.4 minutes and 2.80 minutes, respectively. On the other hand, the average total time to complete all sections of the pilot and full launch versions were 15 and 17 minutes, respectively.

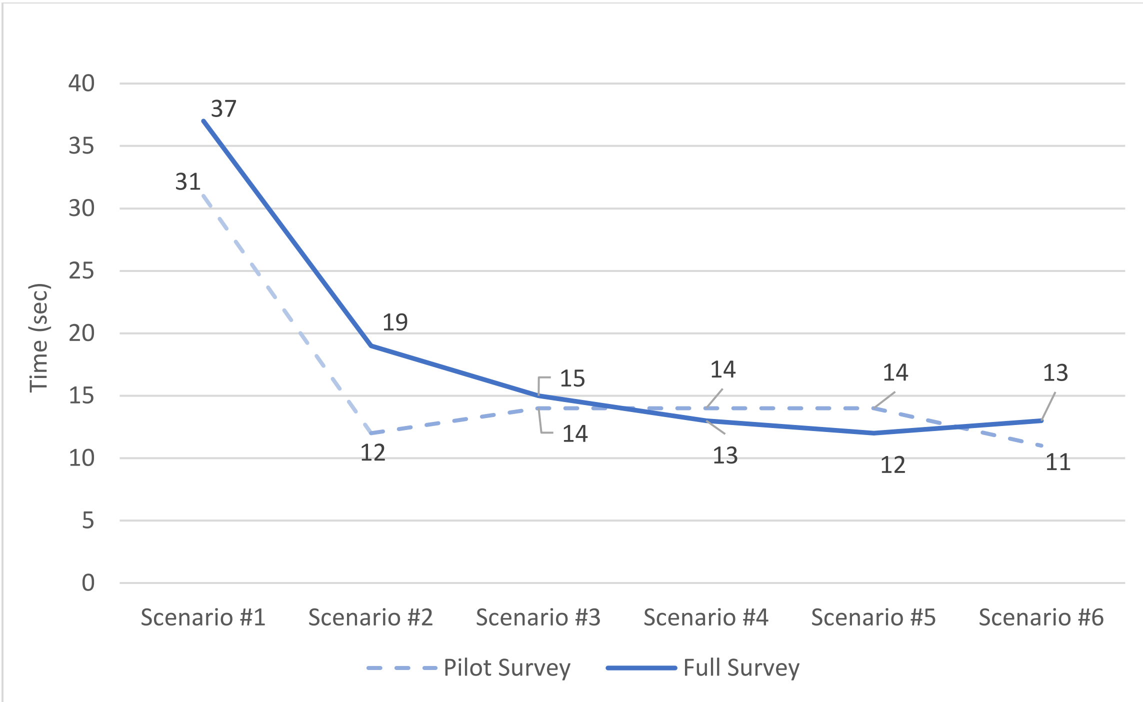


Figure 2-9 Average completion time for each stated preference scenario pilot survey (*N*=102) and full survey (*N* =1,008)

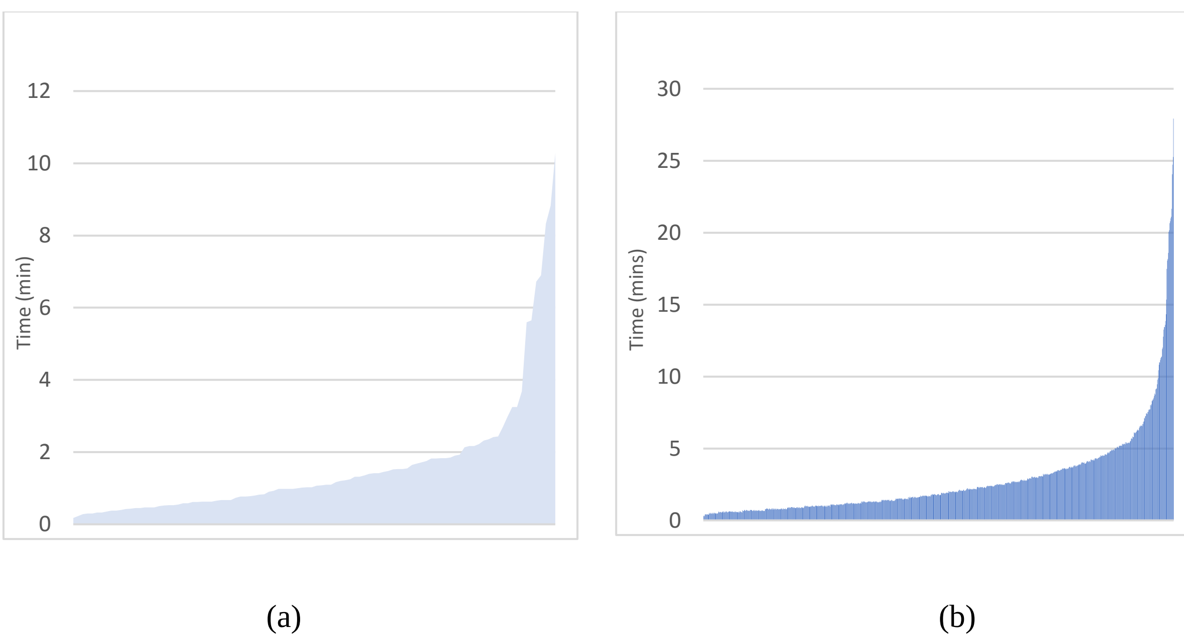


Figure 2-10 Total time for the six choice scenarios per respondent (a) pilot survey (*N*=102); (b) full survey (*N* =1,008)

2.8 Novel Aspects of the CFAS

The Canadian Fleet Vehicle Survey (CFAS) instrument developed for this dissertation stands out from past efforts in several respects. This section highlights three key novel aspects and the rationale for their implementation in the CFAS.

2.8.1 Nation-wide Cast Net

The CFAS distinguish itself from past data collection efforts in its scope as the spatial context was at core of the CFAS conceptualisation. Collection of 3-digits postal codes from the surveyed fleet operating organizations was useful in identifying the spatial coverage in which these organizations would assess the viability of electric vehicles (EVs) in their fleets. Availability of such spatial resolution was key in interpreting the results from the estimated latent class discrete choice model presented in Chapter 5 of this dissertation. As will be discussed in that chapter, the propensity of corporate organization with EV leaning attitude was attributed to the fact that they were located in Quebec, a province with the highest share of clean electricity in the nation. City locations of the responding organizations with micro details of number of employees responsible for maintaining as well as existing of charging stations, enabled this research to derive geographically oriented segments of attitudes and perceptions that exists among these organizations regarding EVs. While several studies have incorporated this aspect on the consumer side (Mohamed et al. 2016; Campbell et. 2012), to our knowledge the present research is first of its kind to collect such information on the fleet side.

2.8.2 Customization of SP Scenarios based on Vehicle Classes and Types

The design of the CFAS was unique in the sense that it included three different types of fleets namely: Car, Pickup Truck and Utility Vehicle fleets in the SP choice scenarios.

Fleet operate entities often use combination of different classes of vehicles in order to meet their operational demands. The design of the CFAS considered this aspect by allowing the participating entities to evaluate the viability of EVs in 3 distinct types of vehicle fleets that they might be operating either exclusively or in some combination. By comparison, almost all the efforts reported in past studies investigated EV adoption in fleets by focusing on a single vehicle class and/or single industry. The CFAS provides a clear advantage as it is able to collect data that will capture the heterogeneity in the vehicle fleet structure and the industries operating these fleets.

2.8.3 Collection of Attitudes and Perceptions

According to Davis (1993), user's acceptance of a new technology is critical for the success or failure of that technology. Past empirical studies have also indicated that the decisions made by large organizations to purchase new equipment are not always based on cost-benefit measures alone (Zehetner, 2011). In a similar vein, past studies on EV adoption indicate that there are stark differences between the motivations set by private consumers and organizations when it comes to their decision-making process for embracing the EV technology (Globisch et al. 2018). This aspect drew serious considerations in the design of the CFAS resulting in an exclusive section that collected attitudinal data pertaining to various aspects of EVs from a fleet operation perspective. More specifically, the attitudinal section was divided into three sets of statements to gauge attitudes and perceptions of the participating organizations regarding the adoption of EVs in their fleets. The statements were rooted in 'Theory of Planned Behaviour' (Ajzen, 1985) to explore the beliefs, perceptions and the resulting behaviour of the responding organization when it comes to assessing the viability of EVs in their fleets. The attitudinal statements in the CFAS were instrumental in capturing various underlying behavioural constructs and mindsets that relate to the EV viability in fleets. These statements offered a rich basis for the empirical analysis conducted in this dissertation.

2.9 Conclusions

This chapter provided an overview of the design of the Canadian Fleet Vehicle Acquisition (CFAS) survey instrument to investigate the viability of Electric vehicle (EV) adoption in fleet operating entities. The full survey was launched in December 2016 with a target of collecting data from over 1,000 randomly selected fleet operating organizations, nationwide. The screening of the sampled organizations was based on the size of their existing fleet (greater than 5 vehicles) as well as the role of the person completing the survey. Only those respondents who influence or make decisions about the acquisition of vehicles for their organizations could complete the survey. The screening mechanism ensured that the collected information is useful and insightful.

Research Now Inc., a marketing research company was engaged to acquire the target sample from their Canada wide panel. The geographical locations of the responding organizations were captured through 3 digits postal code. Casting a wider net, as it turned out allowed us to have a better understanding about the variation in the preference of EVs in various sub-geographies and as it offered a spatial context to the analyses. Recruiting respondents from survey panels compared to traditional survey means have its pros and cons. The former involves targeting specific respondents, which insures better sample representation and higher response rate in a timely fashion. However, the cost of using specialized panel surveys is substantially higher when compared to the traditional means. For instance, the cost per observation in the CFAS came to around $30 CAD.

The CFAS incorporated in its design extensive feedback that was acquired from consultations with several stakeholders from the fleet industry. Aside from being a nation-wide application, the novel aspects of the CFAS included conceptualization of vehicle classes and types and customisation of stated preference (SP) scenarios. To our knowledge, the CFAS is the only data collection effort to date that availed the responding organizations the opportunity to evaluate the viability of EVs in three distinct types of vehicle fleets namely, cars, pickup trucks and utility vehicles. The SP choice scenarios were customized based on the prior choice of vehicle that the responding organization had indicated. In total, nine vehicles types belonging to three distinct vehicle classes were included in the SP choice scenarios. Each of the nine vehicles in the SP exercise, featured in four powertrains as discussed previously. This approach not only lent a whole lot of realism to the SP exercise (Rose and Bliemer, 2008) but it also enabled this research to investigate how the preference of EVs could vary in relation to the vehicle type among the sampled organizations.

2.10 Chapter 2 References

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CHAPTER 3

PROSPECTS OF ELECTRIC VEHICLE ACQUISITION IN CANADIAN FLEET MARKETS – INSIGHTS FROM A RECENT SURVEY

3.1 Introduction

Road transportation in North America is on the verge of some potentially disruptive changes. These involve the adoption of fuel-saving technologies and the use of connected, automated or self-driving vehicles. Global warming and the deterioration of air quality in urban areas due to the extensive reliance on conventional gasoline-based vehicles to satisfy daily transportation needs are partly responsible for these changes. In fact, in 2017, the transportation sector was the second-largest contributor of greenhouse gasses (GHG) in Canada, representing 28% (approximately 201 Mt CO_2 eq) of the total GHG emissions (ENRC, 2019).

Many organizations (both in the public and private domains) have large fleets with extensive daily usage that includes transporting employees, delivering goods, and/or providing services. These commercial activities, many of which takes place in urban areas, contribute significantly to the carbon footprint of the transportation sector. The rate of adoption for fuel-saving technologies in freight transportation is on the rise in developed countries (NACFE, 2018), and the discussions on benefits and costs of adopting such technologies, including all-electric powertrains, have drawn the attention of the fleet industry.

Governments around the globe are working on polices that target the adoption of Electric Vehicles (EVs) by households and firms. A 'Strategic Outlook of the Global Electric Vehicle Market' reveals that up till 2013, the majority of EVs (both Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs)) were procured by governments agencies and private companies (IEA, 2015). The 2018 shares of EVs in Canadian fleets as reported by CAF (2019) are merely 1.0% for pure electric cars and 0.8% for hybrid electric pickup trucks. It is relevant to note that the Canadian national electricity generation emission level (about 167 Mt CO_2 eq/GWh) is considerably below the accepted 600 Mt CO_2 eq/GWh threshold, placing the country as one of the cleanest electric power producers in the world (Kennedy, 2015). This implies that the scarcity of EV ownership in Canada, in general, is due to barriers not related to the source of electricity needed to charge these vehicles.

A considerable number of studies were conducted to understanding these barriers among households over the past 20 years (Potoglou and Kanarogolu, 2007; Mohamed et al. 2016; Ferguson et al. 2018). By comparison, the literature is scarce when it comes to understanding the barriers curbing fleets from adopting EVs and/or the conditions that entice organizations to adopt EVs. Interestingly, fleets are capable of large-scale acquisitions and that makes them ideal candidates for early adoption of new technologies. Further, many fleets operate on predictable depot-based routes and the trip and payload range provided by commonly available EVs can be sufficient for most route operations in mid-size cities. Therefore, adopting EVs among these types of fleets could result in substantial savings for fleet operators.

With a focus on fleets, this chapter provides new insights from a recent online survey called Canadian Fleet Acquisition Survey (CFAS) that was developed and launched in December 2016 to collect data from over 1,000 organizations that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles) in Canadian cities. The collected data includes organization's general characteristics, existing fleet characteristics, future acquisition plans and EV fleet prospects. The CFAS also includes a stated preference (SP) section to identify the circumstances that will lead to higher adoption rates of EVs for fleet usage. This research is the first of its kind in Canada to collect and analyze SP data on the acquisition of EVs in fleets. Furthermore, the CFAS included attitudinal statements to understand the issues that support or deter EV acquisition in fleets.

The remainder of this chapter starts with a background section that provides a summary of existing studies that are most relevant to our work. This is followed by a results section that consists of three parts. The first part highlights the characteristics of the surveyed organizations and their fleets. This is followed by a second part which highlights the SP shares obtained from the CFAS. The third part presents and discusses the results pertaining to the attitudinal statements of the survey. Lastly, a conclusion section is provided to highlight the key accepts of the CFAS.

3.2 Background

Technological advancements in the manufacturing of key EV components, especially the battery components, installation of charging infrastructure, and climate change awareness have renewed public and private sector's interest in EV adoption (IEA, 2016). These advancements have been focused on extending the trip range, reducing the charging time and lowering the capital cost to own an EV. Governments around the globe are supporting policies that encourage public and commercial entities to consider EV adoption on a more substantial scale. This underlines the importance of such entities as being potential early adopters. Higher vehicle acquisition rates, intensive utilization and readiness to invest in refueling/charging infrastructure are the key reasons that have been identified in several studies Sierzchula (2014).

Further, stated preference (SP) methods were used in most of these studies as they provide a close replication of the choices normally facing decision-makers in everyday life while choosing a single option from a set of alternatives. 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 (Hidrue et al. 2011). Our review suggests that most of the earlier SP studies undertaken to assess the adoption of EVs were conducted in response to an event or act that had transpired in recent past. For example, the efforts by Beggs et al. (1981) and Calfee (1985) were in response to the 1970's oil crisis. Low market representation of EVs 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 research to predict the potential EV demand in this American state. Some of these studies included the work of Bunch et al. (1993), Golob et al. (1997), Brownstone et al. (1996), and Brownstone et al. (2000). Later on, the work by Ewing and Sarigöllü (2000), Dagsvik et al. (2002), and Batley et al. (2004) identified various key factors that affect the adoption of

EVs by households, 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. Interestingly, past studies on the acquisition process of fleets had focused on using restricted data that were made available to researchers by fleet operating entities in private or government sector volunteering to participate in the research. These studies either focused on investigating certain aspect of EV adoption or on the viability of a specific vehicle type in fleets (e.g., Correia and Santos, 2014; Feng and Figliozzi, 2013; Haller et al. 2007). In this vein, Davis and Figliozzi (2013), proposed a method to evaluate the competitiveness of electric delivery trucks while Correia and Santos (2014) developed a mathematical model for optimal trip assignment of electric and conventional vehicles in a regional car rental company.

The study by Sierzchula (2014) used semi-structured interviews and project reports to investigate the factors influencing fleet manager adoption of EVs in 14 US and Dutch organizations. The key factors influencing the EV adoption included reducing environmental impact, monetary incentives, and improving the organization's social image in public domain. Similarly, Dong et al. (2014) used GPS based longitudinal travel data collected from gasoline vehicles to analyze the impact of public charging infrastructure deployment on increasing electric miles traveled. Perujo and Ciuffo (2010) investigated the potential impact of EV adoption in private fleets on the electric supply system and on environment in Milan, Italy. The study by Hoen and Koetse (2014) conducted an SP experiment to collect data on the preferences for AFVs of company car drivers in the Netherlands. Purchases behavior of fleet operating entities are often based on past experiences and operational considerations of their needs. On attitudes and perceptions towards EV adoption in fleets, the study by Nesbitt and Davies (2013) provided useful insights as how the perceived value of the PHEVs varied depending on the employee's responsibilities and role in the organization. More recently, the studies by Dimatulac et al. (2018), Mohamed et al. (2016), and Abotalebi et al. (2018) collected revealed and stated preference data on the preference of consumers for EVs for rental and personal use, respectively.

For the purpose of this dissertation, an online survey was designed to collect data from Canadian fleet operators. The full launch of the survey, titled Canadian Fleet Acquisition Survey (CFAS) in December 2016, led to a sample of 1,008 fleet operating organizations that owned and operated fleets. The collected data focused on organization's general characteristics, existing fleet characteristics, future acquisition plans and EV fleet prospects. Fleets were categorized into three broad categories: cars, pickup trucks and utility vehicles. The survey collected information on factors influencing the preferences and motivations of corporate and government entities as they contemplate replacing their current conventional fleets with EVs. The survey also included a stated preference (SP) section to identify the circumstances that will lead to higher adoption rates of EVs by these entities. The CFAS is the first of its kind in Canada to collect and analyze SP data on the acquisition of EVs in fleets. Furthermore, statements regarding the prevailing attitudes and perceptions towards EVs were formulated to gauge organizations' responses towards the issues that support or deter EV acquisition in fleets

To our knowledge, no other study in the past has collected robust and enriched data from fleet operating entities that include characteristics of their existing fleets, their general characteristics, their assessment of EV prospects, their perceptions and attitudes towards EV adoption, and stated choices of adopting EVs in their fleets. It is worth mentioning that the responses were obtained directly from individuals who make, or influence, decisions related to acquisition of their organization's fleets. The following section provides the key insights from the CFAS.

3.3 Results

3.3.1 Characteristics of Surveyed Entities and their Fleets

The surveyed organizations can be classified into six broad categories, as shown in Figure 3-1. Governmental agencies accounted for 18% of the sample, while non-profit organizations (including universities and colleges) accounted for 16%. By comparison, the largest class pertains to for-profit firms, namely corporates. The spatial distribution of the surveyed entities is presented in Figure 3-2. Nearly 39% of all organizations are in Ontario. Quebec accounts for 20% and ranks 2nd, while British Columbia ranks 3rd with 12% share of the total sample. Manitoba accounts for 4% of the total sample while New Brunswick and Nova Scotia have the similar representation with each accounting for 2% of the sample. Finally, the provinces of Saskatchewan and Newfoundland and Labrador each account for 1% of the total sample.

Figure 3-3 shows the distribution of surveyed entities by employee size and the share of fleets they own in the sample. As expected, larger entities with ‘Greater than 500 employees’ own more than half of the total fleets (57%) reported in the sample. Also, entities with employees ranging from 101 to 500 form nearly 23% of the sample and own nearly one fifth of the total fleets. By comparison, smaller entities, while accounting for 64% of the entire sample, only own 23% of the fleets.

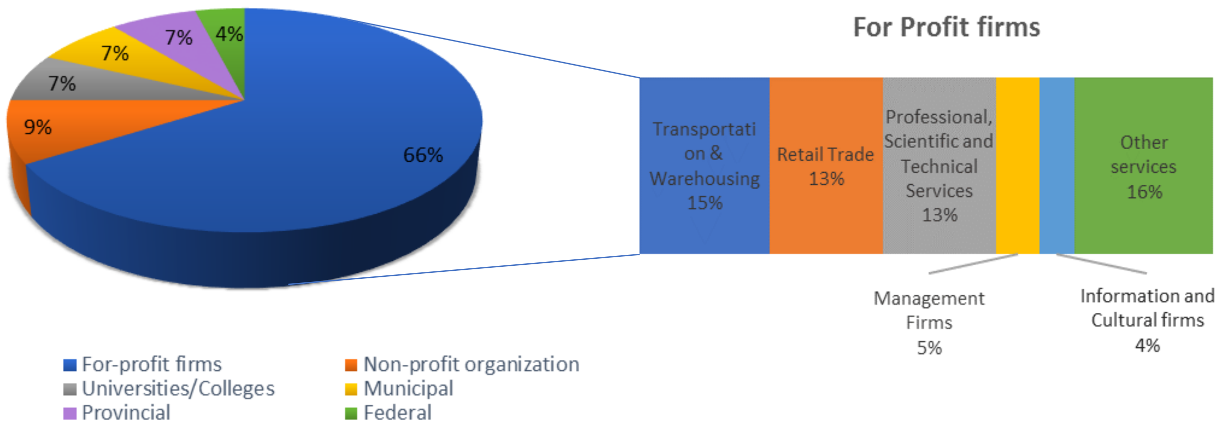


Figure 3-1 Distribution of surveyed entities by sector

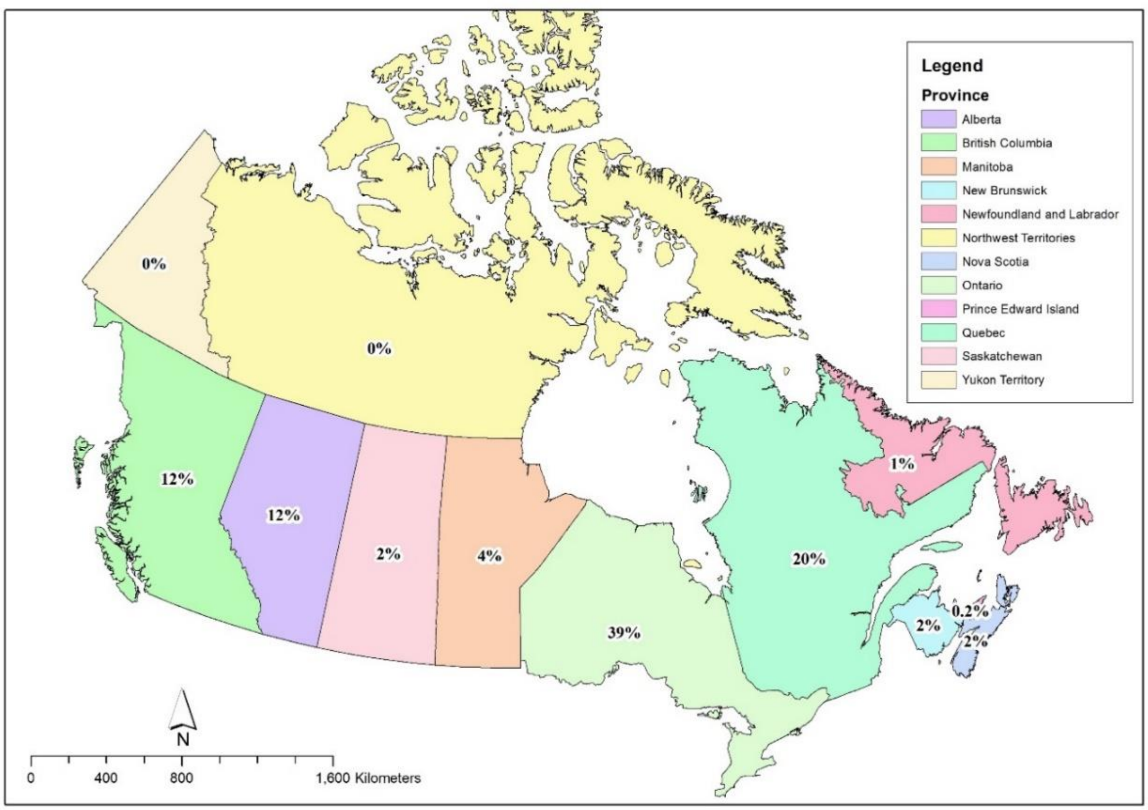


Figure 3-2 Spatial distribution of surveyed entities by Province

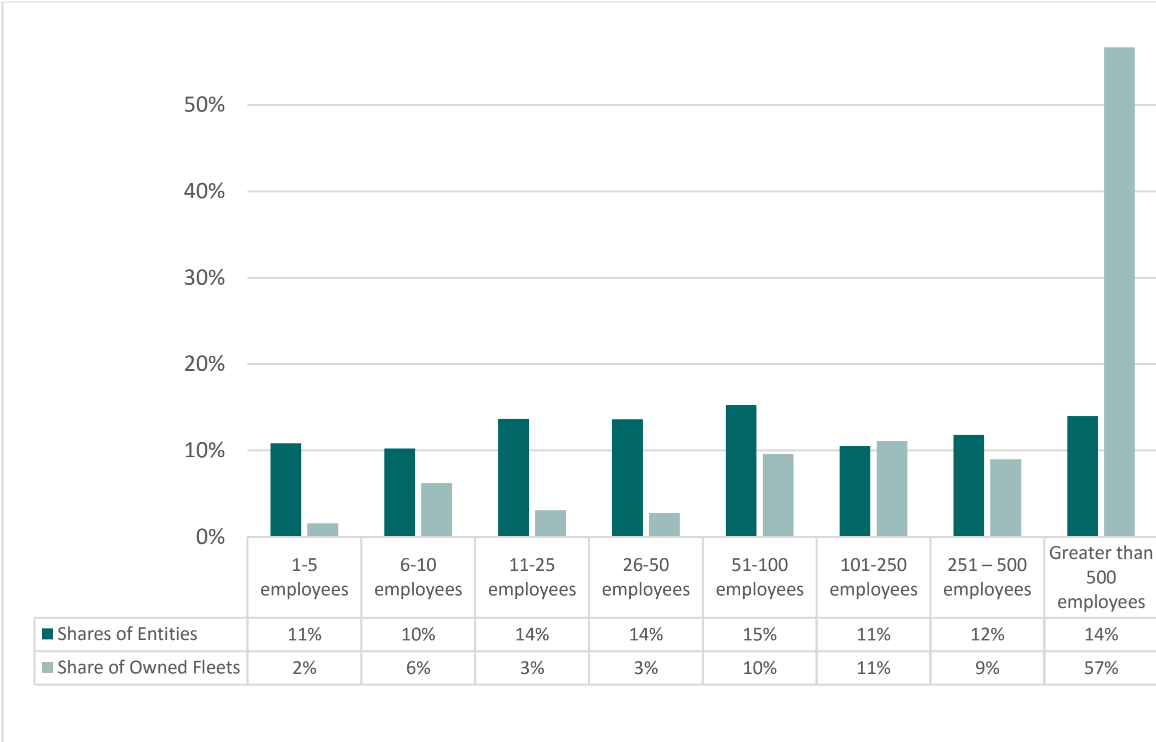


Figure 3-3 Distribution of surveyed entities and fleets by entity employment size

The 1,008 entities in the Canadian Fleet Acquisition Survey (CFAS) report operating one or more type of vehicles that could be classified into three broad categories: car, pickup truck and utility vehicle fleets. Nearly 84% of the surveyed entities own and operate car fleets, while 72% own and operate pickup truck fleets. A significant number of entities (69%) own and operate utility vehicle in their fleets. Nearly 25% own one category of vehicles in their fleets with similar share noted for two categories of vehicles. On the other hand, nearly 50% of all surveyed entities own all three categories of the vehicles in their fleets. In total, 62,172 vehicles are reported for the three categories of fleets. Table 3-1 provides the distribution of these vehicles by vehicle body type and class. Cars account for 29.2% while pickup trucks have a share of 26.4% of the total fleets. On the other hand, utility vehicles such as utility van, bucket truck and large walk-in truck that are used for providing goods and services in urban areas, constitute a significant 44.4% of the reported fleets in our sample. Compact car, intermediate pickup truck and utility van are the three most dominant vehicle types in the reported fleets with shares of 8.2%, 10.8% and 23.8%, respectively. The average size of owned fleets by a given entity is 186 cars, 161 pickup trucks and 62 utility vehicles.

Table 3-1 Distribution of fleet vehicles by body type and class

Dominant Vehicle Type	**Car**	**Pickup Trucks**	**Utility Vehicles**
Compact Car	8.20%	–	–
Intermediate Car	5.90%	–	–
Full Size Car	4.30%	–	–
Compact SUV	2.00%	–	–
Intermediate SUV	2.60%	–	–
Large SUV	0.30%	–	–
Luxury Car	0.90%	–	–
Sports Car	1.20%	–	–
Small Pickup Truck	–	3.70%	–
Intermediate Pickup Truck	–	10.80%	–
Large Pickup Truck	–	10.60%	–
Utility Van	–	–	23.80%
Bucket Truck	–	–	6.90%
Large Walk-in Truck	–	–	12.10%
Mixed	3.80%	1.30%	1.70%
Total	**29.20%**	**26.40%**	**44.40%**

The general characteristics of surveyed fleets in terms of their geographical operation, usage, average annual mileage and acquisition status are shown in Figure 3-4. The distribution of geographical operations of the surveyed fleets shown in Figure 3-4(a) indicates that most of the car fleets (42%) are used for ‘Within a City’ operations, followed second by ‘Within a Province’ operations with a share of 37%. On the other hand, the highest share of geographical operations for pickup truck fleets (56%) is noted for 'Within a Province' category. A clear majority of the utility vehicle fleets in the CFAS, 53% to be exact, as expected, is reported for 'Within a Province' operations.

In terms of fleet usages, Figure 3-4(b) indicates that 37% of car fleets are used for 'Transporting Employees' and a similar share is used for 'Providing Services' while the remaining 26% is used for 'Delivering Goods'. Intuitively, the two dominant usages for pickup truck fleets are 'Providing Services' and 'Delivering Goods' with shares of 40% and 36%, respectively. Unsurprisingly, the highest usage in the case of utility vehicles is noted for 'Delivering Goods' with a share of 43%, followed closely by 'Providing Services' with a share of 41%.

Nearly 37% of the car fleets are reported to have an annual mileage in the range of '25,001 - 50,000 km', as shown in Figure 3-4(c), meanwhile 23% are in the relatively upper range of '50,001-75,000 km'. The highest proportion of the mileage in the case of pickup trucks is noted for the '50,001-75,000 km' range. This ties well with the result noted for 'Within a Province' usage for pickup trucks (Figure 3-4(b)) with a significant share of 56%, implying pickup trucks are likely to have higher annual mileage than the other two types of vehicle fleets. Furthermore, a little over quarter (26%) of all pickup trucks in the sample are reported to be in 'Less than 25,000 Km' annual mileage range. This also correlates well with their 'Within a Site' and 'Within a City' usages, as reported in Figure 3-4(b). Relatively higher variation in annual mileage ranges is noted for utility vehicle fleets when compared to car and pickup truck fleets. More than half of the utility vehicle fleets (58%) are reported to have an annual average mileage between 25,001 to 50,000 km. This is not surprising since 53% of these vehicles reported operating 'Within a Province'. Also, nearly

10% of all utility vehicles in the CFAS are reported to have an annual mileage in the 'Greater than 100,000km' range as shown in Figure 3-4(c).

As expected, vehicles running on conventional gasoline-based fuels account for the majority of surveyed fleets in the sample, as shown in Figure 3-4(d). More specifically, gasoline powered cars account for around 87% of the reported car fleets whereas pickup trucks and utility vehicles running on gasoline constitute more than 50% of their respective fleets. The highest proportion of vehicles using 'Diesel' among the three fleet types is noted for pickup truck fleets with a share of 32%. Interestingly, utility vehicles that use 'Flex Fuel' (more than one fuel, usually gasoline blended with either ethanol or methanol) account for 23% of the total utility vehicle fleets. It is interesting to note that the share of electric powertrain vehicles reported in the sample is the highest (3%) for car fleets though it is still quite insignificant when compared to the share of conventional gasoline cars. In general, the surveyed fleets rely heavily on conventional gasoline and diesel fuel with insignificant shares of flex fuel, ethanol, and liquified petroleum gas (LPG).

Additional characteristics of the surveyed fleets in terms of their average vehicle age, fuel type, replacement cycle, and acquisition status are presented in Figure 3-5. Vehicles in the three fleet types are predominantly within the average age category of '3-5 years', with the highest share of 52% for car fleets, as shown in Figure 3-5(a). Overall, 90% of all cars in the CFAS are less than or 7 years old. This compares to 80% for pickup trucks and 75% for the utility vehicles. The relatively lower shares are intuitive as pickup trucks and utility vehicles are generally associated with longer replacement cycles.

Figure 3-5(b) indicates that around 36.5% of the car fleets are operated on '3-5 years' replacement cycle with as much as 80% of all cars operated on replacement cycles that are less than or equal to 5 years. Nearly 31% of all pickup trucks are operated on ‘3-5 years’ replacement cycle. Utility vehicles, on the other hand, are reported to being operated on longer replacement cycle of ‘5-7 years’ with the highest share of 31.8% of the sampled utility vehicle as shown in Figure 3-5(c). Incidentally, a high correlation can be established between the reported age of vehicles and their replacement cycle, for the three fleet types in our sample. The shorter replacement cycle among fleets are expected since these vehicles in general have a higher mileage compared to privately owned vehicles.

Figure 3-5(c) depicts the ownership status of the surveyed fleets in the CFAS. Outright purchasing and leasing are reported to be the two most preferred options for acquiring vehicles for the three fleet types. More specifically, 43% of car fleets are reported to be ‘Purchased’ outrightly. A similar share is reported for pickup truck fleets while a significantly larger share of 63% is reported in the case of utility vehicle fleets. Leasing accounts for 33%, 26% and 19% for car, pickup truck and utility vehicle fleets, respectively. Interestingly, the lowest shares of ownership are noted for the ‘Rented’ category, in that, only 3% of the car fleets are reported to be acquired through rental programs followed by 12% of pickup truck fleets and 9% of utility vehicles fleets.

Figure 3-5(d) indicates that most fleet vehicles in all three types is acquired in ‘New’ condition with highest share of 83% reported for the pickup truck fleets. Interestingly, the share of ‘Used ‘vehicles among the three fleet types are quite insignificant. On the other hand, a significant proportion of car fleets (27%) are reportedly acquired under the ‘Mixed’ condition (either ‘New’ or ‘Used’).

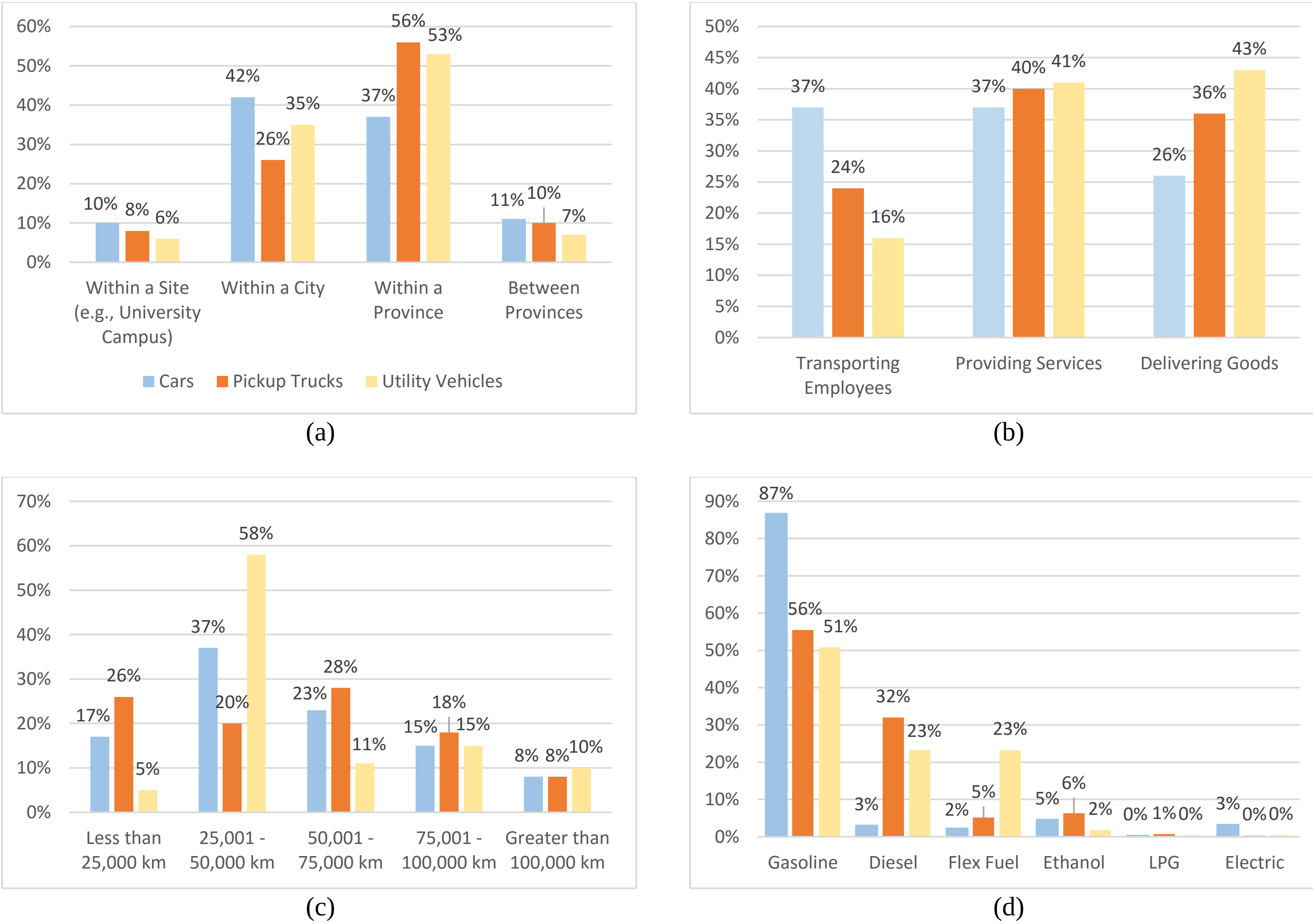
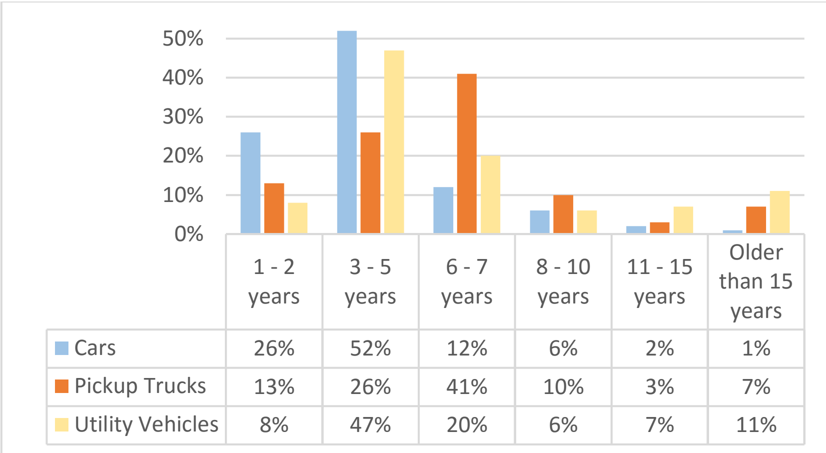
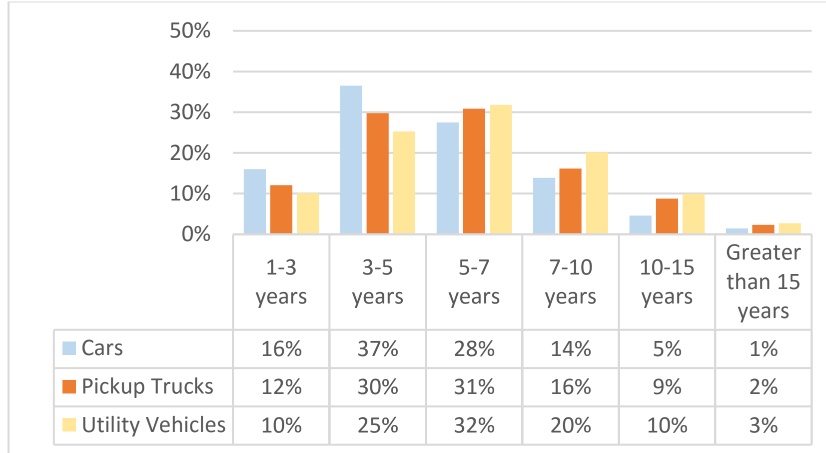


Figure 3-4 General characteristics of surveyed fleets in terrms of (a) geography operation, (b) usage, (c) average annual mileage, and (d) fuel type



(a)



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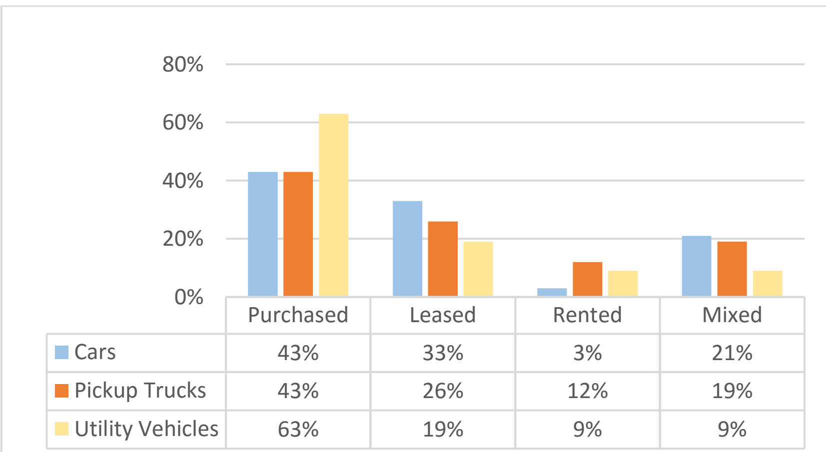
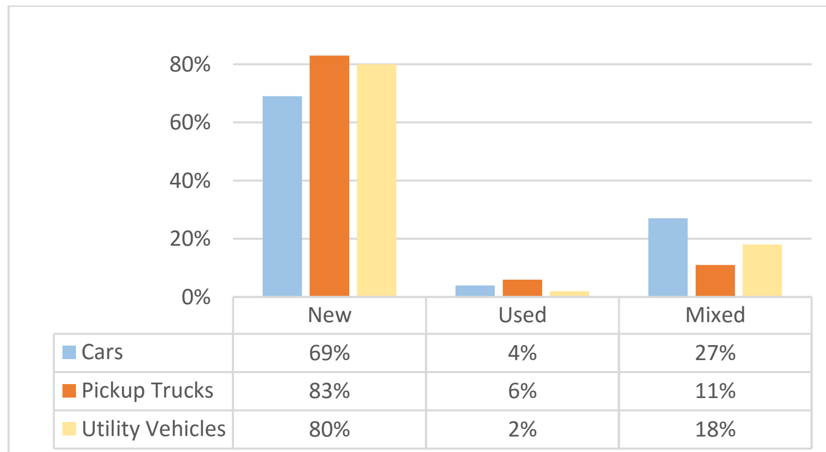


(c)



(d)

Figure 3-5 General characteristics of surveyed fleets in terms of (a) age distribution, (b) replacement cycle, (c) ownership status, and (d) acquisition status

3.3.2 Stated Preference Outcomes

The shares of the choices pertaining to the four vehicle powertrains obtained from the stated preference (SP) section of the CFAS are presented in Figure 3-6. These choices, which are based on evaluating the potential trade-offs between attributes and features of the four powertrains, are broken-down by jurisdictions. Canada wide, as expected, Internal Combustion Engine Vehicles (ICEVs) have the highest market share of 34% among the four powertrains followed second by Hybrid Electric Vehicles (HEVs) with a share of 29%. The remaining two electrified powertrains, Plug-in hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), have shares of 26% and 11%, respectively. Noticeable variation in the shares of the four powertrain choices can be observed for the various Canadian jurisdictions. For instance, the shares of ICEVs ranged from as low as 26% for Quebec to as high as 63% for New Brunswick. The lower preference of ICEVs in Quebec can be attributed to its cleaner electricity generation profile as well as the availability of intensive public charging infrastructure.

The province of Ontario which account for nearly 39% of the sampled entities (n=392) is observed to have 30% share of ICEV powertrain. Also, organizations from the Alberta expectedly have higher preference for ICEVs with an overall share of 47% among the four powertrains. The high preference towards ICEVs can be attributed to Alberta's status as the leading producer of oil and gas in Canada. Similarly, large variation is observed for the preference of HEVs among various provinces. For instance, the shares of HEVs in Nova Scotia and New Brunswick are approximately half of what is observed for the rest of the country. However, the share of HEVs is much higher in the other Atlantic provinces.

Quebec and Ontario are the two leading jurisdictions with a share of 40% each when it comes to the two all-electric powertrains (i.e., PHEVs and BEVs). This is followed closely by British Columbia and Alberta with shares of 37% and 30%, respectively. By comparison, the lagging provinces, as suggested by Figure 3-6, are Saskatchewan and New Brunswick. The SP shares presented in Figure 3-6 are significantly higher when compared to the existing shares in Canadian fleets. For instance, the reported shares of BEVs for cars and light trucks combined was a minuscule 0.5% in 2015 (CAF, 2016). As such, the higher SP shares suggest that if right conditions are put in place, the true EV potential in Canadian markets could well be realized in a relatively shorter period of time especially in the leading provinces.

SP shares of well represented cities in the CFAS are presented in Table 3-2. The results can be used to identify lagging and leading localities for EV adoption at the metropolitan level. The highest preference for ICEVs is noted among organizations from the two key cities in Alberta, namely Edmonton (54%) and Calgary (44%). The high shares of ICEVs suggest that the two metropolitan areas are by far the most lagging jurisdictions in terms of conditions and infrastructure required for EV adoption. Furthermore, the cities of Markham, Surrey and Mississauga, can also be identified as the lagging jurisdictions for EV adoption in Canada. On the other hand, as expected, organizations located in Quebec, a jurisdiction already known for EV adoption, are noted for their highest stated preference for BEVs with an overall share of 33% among the four powertrains. Similar preferences are observed for the PHEVs with a share of 35% for Quebec.

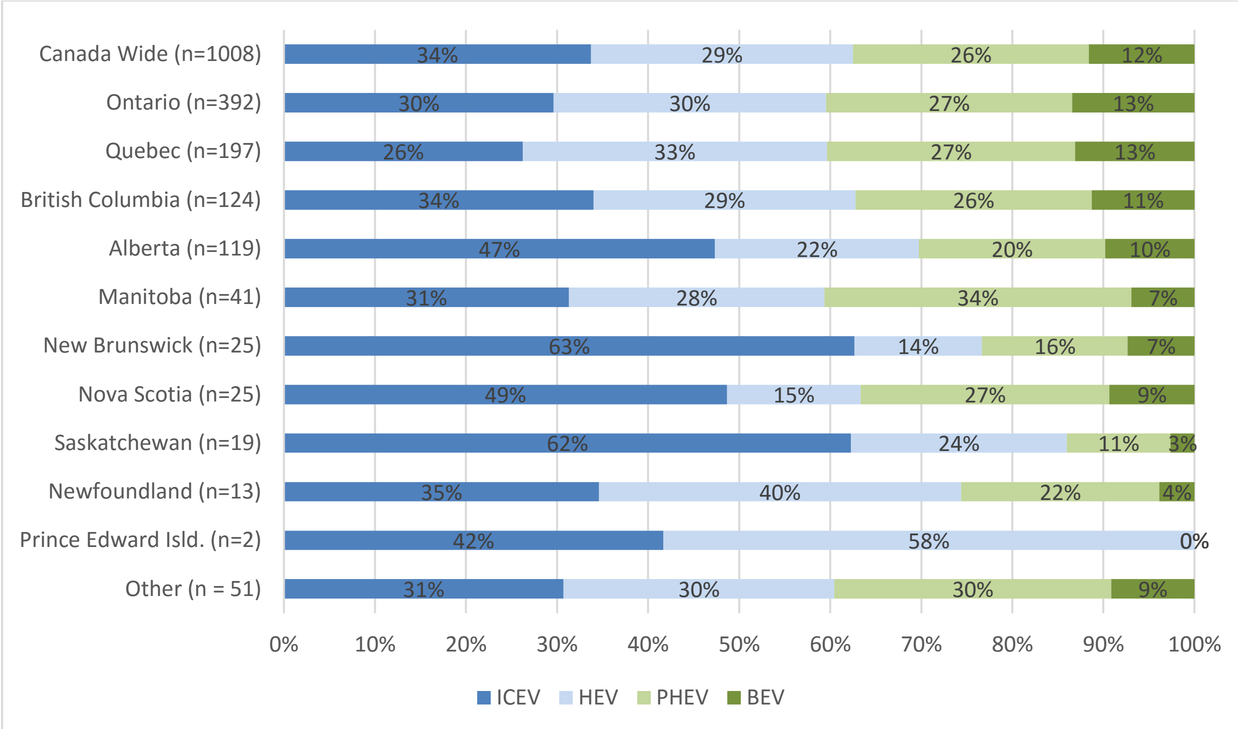


Figure 3-6 Stated preference powertrain shares by Canadian province

Table 3-2 Stated preference powertrain shares by Canadian cities (> 10 entities)

City, Province	# of Responding Organizations	ICEV	HEV	PHEV	BEV
Quebec City, Quebec	13	18%	14%	35%	33%
Ottawa, Ontario	19	25%	27%	30%	18%
Toronto, Ontario	133	25%	33%	26%	16%
Markham, Ontario	13	36%	19%	32%	13%
Vancouver, British Columbia	30	29%	32%	27%	12%
Edmonton, Alberta	28	54%	22%	13%	11%
Montreal, Quebec	57	25%	37%	27%	11%
Calgary, Alberta	61	44%	25%	22%	9%
Winnipeg, Manitoba	33	25%	31%	35%	8%
Mississauga, Ontario	38	31%	38%	24%	7%
Laval, Quebec	10	28%	30%	37%	5%
Surrey, British Columbia	19	32%	46%	18%	4%

Figure 3-7(a) indicates that organizations at the ‘Federal’ and ‘Provincial’ levels have BEV shares of 13.7% and 11.8%, respectively, indicating their keenness to adopt EVs in their fleets. This is in line with the literature where government entities are known to acquire EVs at a mass scale (Sierzchula, 2014). The ‘University/College’ category ranks second in terms of its BEV shares (12.4%). These educational institutions are ideal for adopting BEVs for the following reasons: 1) many of the vehicles in their fleet operate within short distances on the premises; 2) utilizing BEVs would reduce the fleet’s operating cost significantly; and 3) operating BEVs will improve the institution’s public image given their positive environmental benefits. By comparison, ‘Municipal’ and ‘Not for Profit’ entities have a lower share towards BEVs. This is not surprising especially since these entities are often constrained by limited budgets.

Figure 3-7(b) indicates that entities with ‘251-500’ employees’ are associated with the highest share of PHEVs (32%). The SP choices made by small entities with ‘11-25 employees’ indicate a share of 22% for PHEVs, the lowest, compared to all other entity sizes in the CFAS. With respect to the acquisition of BEVs, the equally high preference is noted on both side of the entity size spectrum, i.e., entities both small (‘6-10 employees’) and large (‘Greater than 500 employees’) with identical share of 14%, each. Small entities often face tough competition and risk going out of business if they do not operate efficiently and to that effect it can be assumed that these organizations would want to acquire EVs for their fleets to cut down fuel and operating costs. On the other hand, mega organizations are way more likely to acquire EVs as they often have a climate action plan as part of their business strategy and the capital needed to acquire the technology.

The position of the decision-maker responsible for acquiring fleets in the organization tends to impact the shares of vehicle technology, as suggested by Figure 3-7(c). For instance, the highest share of BEVs (17%) is observed in the case of CEOs. This is understandable as individuals occupying this position are vested with full responsibility and authority to steer their organizations towards adopting cutting-edge vehicle technologies that could save fuel and maintenance costs. Fleet supervisors who are responsible for the operational reliability of their fleets also have relatively higher preference for EV technology as reflected by a combined share of 38.1% for PHEV and BEV. Interestingly, individuals responding to the CFAS under the title 'Other Manager' and 'Director' show a significant preference for ICEV based vehicles in their fleets. The result could be attributed to them not being fully familiar either with the full scope of their organizations' fleet operations and/or the savings that could be achieved by introducing EVs in their fleets.

The highest preference for PHEV among the three vehicle classes in car fleets, as noted in in Figure 3-7(d), is for 'Full Sedan' with a share of 29%. The same class is associated with the highest share of 15% for BEVs. Almost, identical shares of PHEVs are noted for the three vehicle classes of the pickup truck fleets. However, when it comes to acquiring BEVs, the share of 'Small Pickup Trucks' is nearly two times (13%) that of the other two classes of pickup trucks (7% share, each) indicating high preference of all-electric 'Small Pickup Trucks' by the surveyed entities. With respect to utility vehicle fleets, the highest share of PHEV is noted for 'Large Walk-in Truck' (29%) followed second by 'Utility Van' (12%). Interestingly, the same classes are also associated with high shares of BEV powertrain.

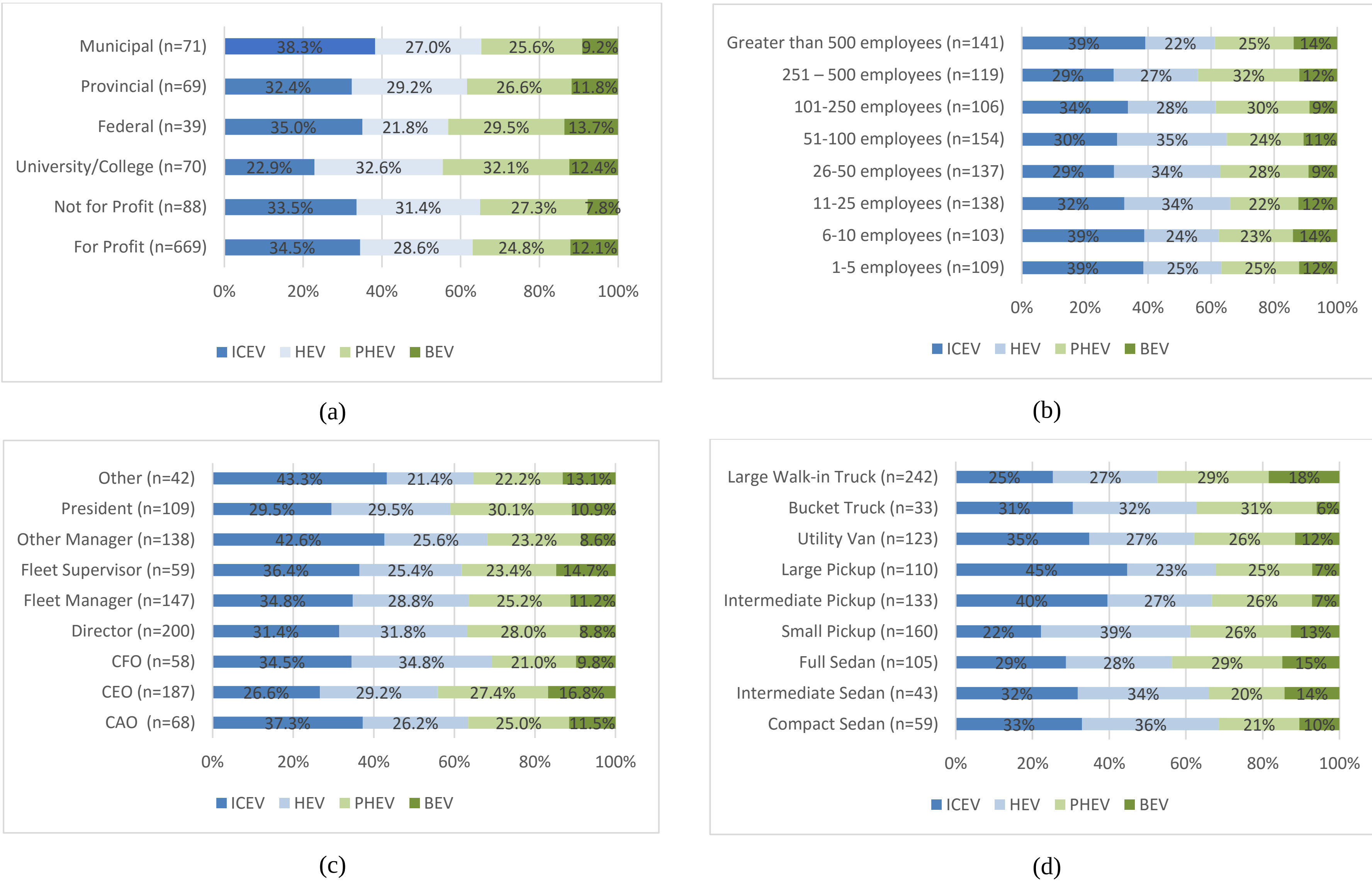


Figure 3-7 SP shares based on surveyed organization's (a) type, (b) size, (c) decision maker's job title, and (d) fleet vehicle class

3.3.3 Electric Vehicle Fleet Prospects

Table 3-3 presents the results on the acquisition of BEVs. More than half (56%) of the participating organizations indicate that they do not have any plan to acquire BEVs for their fleets. Organizations that are likely to acquire BEVs in the next 2 years account for 20% of the total sample. As the time frame to acquire BEVs is projected further in the future, the share of organizations that will likely acquire BEVs drops, i.e., from 16% for the 'In the next 5 years' time frame to 3% for the 'In the next 7 years' time frame. Organizations that were not sure whether they will acquire BEVs for their fleet account for 5% of the total sample. The 'New' condition is heavily favored over other all other conditions with shares of 31% as shown in Table 3-4. Consistent and similar trends are observed on the acquisition outlook for PHEVs.

Table 3-3 Acquisition outlook for battery electric vehicles

Time Frame	Share
In the next 2 years	201 (20%)
In the next 5 years	159 (16%)
In the next 7 years	35 (3%)
Not sure when	52 (5%)
No plans	561 (56%)
Total	1,008 (100%)

Table 3-4 Acquisition condition for battery electric vehicles

Condition	Share
New	309 (31%)
Used	70 (7%)
Not sure	38 (4%)
Mixed	30 (3%)
N/A	561 (56%)
Total	1,008 (100%)

Existence of regulatory imperatives or policies (internal or external), such as 'made in Canada', in fleet procurement could deter acquisition of certain types of vehicles in fleets. The results pertaining to such imperatives for the major categories of organizations are shown in Table 3-5. An overwhelming majority (94%) of the respondents indicate that their organizations do not have any regulatory imperatives in fleet procurement.

Table 3-5 Regulatory imperatives or policies in fleet procurement

Regulatory Imperatives	Federal	Provincial	Municipal	University/ College	Non-profit	For-Profit Firm	Total
Yes	1%	1%	1%	0%	1%	2%	**6%**
No	3%	6%	6%	9%	6%	64%	**94%**
Total	**4%**	**7%**	**7%**	**9%**	**7%**	**66%**	**100%**

3.3.4 Attitudes and Perceptions towards Fleet Electrification

Some of the most valuable insights gained from the CFAS are found in the responses to the statements on attitudes and perceptions of EVs. The responses that covered a multitude of EV aspects were collected via a 7-point, ordered, one dimensional Likert scale. The scale allows the analyst to get a measure of the cognitive and affective aspects of the attitudes and perception of the respondents by allowing them to choose a single option from the scale that best aligns with their view or perception. The responses were measured in terms of two variants of judgments: on agreement (strongly agree to strongly disagree) and on importance (not at all important to extremely important).

In the first set of statements, the sampled entities are asked to express their opinion regarding factors that deter and support the acquisition of plug-in hybrid electric vehicles (PHEV) or BEVs for their fleets. These factors are shown in Table 3-6.

Table 3-6 Key deterring and supporting factors linked to fleet vehicle electrification

Deterring Factors (DFs)	
DF1:	Capital cost
DF2:	Battery replacement cost
DF3:	Cost of human resources (i.e., mechanics)
DF4:	Charging infrastructure cost (i.e., chargers, garage upgrade, etc.)
DF5:	Electricity (Hydro) rates
DF6:	Higher insurance rates
DF7:	Operational reliability due to range limitation and longer charging time
DF8:	Integration with current fleet
DF9:	Cold/hot weather impacts
DF10:	Concerns on the maturity of electric vehicle technology
DF11:	Technology anxiety and fear of obsolescence
DF12:	High risk of being an early adopter of new technologies
Supporting Factors (SFs)	
SF1:	Reduced fuel cost
SF2:	Lower maintenance cost
SF3:	Monetary incentives including municipal & provincial financial support
SF4:	Access to HOV lanes
SF5:	Availability of free parking
SF6:	Availability of public charging stations

The average responses to these two categories of factors are presented in Figure 3-8. On average, 23% of organizations indicate that the deterring factors are 'Extremely Important' in the acquisition of EVs for their fleets. Similar trend is observed for factors that support the acquisition of EVs with nearly 25% of the participating organizations indicating those factors to be also 'Extremely Important'. On the other hand, an insignificant proportion of the participating organizations consider the two categories of factors to be 'Not at all important'. It is important to note that a clear majority of the organizations (approximately 90%) ranked both categories of factors to be important (i.e., scale greater than or equal to 4).

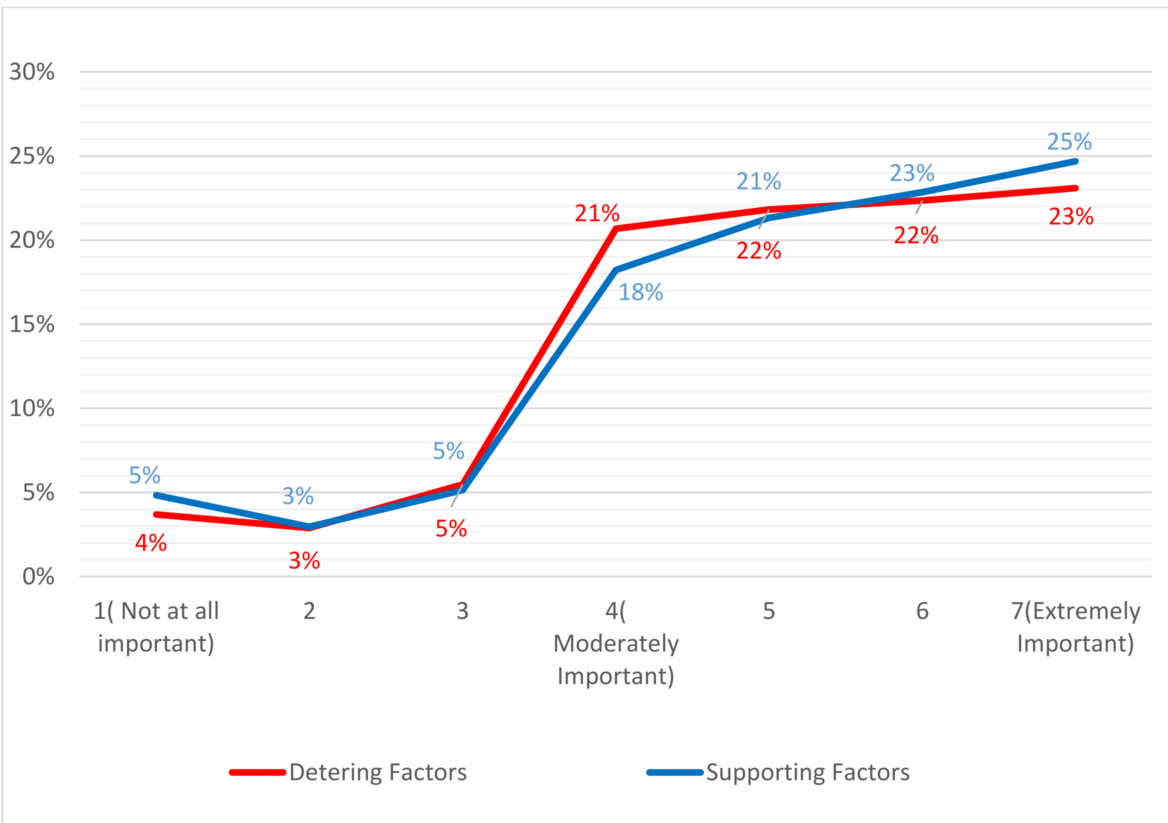


Figure 3-8 Average responses regarding factors that deter and support EV acquisition

In the second set of attitudinal statements (ATs), the organizations are presented with eleven attitudinal statements on the potential benefits of EVs which include: replacing foreign-oil with made in Canada electricity, promoting social image of the organization in public domain. The statements are also formulated to gauge responding organization's responses to industry pressure, their social obligation to support environmental causes and their willingness to spend additional money towards capital cost and installation of charging infrastructure to facilitate EV adoption in their fleets. A few of the designed statements are aimed at understanding the attitudes about the capability of EVs in meeting the operational demand of the responding organizations, as well as, assessing the risks involved in the EV acquisition decision-making. These statements along with the results pertaining to the obtained responses are listed in Table 3-7.

Table 3-7 Agreement/disagreement with factors influencing EV acquisition

Statement (AT) #	1 (Strongly Disagree)	2	3	4 (Neutral)	5	6	7 (Strongly Agree)	Total
AT1	7%	3%	5%	30%	20%	18%	16%	1,008
AT2	5%	6%	6%	25%	23%	22%	12%	1,008
AT3	7%	5%	9%	23%	24%	21%	11%	1,008
AT4	5%	4%	6%	27%	25%	20%	12%	1,008
AT5	5%	4%	5%	23%	25%	23%	14%	1,008
AT6	9%	6%	8%	23%	21%	21%	12%	1,008
AT7	8%	6%	5%	23%	26%	19%	14%	1,008
AT8	8%	6%	8%	25%	21%	21%	13%	1,008
AT9	9%	6%	7%	25%	22%	18%	12%	1,008
AT10	7%	5%	7%	26%	22%	21%	12%	1,008
AT11	9%	4%	7%	24%	25%	19%	14%	1,008

Key:

Statement (AT) #	Statement Description
AT1	Our organization thinks that operating EVs will help replace foreign-oil with made in Canada electricity
AT2	Our organization is confident that using EVs in our fleet is a cost-effective decision
AT3	Our organization is willing to spend more money to adopt EVs in our fleet in the near future
AT4	Our organization thinks that using EVs in our fleet is a prudent decision
AT5	The decision to adopt EVs in our fleet will promote our image, it is a good decision
AT6	Our organization has the technical capabilities to operate a fleet of EVs
AT7	Our organization is confident that a fleet of EVs will meet our operational demands
AT8	Our organization thinks that using EVs in our fleet is not a risky decision
AT9	Following the emerging trend in the industry, we feel pressure to adopt EVs in our fleet
AT10	Our organization is willing to install additional infrastructure to adopt EVs in our fleet
AT11	Our organization feels socially obliged to use EVs to support environmental causes

There appears to be a consistency in terms of the participating organizations' agreement/disagreement to the eleven attitudinal statements on the Likert scale. On average nearly 25% of the organizations are 'Neutral' in their response to all eleven statements with 30% of the organizations being not sure whether or not operating plug-in electric vehicles (i.e., PHEVs or BEVs) will help replace foreign-oil with made in Canada electricity. Similarly, close to 26% of the FOEs are also not sure that using plug-in electric vehicles in their fleet is a prudent decision. Furthermore, nearly 26% of the entities showed a 'Neutral' response towards the willingness to install additional infrastructure to adopt plug-in electric vehicles in their fleet. With respect to perceiving EV adoption in fleets as a cost-effective decision, nearly 25% of the participating FOEs demonstrate a 'Neutral' response. The same could be said about when asked if "*EV adoption in fleets is not a risky decision*" with 25% of the entities opting to remain 'Neutral'. A similar proportion (25%) is found to be not affected by the emerging trend in the industry, and therefore do not feel pressured to adopt plug-in electric vehicles in their fleets. In terms of being in-agreement, on average, 56% of all entities are in some form of agreement with the posed statements compared to only 19% that disagree. On the other hand, on average, nearly a quarter of all entities choose to be neutral when expressing their agreement/disagreement with the statements. The highest level of disagreement is noted for statements AT6, AT9 and AT10 which account for 9% of the entire sample. More specifically, 9% of all respondents strongly disagree to the statement that their entities have technical capabilities (i.e., specialized mechanics) to operate a fleet of plug-in electric vehicles. Also, a similar proportion of respondents indicate their strong disagreement to the notion that they feel pressured to adopt EVs. The same could be said about the statement pertaining to whether they are socially obliged to use EVs in their fleets to support environmental causes.

In the third and last set of attitudinal statements, a pairwise comparison exercise is conducted in which respondents are asked to assess four key aspects of EVs, namely environmental benefits (EB), total cost of ownership (TCO), operational feasibility (OF) and risk of implementing new technology (RINT). The rationale for using these four key aspects is driven by the following hypotheses:

- *H1: A lower total cost of ownership has a positive influence on EV adoption in fleets*
- *H2: Addressing environmental concerns has a positive influence on EV adoption in fleets*
- *H3: Improved operational feasibility has a direct positive influence on EV adoption in fleets*
- *H4: Informed decision-making regarding EVs risks has a positive influence on EV adoption in fleets*

The four aspects resulted in the following six pairwise comparisons that were evaluated by the surveyed respondents:

- *PCM1: Importance of the <u>total cost of ownership</u> of EVs, relative to its <u>environmental benefits</u>*
- *PCM2: Importance of the <u>total cost of ownership</u> of EVs, relative to its <u>operational feasibility</u>*
- *PCM3: Importance of the <u>total cost of ownership</u> of EVs, relative to the <u>risk of implementing new technology</u>*
- *PCM4: Importance of <u>the environmental benefit</u> of EVs, relative to its <u>operational feasibility</u>*
- *PCM5: Importance of the <u>environmental benefit</u> of EVs, relative to the <u>risk of implementing new technology</u>*

- *PCM6: Importance of the operational feasibility of EVs, relative to the risk of implementing new technology*

Figure 3-9 presents the aggregated results pertaining the above pairwise comparisons. Nearly 20% of all participating entities indicate that relative to its environmental benefits, the total cost of ownership of EVs is ‘Extremely Important’. Similarly, the operational feasibility of EVs relative to their total cost of ownership is also considered ‘Extremely Important’ by 18% of all FOEs. On average, nearly 63% of the respondents indicate that the two underlined aspects describing each PCM are in some form important. On average, 25% of the respondents think that the two aspects are ‘Equally Important’. By comparison, only 4% of the respondents think that the two aspects are ‘Not at all Important’.

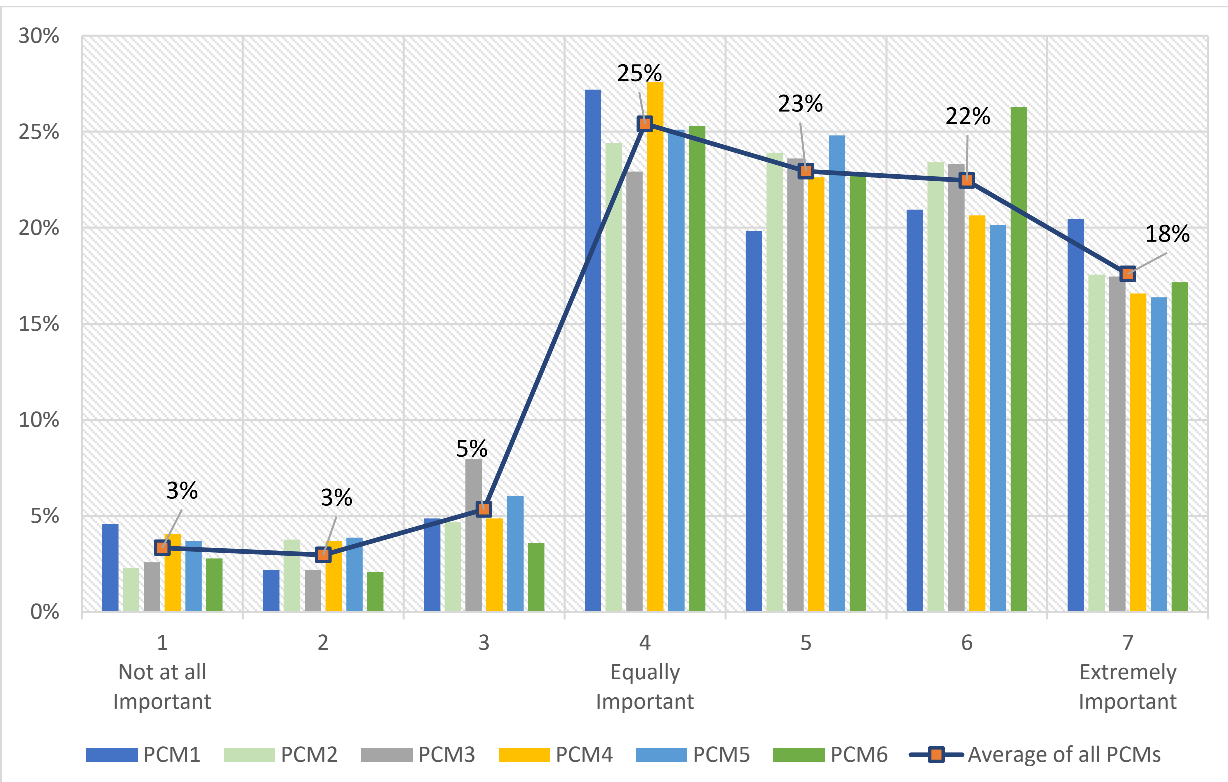


Figure 3-9 Responses to the pairwise comparisons of different aspects influencing electric vehicle acquisition

3.4 Summary

This chapter presented the key insights from an online survey aimed at understanding the barriers curbing fleets from adopting Electric Vehicles (EVs) and the conditions that must be put in place to entice organizations to adopt EVs. To date, the bulk of studies on EV acquisition have been focused on households. In that respect, our research is the first of its kind to investigate the potential of EV adoption by Canadian fleets. The developed survey tool titled 'Canadian Fleet Vehicle Acquisition' (CFAS), collected data from over 1,008 organizations, from both corporate and government sectors, that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles) in various Canadian jurisdictions. The collected data from the responding organizations include characteristics of their owned fleets, their general characteristics, their assessment of EV prospects, their perceptions and attitudes towards EV adoption. The CFAS also included a stated preference component to investigate the factors influencing the decisions of adopting EVs in fleets. The responses were obtained directly from individuals who made, or influenced, decisions related to the acquisition of fleets in their organizations.

Based on the CFAS results we reported in this chapter, several insights could be formulated as follows:

- *Car fleets have the highest potential for adopting EVs within a 5 years period. This could be supported by the following CFAS outcomes: more than half of the existing car fleets are replaced within 5 years; around 42% of car fleets operate within their respective cities; and over 87% of the car fleets are powered by gasoline. The adoption of EVs in car fleets is feasible given that the trip range offered by most of the currently available EVs is suitable for city operations.*

- *A considerable number of utility vehicle fleets could become EV adopters within the next 5 years. According to the CFAS, 35% of these fleets operate within their respective cities; more than half of these fleets are gasoline-based and 35% of them are replaced within 5 years.*

- *Many pickup truck fleets and utility vehicle fleets, alike, could become EV adopters over the next 7 years as technological advancement in electric powertrains improve trip range. The CFAS suggests that more than half (56%) of the pickup truck fleets are used within their provinces; a similar share of 53% is noted for the utility vehicle fleets; and over 70% of both types of fleets are replaced within 7 years.*

- *Certain Canadian provinces will need more aggressive polices to encourage the adoption of EVs among fleets. According to the stated preference choices in the CFAS, fleets in Atlantic provinces (namely, Nova Scotia and New Brunswick) are more likely to gravitate towards conventional ICEVs; likewise, fleets operating in the Prairies (namely, Alberta and Saskatchewan) also prefer gasoline-based vehicles. Fleets in three largest provinces (namely: Ontario, Quebec and British Columbia) are more likely to adopt EVs in their fleets.*

- *Certain Canadian cities, as in the case of provinces, will need to account for the conditions that could promote or deter EV adoption when revising their transportation master plans. The stated preference choices in the CFAS indicate that fleets in some cities (e.g., Quebec City; Ottawa and Toronto) will potentially* *lead the adoption of EVs. In contrast, some cities (e.g., Calgary; Edmonton and Markham) are less likely to embrace EVs.*

- *Data from the CFAS indicate that EV acquisition in the next 2 to 5 years has better prospects (about 17%) compared to the long-term acquisition in the next 7 years (about 3%).*

- *Reductions in the costs of battery replacement and charging infrastructure, along with improvements in driving range limit and charging time could lead to noticeably higher EV preferences. Also, incentives (monetary and non-monetary) could support the adoption of EVs. The CFAS indicates that the majority of the organizations (approximately 90%) believe that these factors are important in EV acquisition.*

- *Operational reliability offered by existing EVs seems a strong deterrent for most fleet operations. Nearly three quarters of the participating organizations consider range limitation and longer charging time key deterrents for acquiring EVs for their fleets.*

- *EV adoption in fleets can lead to significant reduction in operating cost. According to the CFAS, nearly three quarters of the participating organizations see the reduced fuel and maintenance costs as the key factors supporting the acquisition of EVs in their fleets.*

- *Risks associated with being an early adopter of a new technology are for the most part not valid for EV adoption in fleets as nearly 80% of the participating organizations believe that using EVs in their fleets is not a risky decision.*

- *Availability of on-site mechanics specializing in EV maintenance and repairs is likely to affect the adoption of EV. Nearly one quarter of the surveyed organization report that they do not have technical capabilities to operate a fleet EVs.*

- *Data from the CFAS suggest that purchase cost is not a significant barrier for EV adoption. More than half of the surveyed organizations are willing to spend more money to adopt EVs in their fleet in the near future.*

- *Introduction of EVs in fleets is expected to improve public image of organizations. Nearly two thirds of the surveyed organizations agree that decision to adopt EVs in their fleet will promote their image.*

- *There are good prospects towards adopting EVs in Canadian fleets. According to the CFAS, more than 40% of the participating organizations have charging stations at all or most fleet locations. Also, close to 20% has charging stations at some fleet locations.*

3.5 Chapter 3 References

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CHAPTER 4

INVESTIGATING ATTITUDES TOWARDS ELECTRIC VEHICLE FEASIBILITY IN CANADIAN FLEETS - AN EXPLORATORY ANALYSIS APPROACH

4.1 Introduction

Electric Vehicles (EVs) are fast emerging as a viable option to the conventional gasoline-fueled vehicles. Although the technology behind EVs have existed for over one hundred years (Hoyer, 2008), certain push and pull factors have influenced its utilization to power vehicles. Dependency on fossil-fuels due to their low cost to power conventional vehicles has been the key push factor at play. Factors that provided a pulling effect in recent years include advancement in electrical motor and battery technology (Lebeau et al. 2013). As a result, the global EV market started picking up about a decade ago and has continued to grow rapidly with 2018 sales growing to nearly two million vehicles, an increase of 63% from the previous year (Hertzke et al. 2019). EV sales in both US and Canada are also on the rise with market shares of 1.8 and 3.3%, respectively in 2019 (EEI, 2019; EMC, 2019).

Another important pull factor is the promise that EVs provide as eco-friendly technology to combat climate change and global warming. Organizations, in both public and private spheres are operating in an environmentally conscious world and many have been receptive to the idea of relying on eco-friendly products (EV20, 2012). As such, there has been an increased focus and attention by entities from both the public and private sectors to engage in being part of the solution of the ongoing greenhouse gasses (GHG) emissions problem. These attitudes can lead to a win-win situation since they also help improve the social image of mega organizations focusing on the adoption of low carbon technologies. This is evident by the recent decision of the Amazon Inc. to acquire 100,000 all-electric vans for its delivery operations, part of its carbon-neutral vision for the next 20 years (CNBC, 2020).

Empirical studies on the penetration and diffusion of new vehicles technologies have always focused on attitudinal barriers (Egbue and Long, 2012; Lane and Potter, 2007). In fact, one of the most critical factors influencing the success or failure of a new technology is users' acceptance (Davis, 1993). A thorough review of past studies on EV adoption indicates that there are stark differences between the motivations driving the decisions of private consumers versus organizations when it comes to embracing the EV technology (Globisch et al. 2018). Although EVs have come a long way since their inception, their acceptance is still affected by their unfavorable historical traits of lack of performance, range limitation and functionality issues (Davis et al. 2013; Wikstrom et al. 2016).

Empirical research on the acquisition processes undertaken by organizations shows that the purchase decisions are not always based on cost-benefit measures alone (Zehetner, 2011). For instance, if a rational evaluation of purchasing alternatives is not possible personal feelings might come into play before arriving at the final purchasing decision. Furthermore, non-cognitive factors such as trust matters, cultural influence, intuition, social responsibility, and perceptions also impact professional decision-making process (Zehetner, 2011). To that effect, constructs such as subjective norms are found to be quite important in influencing the acquisition of EVs in commercial fleets (Globisch et al. 2108). Environmental benefits and perceived ease of use are identified as relevant antecedents to

EV acceptance in fleets (Globisch et al. 2108). This finding is in fact partly corroborated by Seitz et al. (2015) whereby early adoption of EVs in larger than average organizations is driven by non-economic considerations such as corporate image and social responsibility in the public domain.

Aside from financial barriers, operational barriers play a pivotal role in the acquisition decisions of new technologies aimed at the decarbonization of transportation related emissions. Skippon and Chappel (2019) and Wikstrom et al. (2016) identified potential barriers and challenges that could hinder the adoption of battery electric vehicles (BEVs) in commercial fleets if not tackled. These challenges pertain to the issues related to BEV deployment, handling failures, promotion of BEV usage. Wikstrom et al. (2016), through their focus-group based research findings, further suggested that the introduction of BEVs to fleets should be supported through assistance and commitment from external sources such as government initiatives and policies.

The 2018 fleet vehicle registrations (413,212 as reported in CAF, 2019) accounted for more than 50% of total vehicle registrations (787,865 as reposted by Statistics Canada, 2020) in that year. These fleet vehicles, which are used for various purposes including rental, providing services and delivering goods, are associated with significant GHG emissions. Hence, the success of any low emission or decarbonization technology including electric powertrain vehicles will heavily depend of the adoption of such technologies by Canadian fleet operating entities (FOEs). It is not surprising that the transportation sector was the second-largest contributor of GHG emissions in Canada, representing 28% of the total emissions in the year 2017 (ENRC, 2019). As part of its zero-emissions vehicles (ZEVs) mandate, Canada recognizes that reducing transport related emission is imperative in achieving a 30% GHG emissions reduction target (below 2005 levels) by 2030. Interestingly, technology uncertainty and awareness were two key barriers that were identified with respect to the adoption of ZEVs (Natural Resources Canada, 2019).

While significant strides have been made over past decades to study the applicability of alternative fuel vehicles in fleets, nevertheless, past studies have focused on using restricted data that were made available to researchers by FOEs in private or government sector volunteering to participate in the research. To our knowledge, this research is first of its kind in Canada that investigates attitudes towards electric vehicle feasibility in Canadian fleets via the responses to the attitudinal statements that were obtained directly from individuals who make or influence the decisions related to acquiring vehicles in their organization's fleets. The research is also aimed at ascertaining potential differences in the perceptions of corporate and governmental FOEs towards EVs.

The remainder of this chapter is organized as follows: Section 2 provides the highlights of the attitudinal data utilized in this research. The detail of the methods used to analyze the attitudes of Canadian FOEs is presented in Section 3. The results of this research are presented in Section 4 which is followed by a section that provides the conclusion of the research.

4.2 Attitudinal Data on Electric Vehicle Fleet Acquisition

The data employed in this chapter comes from the attitudinal section of the Canadian Fleet Acquisition Survey (CFAS). The survey, which was conducted in December of 2016, collected responses from over 1,000 Canadian organizations that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles). The responses to a variety of attitudinal statements that covered a multitude of EV aspects were collected via a 7-point, ordered, one dimensional Likert scale. The details of the three attitudinal datasets is provided in Section 3.3.4 of Chapter 3 of this dissertation.

4.3 Methodology

4.3.1 Exploratory Factor Analysis

Exploratory Factor Analysis (EFA) is a multivariate statistical method used to reveal the unobservable underlying factors that are linearly related to the observed variables of interest (Tryfos, 1998). The method reduces the dimensionality of the observed data by compacting the variables of interest into clusters of inter-correlated variables called 'factors' or 'constructs'. Each observed variable y_1, y_2, y_3, …, and y_n is assumed as a potential measure of every factor. Here, a linear combination of the observed variables is used to calculate each of the factors F_a and F_b, as shown in Figure 4-1.

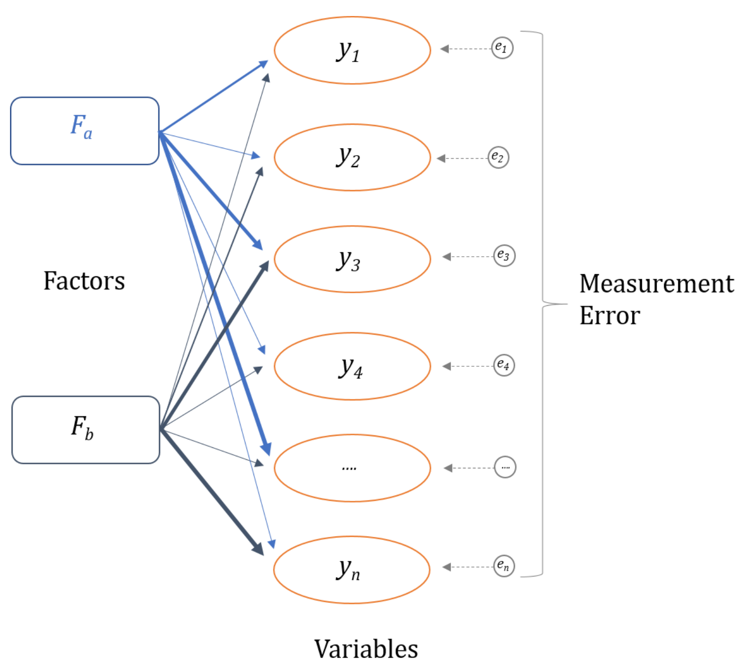

Figure 4-1 An illustration of the Exploratory Factor Analysis
(adapted from Tucker and MacCallum, 1997)

The elements that influence observed variables include common factors, specific factors and measurement error. Common factors, as the name implies, give rise to more than one of the observed variables. Specific factors, on the other hand, account for only one of the observed variables. The third element that influences observed variables is measurement errors which are caused mainly by the lack of perfect information regarding the observed variables. These elements directly contribute to the variance of the observed variables as well. The key objective of the analysis is to determine the relationship between observed variables and factors and to explain the covariance among variables. Figure 4-2 shows the breakdown of the total variance structure of the observed variables. The EFA approach starts with the assumption that the variables are correlated and partitions the total variance of the measured variables into common and unique variances (Watkins, 2018). The former is also referred to as '*communality'* while the latter, which is due in part to factors that influence only the specific observed variable and measurement error, is often referred to as '*uniqueness'*.

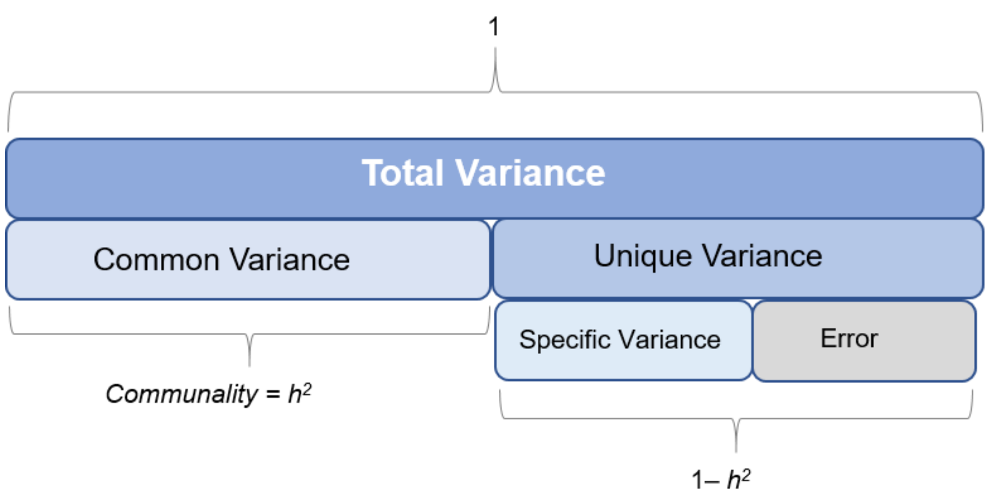

Figure 4-2 Variance breakdown of observed variables
(adapted from Neill, 2013)

The parameters associated with the linearly related observed variables are referred to as *loadings*. These numerical coefficients correspond to the directional paths connecting common factors to observed variables and provide the basis for interpreting the latent constructs. Higher loading of a variable in a factor means that the observed variable bears a stronger association with the factor. A rule of thumb is to consider loadings above 0.30.

The factors (i.e., latent constructs) in EFA are extracted from correlation matrices whereby the eigenvalue of a construct represents the amount of variance that is explained by that specific factor. Typically, the first factor extracts the most common variance followed by remaining sequential factors accounting for successively smaller portions of the total variance. The eigenvalues have been used as a guide to retain the number of factors in EFA (Watkins, 2018). To account for 100% of the variance, estimation software packages usually start by extracting the number of factors that equate to the number of variables include in the analysis. However, not all extracted factors make conceptual sense and could not be included in further analysis (Costello and Osborne (2005). Instead, a distinct break in the slope of scree plot depicting the relationship between eigenvalues and the ordinal number of the factors is used as a reference point to ascertain the number of true factors to be retained in the analysis (Cattell, 1966).

Factor rotation, in EFA is performed with the purpose to refine and clarify the factor structure and provide interpretation. The two most commonly used methods of factor rotation include, orthogonal and oblique rotations. As the name implies, the orthogonal rotation assumes no correlation among the factors whereas the latter allows the factors to be correlated in order to arrive at an optimal solution to the problem. In the SAS statistical software, orthogonal rotation includes techniques such as *varimax*, *quartimax*, and *equamax*, while oblique rotation can be performed using *oblimin*, *promax*, and *goemin* procedures (SAS User Guide, 2020). In this research, a combination of the two rotations was used to derive an optimal structure of the factors in SAS. First, the factors were orthogonally rotated using *varimax* followed by an oblique rotation specified via *promax*. Since the objective of EFA is to explore the data and reduce the number of variables, its output can be used as input to confirmatory factor analysis and discrete choice modeling (DiStefano et al. 2009). In this respect, the latent constructs (i.e., factors) from the analysis in this chapter were used to model the acquisition time frame of electric vehicles, as will be discussed in Chapter 6 of this dissertation.

The consistency (i.e., internal reliability) of the extracted factors in EFA, can be checked using Cronbach Coefficient α (Cronbach, 1951), which examines the covariance matrix (all possible pairs) to draw a conclusion of the consistency of the response pattern (Yu, 2001). Mathematically, α is measured in terms of the ratio of true score variance to observed score variance and ranges from 0 to 1. Typically, higher values of α imply higher consistency with values greater than 0.7 and above generally considered acceptable (Yu, 2001).

4.3.2 Analytical Hierarchy Process

The analytical hierarchy process (AHP) is a multicriteria decision-making approach widely used to determine the suitability of an alternative subject to several criterion (Saaty, 1980). The approach uses a hierarchical structure consisting of attributes (concerns in our case) of alternatives to decompose the preference of a decision makers towards the alternative (Kallas, 2011). The method derives ratio scales (i.e., weights) from pairwise comparisons facilitating separation of decision maker's various concerns towards the alternatives. The input can be obtained from actual data such as ownership cost, fuel economy, charging time etc., or from subjective opinions about one criterion relative to another. Typically, miniscule inconsistency in the judgment of the decision makers can be brought about by lack of information but these could be accounted for in AHP. However, if the pairwise judgments are made in an illogical fashion then the outcomes will be highly inconsistent. If n elements are involved in the pairwise comparisons, then the collected responses are organized into a pairwise comparison matrix **V** with a size $n \times n$. The ratio scales or weights are derived from the principal Eigen vector **w** of the pairwise comparison matrix **V**, while the consistency index is derived from the principal Eigen value λ_{max}. That is, $\mathbf{Vw} = \lambda_{max}\,\mathbf{w}$.

In practice, implementation of the AHP to a decision problem involves four key sequential steps as shown in Figure 4-3.

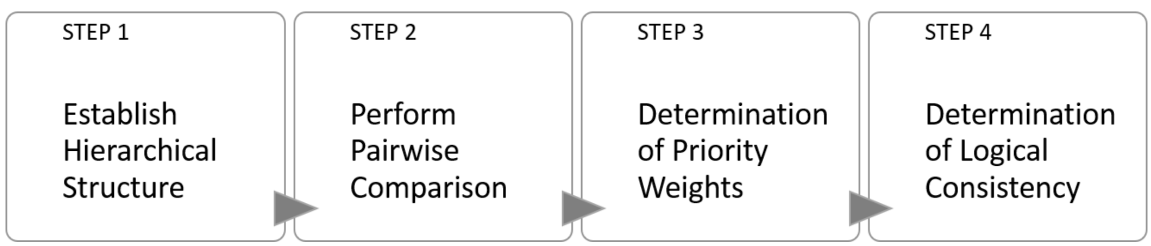

Figure 4-3 Steps involved in implementing Analytical Hierarchy Process

In the first step, the problem and its elements are structured into groups of criteria, sub-criteria and alternatives in a hierarchical fashion. Once the hierarchical structure of the choice problem is established, the AHP requires designing a pairwise comparison. The concept of pairwise comparison is commonly employed in a variety of multicriteria decision-making methods. More specifically, it allows a respondent to express his/her preference along with its strength for a given pair of decision elements, with respect to an intangible factor (Abel and Mikhailov, 2015). Traditionally, a nine-point Saaty scale is used to elicit respondents' judgments to the pairwise comparison (Saaty, 1980) as shown in the example illustrated in Figure 4-4. In the example, the element 'total cost of ownership' is preferred 9 times more than 'operational feasibility', resulting in a preference strength of 9. The two elements are equally important if a response of 1 is elicited. In short, the pairwise comparisons provide relative measurement of the elements (i.e., concerns) used in the construct of these comparisons.

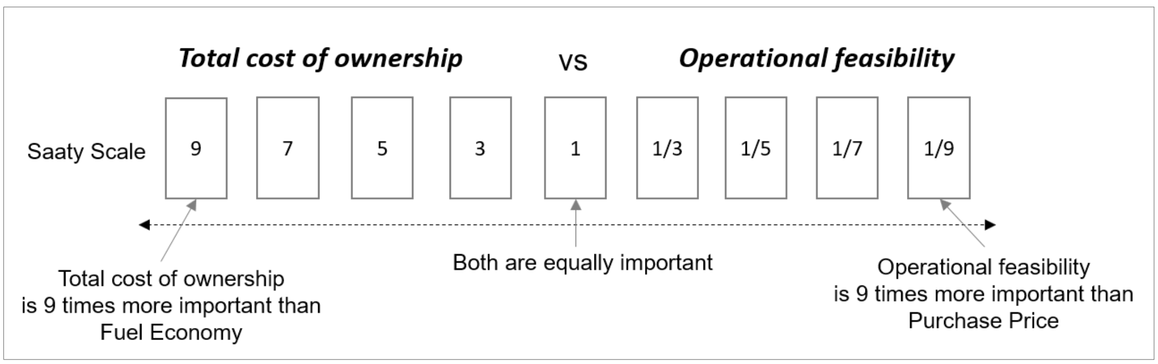

Figure 4-4 Illustration of a pairwise comparison using Saaty scale

Following Wang et al. (2020), an element V_{ij} in the $n \times n$ pairwise comparison matrix represents the pairwise comparison value of the i^{th} element with respect to the j^{th} element ($i, j = 1, ..., n$). Element V_{ji} in the pairwise comparison matrix is equal to ${}^{1}/_{V_{ij}}$ (where $i \neq j$). Also, element V_{ij} is set to unity for $i = j$. In the third step, the hierarchical priority weight w_i for element i in vector $\mathbf{w} = [w_1, w_2, \dots, w_n]'$ is calculated as follows:

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \left(\frac{V_{ij}}{\sum_{i=1}^{n} V_{ij}} \right) \tag{4.1}$$

In the last step of the AHP, the determination of logical consistency is performed. This property of the pairwise comparison matrix is checked to ensure the consistency of decision maker's preference. It is the extent to which the judgments are coherent. For this, the Consistency Ratio (C.R), proposed by Saaty (1980), can be used to measure the level of cardinal inconsistency of the responses. Here, the principal eigenvalue (λ_{max}) is calculated first. For a perfectly consistent pairwise comparison matrix, $\lambda_{max} = n$. To calculate λ_{max}, the elements of the vector containing the weighted sum values are calculated first by applying the priority weight matrix **w** to the pairwise comparison matrix **V** as follows: **S** = **Vw**. Here, **S** is an $n \times 1$ vector where element i is equal to:

$$s_i = \sum_{j=1}^{n} V_{ij} w_j \tag{4.2}$$

λ_{max} can then be calculated as follows:

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^{n} \frac{s_i}{w_i} \tag{4.3}$$

Once λ_{max} is calculated, the Consistency Index (C.I) of the pairwise comparison matrix **V** is calculated by the following expression:

$$C.I = \frac{\lambda_{max} - n}{n - 1} \tag{4.4}$$

Table 4-1 presents the Random Index (R.I), which is obtained by calculating the eigenvalues of pairwise comparison matrices that are based on repeated random judgments (Saaty, 1980). The arithmetic average value from the generated indices, shown in Table 4-1, is then used to determine the logical consistency in the obtained responses from our survey via the Consistency Ratio (C.R).

Table 4-1 Random index for Saaty scale

n	1	2	3	4	5	6	7	8	9	10
$R.I$	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The ratio $(C.R)$ can be calculated using the following expression:

$$C.R = \frac{C.I}{R.I} \tag{4.5}$$

A C.R. value greater than 10% would mean that the obtained pairwise comparisons are not logical and reflect random or irrational decision-making judgments (Wang et al. 2020). It is worth noting that the R.I reported in the classical Saaty scale for *n* (4) = 0.90 (see Table 4-1) would not be applicable for responses obtained from the 7-point Likert scale used in our research. Hence a transformation approach of the Saaty Scale to a 7-point Likert scale was performed to approximate the R.I for the four elements involved in the six pairwise comparisons presented to the respondents. Hence, a Monte-Carlo simulation exercise was conducted to approximate the R.I for *n* (4) on a 7-point Likert scale. This exercise, which was based on 1,000 simulation runs, resulted in a R.I value of 11.877.

In the context of AHP, aggregation of pairwise comparison judgments is a key consideration that can affect the outcome of the analysis. The process of deriving a weight vector from responses of multiple decision makers needs to incorporate any inconsistency in the collected responses (Abel and Mikhaliov, 2015). Further, Koczkodaj and Szarek (2010) note that pairwise comparison matrices with inconsistencies result in large errors, which in turn produce approximations that make little practical sense. A variety of methods are available to aggregate the responses of each decision-maker (organization in our case) into a single weight vector. These include Geometric Mean Method (GMM) and Weighted

Arithmetic Mean Method (WAMM). These methods can be used to aggregate individual pairwise comparisons into a single aggregated **V** matrix from which a single weight vector can then be derived for the decision-making process.

In this research, the GMM was adopted to aggregate the responses of multiple organization into a single aggregated pairwise comparison matrix. GMM assumes equal weights of importance of each responding organization resulting in a single group weight vector from the aggregated matrix. The GMM is more suitable for aggregation of judgments as opposed to the WAMM since the former ensures that the aggregation of extreme judgments or response to a given pairwise comparison undergoes equal treatment (Aczel and Saaty, 1983). However, this is not the case in the WAMM which results in unequal concession during aggregation (Abel and Mikhaliov, 2015). It is worth noting that as a limitation, higher levels of inconsistency, if present in the responses or judgements of the responding organizations, will likely lower the accuracy of the derived weight vector.

4.4 Results

4.4.1 Explanatory Factor Analysis

4.4.1.1 Full Sample

The results of the Explanatory Factor Analysis (EFA) conducted on the responses to the attitudinal statements of the CFAS are presented in Tables 4-2, 4-3 and 4-4. Table 4-2 provides the results pertaining to the relative importance of the deterring factors that could influence the acquisition of Plug-in Electric Vehicles (BEV or PHEV) for responding organizations' fleets. Based on the scree plot (Figure 4-5) of the conducted EFA, the model with four latent factors was deemed as the most appropriate. It is worth noting that the first factor accounts for the largest pattern of relationship that might exist in the observed responses and was labeled as “Technological Concerns” given the nature of the variables with the highest loadings in it. This is followed by the second factor (labeled as “Monetary Concerns”) which uncorrelated with the first factor and explains the next largest pattern. Likewise, the third and fourth factors are also uncorrelated to the first two factors or to each other (Rummel, 1967). These two factors were labeled as “Charging Concerns” and “Operational Concerns”, respectively. The model met the recommended thresholds of sampling adequacy since the Kaiser-Meyer-Olkin (KMO) statistic is greater than 0.7 and the consistency of the entire scale has a Cronbach Coefficient α that is also greater than 0.7 for all constructs in the model (Hair et al. 2010).

The clustering of responses to the various deterrents is sensible and interesting. The technological concerns factor is heavily influenced by the risk that the responding organizations perceive by being early adopters of EV technology in their fleets. The same factor is also significantly dominated by the anxiety and fear that EV technology might never pickup and become obsolete. Furthermore, integration of EVs with the existing fleets is also perceived as one of the technological concerns among the sampled organizations. The percent total variance (PTV) associated with this factor is noted to be 14.4. PTV describes the robustness and strength of the relationship among variables identified in the latent pattern. It relates to the total variation among the variables explained by the latent pattern. On the other hand, the percent common variance (PCV) explained by this factor is noted to be 31.2. This value measures how much of the variation in responses is accounted for by all the factors contributing to each pattern. In other words, it indicates how the regularity is divided among the factor patterns.

The monetary concerns factor is equally informed by mainly battery replacement cost and as well as capital cost involved in acquisition of EVs. The charging concerns factor mainly arises from the electricity rates and the various cost pertaining to the development of charging infrastructure. It is interesting to note that the operational concerns factor is mainly informed by the Canadian weather attributes (extended range of cold/hot temperatures), as well as the operational reliability due to trip range limitation and longer charging time. These results identify substantial contributors to the underlying beliefs and perception of the sampled organizations regarding various deterrents associated with the adoption of EVs is fleets.

As in the case of the deterring factors, the scree plot of the supporting factors identified a model with two latent constructs. As shown in Table 4-3, the first factor, monetary considerations, is informed by three observed variables. The first two variables, which include reduced fuel costs and lower maintenance cost, have equal effect given their loading values in factor 1. Monetary incentives including municipal & provincial financial support is also noted as a significant contributor to the organization's perception regarding the adoption EVs in their fleets. The second latent factor is labeled as "Non-monetary Considerations" and is found to be mainly affected by Access to HOV lanes and availability of free parking. The Availability of public charging stations also emerges as a dominant contributor although its impact is less pronounced compared to the first two variables. Overall, monetary considerations appear to have a much higher variance when compared to non-monetary considerations as far as the supporting factors that could lead organizations to adopt EVs in their fleets.

Table 4-2 Factor analysis of the responses to the attitudes towards common EV deterrents (*N*=1,008)

Latent Construct	Specifics	Factor Loading	Cronbach's α	Percent Total Variance	Percent Common Variance	Eigenvalue
Technological Concerns			**0.950**	**14.4**	**31.2**	**6.596**
	▪ Integration with current fleet	0.469				
	▪ Technology anxiety and fear of obsolescence	0.800				
	▪ High risk of being an early adopter of new technologies	0.771				
Monetary Concerns			**0.950**	**13.0**	**28.1**	**0.696**
	▪ Capital cost	0.749				
	▪ Battery replacement cost	0.759				
	▪ Cost of human resources (i.e., mechanics)	0.421				
Charging Concerns			**0.950**	**10.4**	**22.5**	**0.406**
	▪ Charging infrastructure cost (i.e., chargers, garage upgrade, etc.)	0.417				
	▪ Electricity (Hydro) rates	0.637				
	▪ Higher insurance rates	0.611				
Operational Concerns			**0.950**	**8.4**	**18.2**	**0.220**
	▪ Operational reliability due to range limitation and longer charging time	0.554				
	▪ Cold/Hot weather impacts	0.604				
	▪ Concerns on the maturity of electric vehicle technology	0.476				

KMO = 0.926

Table 4-3 Factor analysis of the responses to the attitudes towards considerations that support EV adoption in fleets (*N*=1,008)

Latent Construct	Specifics	Factor Loading	Cronbach's α	Percent Total Variance	Percent Common Variance	Eigenvalue
Monetary Considerations			**0.910**	**36.5**	**55.7**	**3.594**
	▪ Reduced fuel cost	0.891				
	▪ Lower maintenance cost	0.903				
	▪ Monetary incentives including municipal & provincial financial support	0.672				
Non-monetary Considerations			**0.910**	**29.0**	**44.3**	**0.695**
	▪ Access to HOV lanes	0.850				
	▪ Availability of free parking	0.870				
	▪ Availability of public charging stations	0.457				

KMO = 0.822

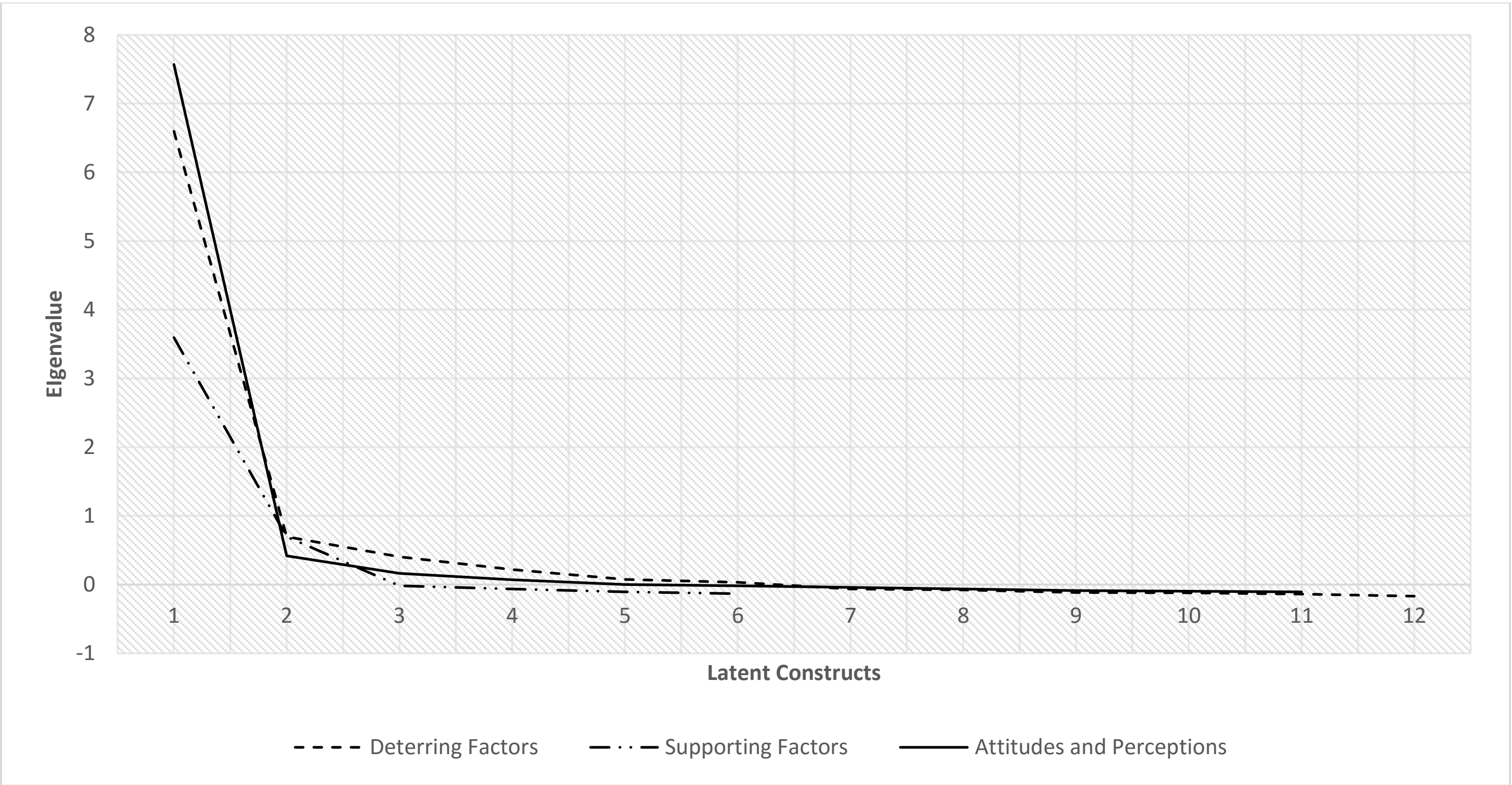

Figure 4-5 Scree plots of the EFA for the full sample of responding organizations

The results of the EFA applied to the attitudinal statements of the CFAS are presented in Table 4-4. These results pertain to the level of agreement or disagreement that the surveyed organizations expressed to various statements covering key aspects that these organizations are likely to be evaluate before acquiring EVs for their fleets. Based on the scree plot in Figure 4-5, the model with four latent constructs (factors) was deemed as the most appropriate. These constructs represent substantively meaningful independent and uncorrelated patterns of the relationships among the variables included in the data. The constructs can also be thought of as four categories with empirically different concepts by which the surveyed organizations can be classified to describe their attitudes and perceptions towards the adoption of EVs in fleets.

The first construct in Table 4-4 can be used to classify a group among the surveyed organizations that can be labelled as the one with “early adopter attitude”. Collectively, these organizations believe that adopting emerging technologies is not a risky decision and that a fleet of EVs can meet their operational needs. The second construct represents organizations that have a positive attitude towards the economic benefits of adopting EVs in their fleets. Obligatory attitude is the third construct and is mainly informed by the agreement of a group of organizations that feel equally obliged to adopt EVs in their fleet as result of the emerging trends in the industry and partly due to their social obligations. The same group of organizations are also willing to install additional infrastructure to adopt EVs in their fleet. Lastly, the fourth construct represents a group among the surveyed organizations that exhibit an attitude that could be labeled as EV technology believers. These organizations believe that adopting EVs in their fleets is a prudent decision which will also promote their image in public domain.

Table 4-4 Factor analysis of the responses to the attitudinal statements regarding EV adoption in fleets (*N*=1,008)

Latent Construct	Specifics	Factor Loading	Cronbach's α	Percent Total Variance	Percent Common Variance	Eigen Value
Early adopter attitude			**0.967**	**18.3**	**40.6**	**7.568**
	▪ Our organization has the technical capabilities (i.e., specialized mechanics) to operate a fleet of Plug-in Electric vehicles (BEV or PHEV)	0.690				
	▪ Our organization is confident that a fleet of Plug-in Electric vehicles (BEV or PHEV) will meet our operational demands	0.720				
	▪ Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is not a risky decision	0.750				
Economically driven attitude			**0.967**	**17.3**	**38.4**	**0.418**
	▪ Our organization thinks that operating Plug-in Electric vehicles (BEV or PHEV) will help replace foreign-oil with made in Canada electricity	0.780				
	▪ Our organization is confident that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a cost-effective decision	0.780				
	▪ Our organization is willing to spend more money to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet in the near future	0.510				

Table 4-4 - continued

Latent Construct	Specifics	Factor Loading	Cronbach's α	Percent Total Variance	Percent Common Variance	Eigen Value
Obligatory attitude			**0.967**	**7.4**	**16.5**	**0.163**
	▪ Following the emerging trend in the industry, we feel pressure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet	0.440				
	▪ Our organization is willing to install additional infrastructure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet	0.500				
	▪ Our organization feels socially obliged to use Plug-in Electric vehicles (BEV or PHEV) to support environmental causes	0.560				
EV Technology believer attitude			**0.968**	**2.0**	**4.50**	**0.001**
	▪ Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a prudent decision	0.300				
	▪ The decision to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet will promote our image, it is a good decision	0.300				

KMO = 0.956

4.4.1.2 Corporate vs. Government Organizations

To explore the potential variation of attitudes that might exist in corporate and government fleets towards adopting EVs in their fleets, separate EFA was conducted for the two main categories of the surveyed organizations. The sample consisted of 668 commercial and 340 government organizations. The results representing the factor loadings of all 12 deterring variables are presented in Figure 4-6. The scale in the figure represents factor loading. Four latent factors were identified in the EFA. With respect to the first latent factor shown in Figure 4-6(a), for the most part, factor loadings for corporate and government fleets exhibit similar patterns with slight variation in their response to electricity/hydro rate (DF5) and higher insurance rates (DF6). We suspect that this behavior could be tied to the location of these organizations. The majority of both types of organizations in our sample are located in Ontario and Quebec. However, the tariffs for hydro and insurance vary significantly between these two Canadian provinces, with the latter being the cheaper of the two. Some variation is also noted for operational reliability due to range limitation and longer charging time (DF7). A correlation of 0.84 is noted for this this factor between the two types of organizations indicating that the responses to the deterring factors among the two sectors is very similar. Likewise, similar patterns can be observed for the second latent factor with minor variation in responses to the concerns related to the integration with current fleet (DF8) with an overwhelming correlation of 0.92. On the other hand, slightly more diverging patterns are noted in the remaining two latent factors obtained from the EFA. More specifically, factor 3 in Figure 4-6(c) exhibits relatively large variations for concerns related to integration of fleets between the two types of organizations (DF8). A probable explanation of this variation could be that the FOEs belonging to the government sector are more apprehensive of the issues that could arise form EV integration with the current fleets. This behavior could be tied to the fact that nearly 13% government FOEs owned EVs in their existing fleet (compared to only 5% of the cooperate FOEs that owned EVs in their existing fleets). We also see noticeable differences in the responses of the two sectors towards electricity/hydro rate (DF5) and higher insurance rates (DF6) in factor 4 as shown Figure 4-6(d). We suspect that FOEs belonging to the corporate sector are less concerned with costs associated with electricity and insurance. It is likely that many of these FOEs are located in Quebec and in their assessment, the benefits attained from adopting EVs in their fleets will outweigh the above costs. Despite these differences, strong correlation values of 0.86 and 0.87 are noted for factors 3 and 4, in Figures 4-6(c) and (d), respectively.

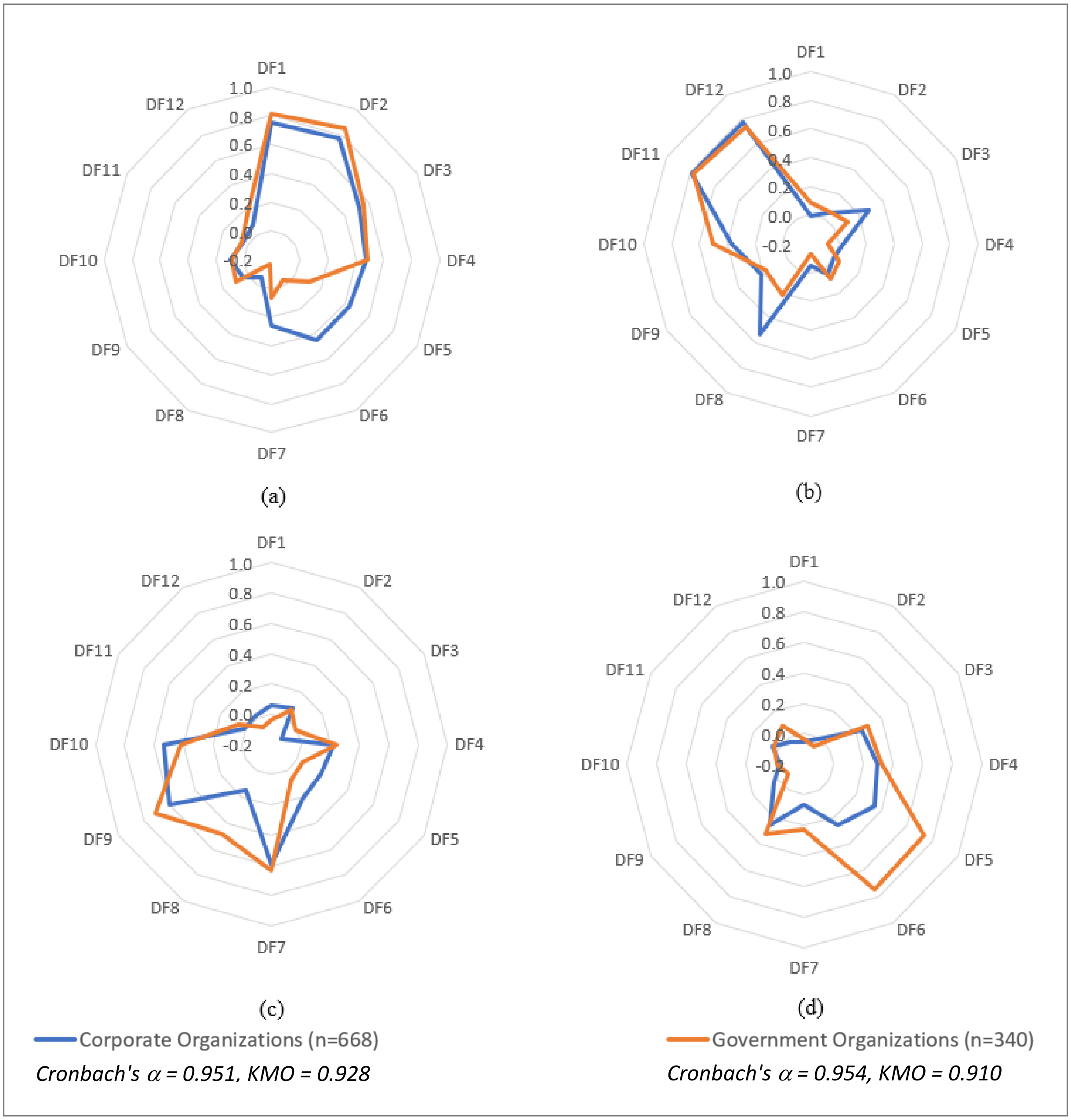

Figure 4-6 Comparison of responses to the deterring factors influencing EV acquisition (a) Factor 1, (b) Factor 2, (c) Factor 3, (d) Factor 4 by corporate and government organizations

The results pertaining to the factor loadings of the 6 supporting variables are presented in Figure 4-7. The EFA analysis on the supporting factors yielded two factors with similar patterns under varying loading magnitudes. A high correlation coefficient of

0.98 is noted for both factors reflecting similar attitudes and perceptions towards the factors that support the adoption of EVs in fleets among the two surveyed sectors: corporate and government. More specifically, lower reduced fuel and maintenance costs (SF1, SF2), monetary incentives including municipal & provincial financial support access (SF3) along with access to High Occupancy Vehicle (HOV) lanes and availability of free parking on municipal lots (SF4, SF5) are the key variables that contribute to the degree and direction of the relationship observed in both factors resulting from the EFA. Since the loadings for all the variables are positive, these variables are expected to entice the adoption of the EVs in the fleets of the two sampled sectors.

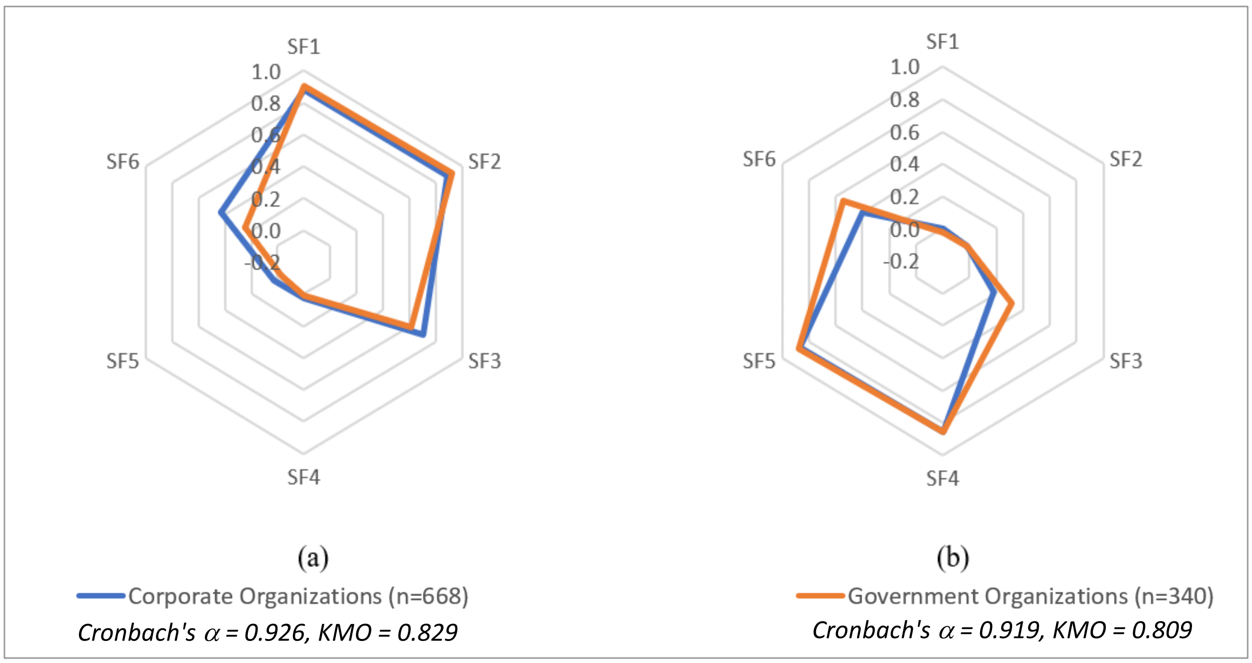

Figure 4-7 Comparison of responses to the supporting factors influencing EV acquisition (a) Factor 1, (b) Factor 2 by corporate and government organizations

The results pertaining the EFA of the responses to the attitudinal statements are presented in Figure 4-8. The analysis yielded four independent factors of common variation among the set of 11 attitudinal statements (ATs) that were evaluated by the corporate and government sectors. The loadings associated with each of the four factors are shown in Figures 4-8(a) through (d). The correlation coefficients of the loadings from the corporate and government EFA for the first three factors are noted to be above 90% (i.e., 0.91, 0.97 and 0.94) implying strong relationship in the attitudes and perceptions exhibited by the two sectors towards the various issues affecting the viability of EVs in fleets. The patterns presented in Figure 4-8(d) show some divergence in responses between the two types of organizations especially for the prudency (AT4) and social impacts (AT5) attitudes of EV adoption in fleets. A logical explanation for this divergence could be rooted in the fact that government entities, by virtue of a well-defined hierarchical and collaborative decision-making process, are more likely to make well informed decisions as they would be more concerned with their public image, hence show more favorable response to the two issues compared to their corporate counterparts. The divergence results in a relatively lower correlation coefficient of 0.79 for the loadings associated with the two types of organizations for this factor.

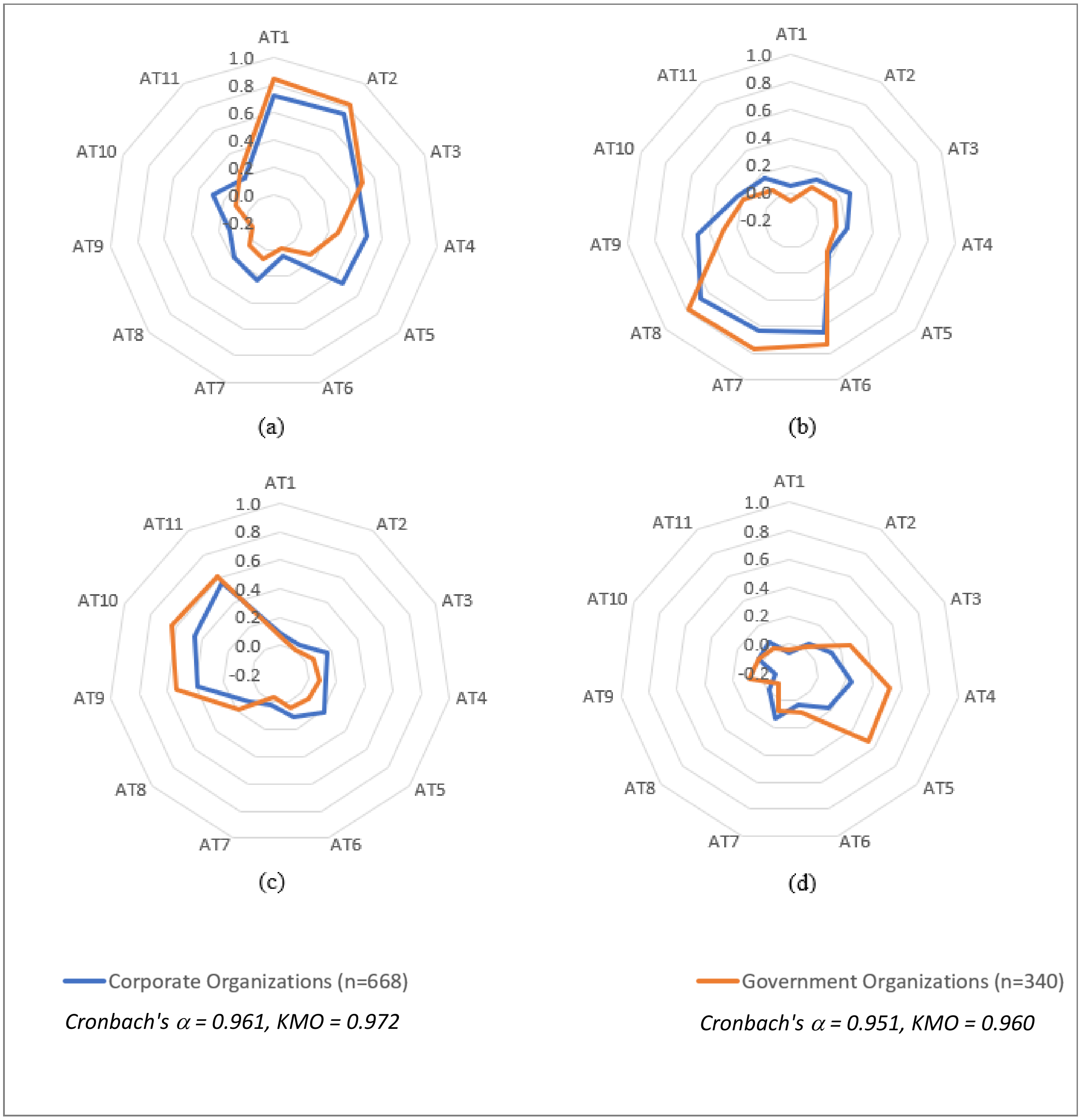

Figure 4-8 Comparison of attitudes and perceptions regarding EV acquisition (a) Factor 1, (b) Factor 2, (c) Factor 3, (d) Factor 4 by corporate and government organizations

4.4.1.3 Transportation and warehousing Organizations vs. Retail Trade Organizations

The 668 corporate organizations in our sample can be further classified into several industrial sectors that included transportation and warehousing with a share of 23%, and retail trade with a share of 20%. EFA analysis was conducted on the responses from these two types of industries to investigate any potential difference in attitudes and perceptions towards EV adoption. The factor loadings pertaining to the observed deterring factors that contribute to forming four latent constructs are presented in Figure 4-9. A quick glance at the results reveal a fair level of consistency in the first three patterns (i.e., Figures 4-9(a), (b) and (c)) which is also supported by the relatively higher correlation coefficients for the three patterns with values of 0.97, 0.85 and 0.81, respectively. A modest correlation of 0.69 is noted for the fourth latent construct shown in Figure 4-9(d). Stark difference in the responses to issues such as, charging infrastructure cost (DF4), electricity rates (DF5) and higher insurance rates (DF6) are noted between the two types of organizations. Apparently, the FOEs from the 'Transportation and warehousing' sector are more concerned with costs associated with the above deterrents compared to their 'Retail Trade' counterparts. This is not surprising since the transportation and warehousing industry, unlike the retail trade industry, operate on very thin profit margins.

Figure 4-10 presents the loadings of the EFA for the responses obtained from the organizations belonging to transportation and warehousing, and retail trade sector regarding the six supporting statements. No noticeable differences in behavior are discerned from the results implying similar assessment of the factors that are likely to support EV adoption in the fleets of these two sectors. Nearly perfect correlation coefficients of 0.97 and 0.99 are noted for the first and second factors shown in Figure 4-

10(a) and (b), respectively.

Figure 4-11 presents the loadings of the EFA for the responses to the attitudinal statements. As in the case of the EFA result from the full sample, four independent patterns of common variation among the set of 11 attitudinal statements were identified. The loadings depicting the influences in the responses are shown in Figures 4-11(a) through (d). The correlation coefficient for the first pattern is noted to be 0.66 whereas for the remaining three factors, the correlation is significantly low with respective values of 0.28, 0.20 and 0.20. This in turn implies variations in attitudes and perceptions towards the various issues affecting the viability of EVs in fleets among the two industries.

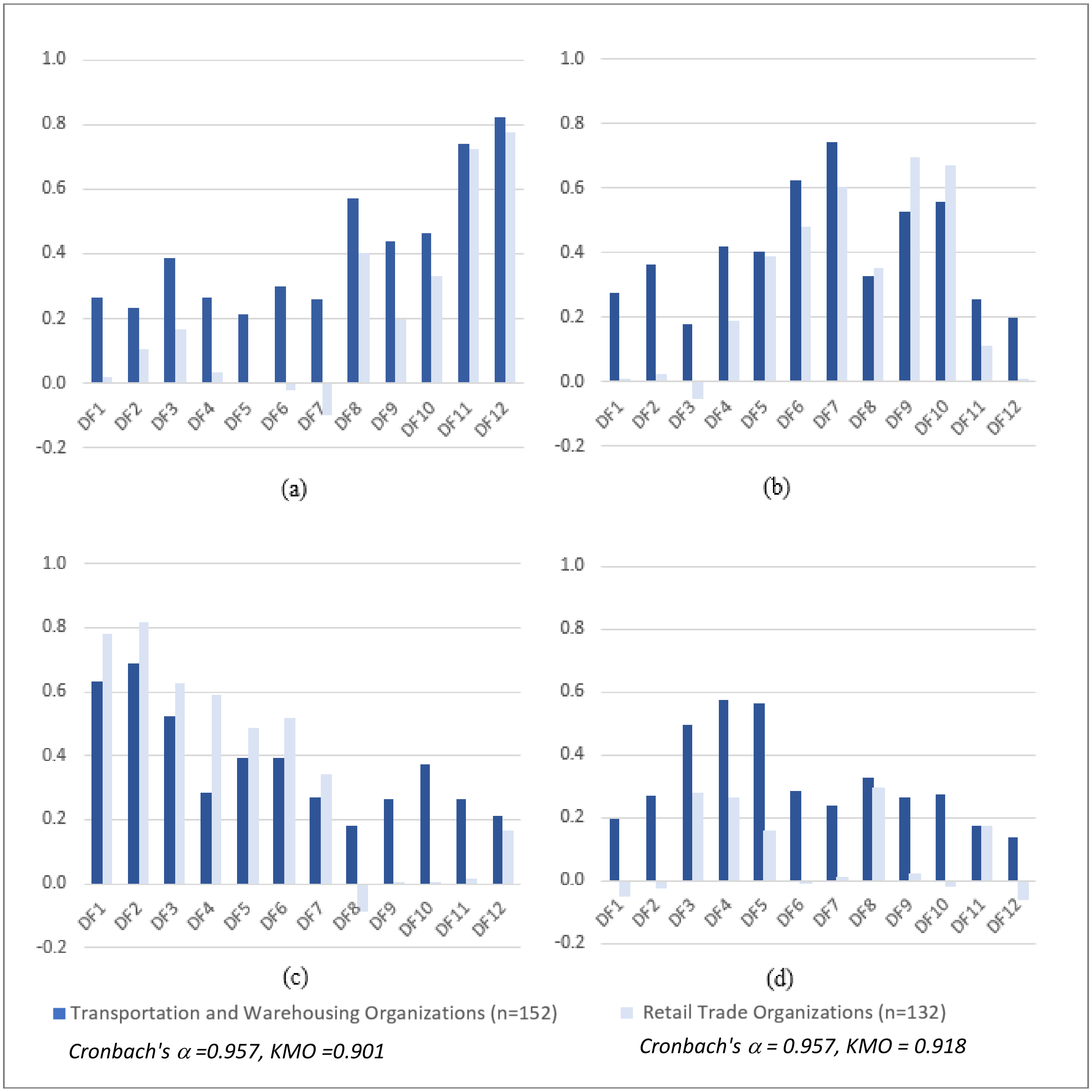

Figure 4-9 Comparison of responses to the deterring factors (DF) influencing EV acquisition (a) Factor 1, (b) Factor 2, (c) Factor 3, (d) Factor 4 by organization type

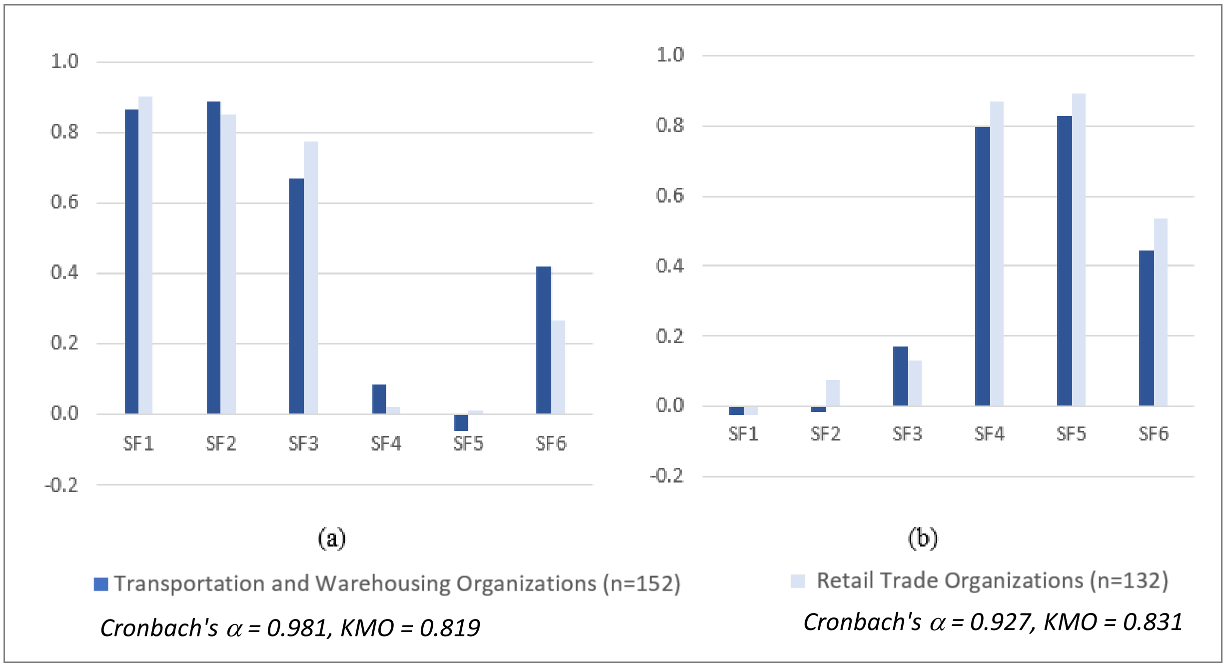

Figure 4-10 Comparison of responses to the supporting factors influencing EV acquisition (a) Factor 1, (b) Factor 2 by organization type

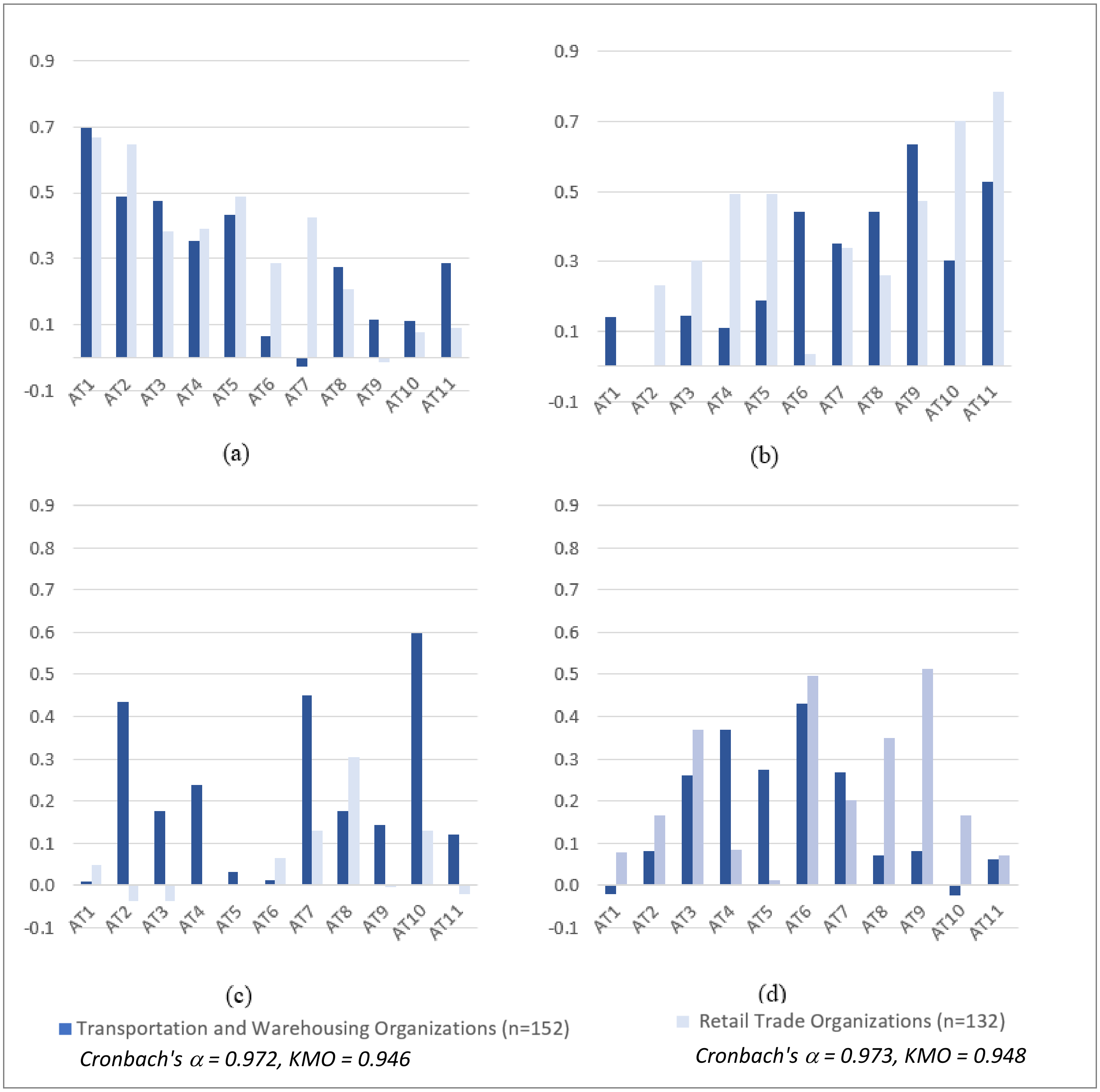

Figure 4-11 Comparison of attitudes and perceptions regarding EV acquisition (a) Factor 1, (b) Factor 2, (c) Factor 3, (d) Factor 4 by organization type

4.4.2 Analytic Hierarchy Process

The results of the Analytic Hierarchy Process (AHP) analysis conducted for the full sample are presented in Table 4-5. As the results show, the obtained responses for the pairwise comparisons were logical and consistent given the C.R value of 0.071 (< 0.1). The results show six pairwise comparison that were used as key contributing factors explaining the behavior of sampled organizations towards EV acquisition in their fleets. AHP is regarded as one of the most pragmatic approaches for deriving relative weights of importance through a series of pairwise comparisons. The approach can detect the relative weight or importance of each indicator/attribute in the model and thereby overcomes the limitations of the direct weight election (Saaty and Vargas 2000; Khalil, 2002). The analysis indicates that the risk of implementing new technology was perceived with relatively higher importance given the weighting score of 63 percent. Operational feasibility ranked second with a weight of 24 percent. Organizations appear to place more emphasis on environmental benefits with a weight of 11 percent. Finally, the total cost of ownership is relatively less important as indicated by the lowest weight of only 2 percent. The results obtained are convergent with the findings of previous studies where risk of implementing a new technology (guinea-pig syndrome) is often regarded as one of the most critical elements in acquisition decisions of any new product. Overall, the results suggest that the 4 indicators can be considered as key contributing factors in explaining the preferences of the responding organizations. Table 4-6 provides the results from applying the AHP analysis to the two sub-samples representing corporate and government organizations. As the results suggest, both corporate and government organizations have very similar perception towards evaluating the four factors.

Table 4-5 Results of the AHP analysis for the full sample

Attributes/Elements (n)	***EB***	***TCO***	***OF***	***RINT***	**Weighted Sum Values (S)**	**Criteria Weight (w)**	$\frac{S}{w}$	$CI = \frac{\lambda_{max} - n}{n-1}$	$CR = \frac{CI}{RI}$
Environmental benefits (EB)	0.11	0.31	0.02	0.06	0.50	0.11	4.54		
Total cost of ownership (TCO)	0.01	0.02	0.02	0.05	0.10	0.02	4.12		
Operational feasibility (OF)	1.25	0.34	0.24	0.04	1.86	0.24	7.92	0.840	0.071
Risk of implementing new technology (RINT)	1.20	0.30	3.85	0.63	5.98	0.63	9.49		

Principal eigenvalue of the **V** matrix $= \lambda_{\max}$ = avg. ratio for all four elements = 6.52, Random Index (R.I) for *n* (4) =11.877

Table 4-6 Results of the AHP Analysis for corporate and government organizations

Attributes/Elements (n)	**AHP Criteria Weight (CW)**		
	Full Sample (*N*=1,008)	**Corporate FOEs (*n*=668)**	**Government FOEs (*n*=340)**
Environmental benefits (EB)	0.11	0.10	0.10
Total cost of ownership (TCO)	0.02	0.01	0.03
Operational feasibility (OF)	0.24	0.23	0.23
Risk of implementing new technology (RINT)	0.63	0.66	0.64
Consistently Ratio (C.R)	0.071	0.075	0.074

4.5 Conclusions

This chapter examined attitudes of Canadian fleets operating entities (FOEs) towards Electric Vehicle (EV) adoption via the Exploratory Factor Analysis (EFA) and Analytical Hierarchy Processes (AHP) approaches. With respect to the EFA model estimated for the full sample of the FOEs on the factors that deter EV adoption, *Technological Concerns* and *Monetary Concerns* were identified as the two most dominant constructs accounting for more than 25% of the total variance in the collected responses. On the other hand, latent constructs for the supporting factors, included *Monetary Considerations* and *Non-monetary Considerations* with shares of 36.5% and 29% of the total variance in the responses, respectively. *Monetary Considerations* were primarily informed by lower maintenance and fuel cost whereas access to HOV lanes and availability of free parking contributed significantly contributed to the *Non-monetary Considerations*.

The EFA model on the attitudes relating to various EV aspects identified four latent constructs of behavior. The FOEs in the *Early Adopter Attitude* construct believe that adopting emerging technologies is not a risky decision and that a fleet of EVs can meet their operational needs while the *Economically Driven Attitude* represents FOEs that have a positive attitude towards the economic benefits of adopting EVs in their fleets. Together the two constructs accounted for nearly 36% of the total variance in the sampled responses.

To explore the potential variation of attitudes that might exist in the corporate and government FOEs towards adopting EVs in their respective fleets, separate EFA models were estimated. The sub-samples consisted of 668 corporate and 340 government FOEs. The four latent factors identified for the deterring factors for both sub samples had high correlations implying that the overall responses to the deterring factors are quite similar between the corporate and government FOEs. However, slight variation in the response to some of the deterring factors that included electricity/hydro rate, higher insurance rates and operational reliability due to range limitation and longer charging time was also noted. The EFA analysis on the supporting factors yielded two factors for both sub-samples with near perfect correlation (98%, for each factor). The high correlation reflects similar attitudes and perceptions towards the factors that support the adoption of EVs in fleets among the sampled corporate and government FOEs. Similar results were obtained for first three factors of the EFA of the responses to the attitudinal statements with correlations above 90% implying strong relationship in the attitudes and perceptions of the two sectors towards the various issues affecting the viability of EVs in fleets.

A fair level of a consistency in the responses of the two specific types of corporate FOEs belonging to *Transportation and warehousing, and Retail Trade* sectors (accounting for 42% of all the corporate FOEs), was noted in the estimated EFA models that covered both the deterring and the supporting factors. However, weaker correlations among the four factors emerging from the EFA of the attitudinal statements reflect variation in attitudes and perceptions towards the various issues affecting the viability of EVs in fleets among the two industries.

The results of the AHP analysis conducted for the full and sub-samples of FOEs demonstrate that the obtained responses for the six pairwise comparisons were logical and consistent. The risk of implementing new technology was perceived with relatively higher importance with an average weighting score of 60%. The results obtained are convergent with the findings of previous studies where risk of implementing a new technology (guinea-pig syndrome) is often regarded as one of the most critical elements in acquisition decisions of any new product.

EFA by nature and design is appropriate for exploring the unobserved patterns or relationships in a given dataset. Hence, rather than drawing substantive conclusions from the conducted EFA analyses, the findings were used to help inform the specifications of the latent variable and other behavioural modeling techniques that were employed in the subsequent chapters. This allowed us to test various hypotheses with respect to the attitude and perceptions of the sampled FOEs towards EV adoption. Future research efforts in investigating these attitudes and perceptions can incorporate the decision weights from the conducted AHP into inferential structural equation modeling framework to better quantify the influence of FOEs beliefs on their acquisition decisions.

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CHAPTER 5

THE DEMAND FOR ELECTRIFICATION IN CANADIAN FLEETS: A LATENT CLASS MODELING APPROACH

5.1 Introduction

The discussions on the benefits and costs of adopting Electric Vehicles (EVs) are not limited to the private consumers sector alone but have also drawn the attention of stakeholders in the fleet industry in recent years. Fleet operating entities (FOEs), in government and private sectors alike, have large fleets with extensive usage, and therefore contribute significantly to the global carbon footprint. It can be argued that many FOEs are more likely to adopt low-emission technologies at an early stage not only to reduce their carbon-footprint but also improve their corporate social image while remaining competitive. Competitiveness arises from the fact that EVs have the potential to generate substantial operational savings. Despite the potential benefits of EVs in fleets, their current share in Canada is still miniscule (CAF, 2019). Interestingly, the significantly low number of EVs in fleets along with the potential benefits they offer to businesses create a fertile ground for studying their demand and acquisition by FOEs. The latter is also inspired by the lack of studies in the transportation literature. Therefore, the objective of this chapter is to address the existing gap by studying the factors that could influence the demand and acquisition of EVs by Canadian FOEs, namely corporate and government entities.

The work in this chapter is focused on estimating a latent class discrete choice model using Canada-wide data. The data were collected from an online survey that was launched in December 2016, entitled 'Canadian Fleet Acquisition Survey' (CFAS). The survey collected responses from over 1,000 organizations that owned and operated light fleets (i.e., cars, pickup trucks and utility vehicles) in Canadian cities. The collected data included organizations' general characteristics, existing fleet characteristics, future acquisition plans and EV prospects for fleet renewal. A major component of the CFAS included an SP section which formed the basis of the modeling exercise. The CFAS also included attitudinal statements to understand the issues that support or deter EV acquisition in fleets. This research is the first of its kind in Canada to collect and analyze SP data on the acquisition of EVs in fleets.

The remainder of this chapter is organized as follows: Section 2 provides a review of the state of the existing knowledge on the subject matter. Key highlights from the collected data including insights regarding attitudes and perceptions of the responding organizations in acquiring EVs for their fleets are presented in Section 3. Next, Section 4 provides an overview of the latent class modeling approach used in the analysis. The result from the estimated models along with the willingness-to-pay estimates are presented in Section 5. The chapter ends with a conclusions section that provides guidelines for stakeholders and decision makers.

5.2 Background

The focus on using energy efficient transport technologies and reducing dependence on gasoline-based fuels has led to waves of studies on the adoption of alternate fuel vehicles (AFVs), including EVs. A thorough review of the literature on the subject matter points to many concepts and considerations that are critical to the emergence of AFVs. These include reluctance in adopting emerging technologies from entrenched dominant technologies and policy barriers towards a change in the status-quo (Sierzchula, 2014). On the upside, technological advancements in the manufacturing of key EV components, especially the battery components, installation of charging infrastructure, and climate change awareness, have renewed governments' interest in EV adoption (IEA, 2016). These advancements have been focused on extending trip range, lowering charging time and capital cost to own an EV.

Public agencies and private sector organizations are responsible for the majority of global EV purchases as reported by Sierzchula (2014). As such, governments around the globe are supporting policies that encourage fleet operating entities to consider EV adoption on a more substantial scale. This underlines the importance of such entities as being potential early adopters. Higher vehicle acquisition rates, intensive utilization, and readiness to invest in refueling and charging infrastructure have been identified as the key reasons for early EV adoption among FOEs (IEA, 2011 and Dijk et al. 2013). That is, these organization can be considered as the forerunners in early adoption of EVs. Given the infancy of the EV market penetration in Canada, there is ample room for research to explore the potential social and economic implications of marketing EVs for fleet usage.

The use of the Stated Preference (SP) method to understand the potential for accepting new technologies when acquiring vehicles is in ascendency in transportation research. Contemporary design of SP methods is catered for the development of discrete choice models, which capture the behavior consumers normally exhibit in everyday life while choosing a single option from a set of alternatives. In the latter, alternatives can be described in terms of their characteristics and attributes rather than their whole value (Hidrue et al. 2011). 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 demand for EVs in the US. Some of these studies, including the work of Bunch et al. (1993); Golob et al. (1997); Brownstone et al. (1996) and Brownstone et al. (2000). Later, the work by Ewing and Sarigollu (2000); Dagsvik et al. (2002); Batley et al. (2004); Adler et al. (2016); Globisch et al. (2018); Li et al. (2018); and Skippon and Chappell (2019), identified various key factors that affect the adoption of EVs, which included reliability, limited trip range, longer charging hours, scarce charging infrastructure, high purchase and maintenance cost. The results from these studies also pointed to a low probability of EV adoption among conventional gasoline vehicle users.

While some strides have been made over the last three decades to model the acquisition process of AFVs in fleets, past studies were focused on using restricted data that were made available to researchers by FOEs in private or government sectors volunteering to participating in the research. These studies either focused on investigating certain aspect of EV adoption or on the viability of a specific vehicle type in fleets (e.g., Correia and Santos, 2014; Feng and Figliozzi, 2013; Haller et al. 2007). In this vein, Davis and Figliozzi (2013) proposed a method to evaluate the competitiveness of electric delivery trucks while Correia and Santos (2014) developed a mathematical model for optimal trip assignment of electric and conventional vehicles in a regional car rental company. The study by Sierzchula (2014) used semi-structured interviews and project reports to investigate the factors influencing fleet manager adoption of EVs in 14 US and Dutch organizations. The key factors influencing the EV adoption included reducing environmental impact, monetary incentives, and improving the organization's social image in public domain. Similarly, Dong et al. (2014) used GPS based longitudinal travel data collected from gasoline vehicles to analyze the impact of public charging infrastructure deployment on increasing electric miles traveled. Perujo and Ciuffo (2010) investigated the potential impact of EV adoption in private fleets on the electric supply system and the environment in Milan, Italy.

The study by Golob et al. (1997) was among the first to use an SP survey to study the demand for AFVs among 2000 FOEs in California. The study concluded that cost was more important to public entities while private entities were more concerned with their operational needs and not the environment. Hoen and Koetse (2014) conducted an SP experiment to collect data on the preferences for AFVs of company car drivers in the Netherlands. Similar to the findings in Golob et al. (1997), purchase behaviors of FOEs in the Netherlands were often based on past experiences and operational considerations for their needs. In relation to the attitudes and perceptions towards EV adoption in fleets, the study by Nesbitt and Davies (2013) provided useful insights on how the perceived value of Plug-in Hybrid Electric Vehicles (PHEVs) varied depending on the employees' responsibilities and roles in the organization. More recently, the study by Dimatulac et al. (2018) collected revealed and stated preference data on the preference of consumers for EVs in rental fleets. Rental fleets were classified as commercial fleets where consumers were more influential as their preference for certain powertrain would entice the rental companies to acquire the specific powertrain, including EVs.

5.3 CFAS Data

The work in this chapter builds on the existing body of literature by conducting a survey to collect enriched data from FOEs across Canada. Responses in the CFAS were obtained directly from individuals who make, or influence decisions related to the acquisition of fleets in their organizations. The survey was conducted over a course of nine days in December 2016. The data collection was administered by Research Now Inc. (RNI), a market research company (RNI, 2016). RNI maintains large survey panels with respondents representing Canadian businesses that own and operate fleets. The survey was designed such that it can be completed within 15-20 minutes.

The spatial distribution of the surveyed entities is presented in Figure 5-1. Nearly 39% of all organizations were in Ontario. Quebec accounted for 20% and ranked 2nd, while British Columbia ranked 3rd with 12% share of the total sample. Manitoba accounted for 4% of the total sample, while New Brunswick and Nova Scotia had similar representation with each accounting for 2% of the sample. Finally, the provinces of Saskatchewan and Newfoundland and Labrador each accounted for 1% of the total sample. Corporate or 'For-profit firm' entities dominated the sample with a major share of 66% while 'Non-profit organization' entities had a share of 9%. The 'Municipal', 'Provincial' and 'University/College' categories each had a share of 7% in the sample. Lastly, the organizations representing 'Federal' government accounted for 4% of the total sample. In total, these categories represented about 34% of the total sample and were labelled as 'Government' entities.

Figure 5-2 shows the distribution by fuel type for the three types of vehicle fleets for 'Government' (Figure 5-2a) and 'Corporate' organizations (Figure 5-2b). As expected, a significant majority of organizations both in ‘Government’ and ‘Corporate’ sectors use gasoline fuel for their car, pickup truck and utility vehicle fleets. More specifically, gasoline powered cars accounted for 55% and 68% of total car fleets in ‘Government’ and ‘Corporate’ organizations, respectively. By contrast, the shares of gasoline-based pickup truck and utility vehicles in ‘Government’ and ‘Corporate’ fleets were quite similar. Also, an exact proportion of the diesel-based fleets (21%) featured pickup trucks for both types of organizations. It is interesting to note that the shares of electric powertrain vehicles were highest among car fleets (9% and 2% for ‘Government’ and ‘Corporate’ organizations, respectively), though still quite insignificant when compared to the shares of conventional gasoline and diesel fuels.

Table 5-1 presents the results pertaining to the acquisition outlook of battery electric vehicles (BEVs) by the sampled organizations. More than half (56%) of the participating organizations indicated that they did not have any plan to acquire BEVs for their fleet vehicles. Organizations that were likely to acquire BEVs for their fleet in the next 2 years had a share of 20% in the total sample, as shown in Table 5-1. As the time frame to acquire BEVs was projected further in the future, the share of organizations that will likely acquire BEVs dropped (i.e., from 16% for the ‘In the next 5 years’ time frame to 3% for the ‘In the next 7 years’ time frame). The organizations that were not sure whether they will acquire BEVs for their fleet accounted for 5% of the total sample. Similar trends were observed among the shares of organizations planning to acquire PHEVs for their fleet presented. As for the condition of BEVs under which these vehicles will be acquired, the ‘New’ condition was heavily favored over other all other conditions with shares of 31% and 29% for both BEVs and PHEVs powertrains, respectively.

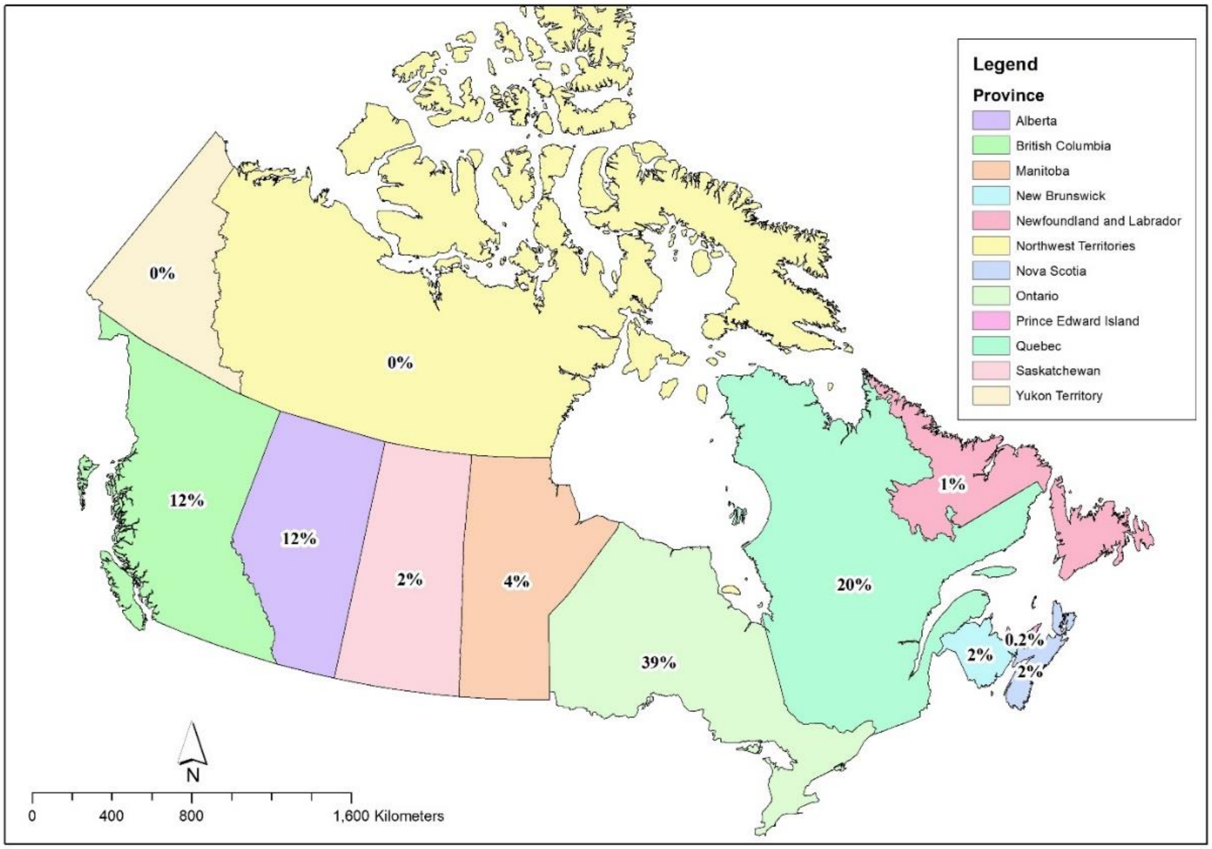
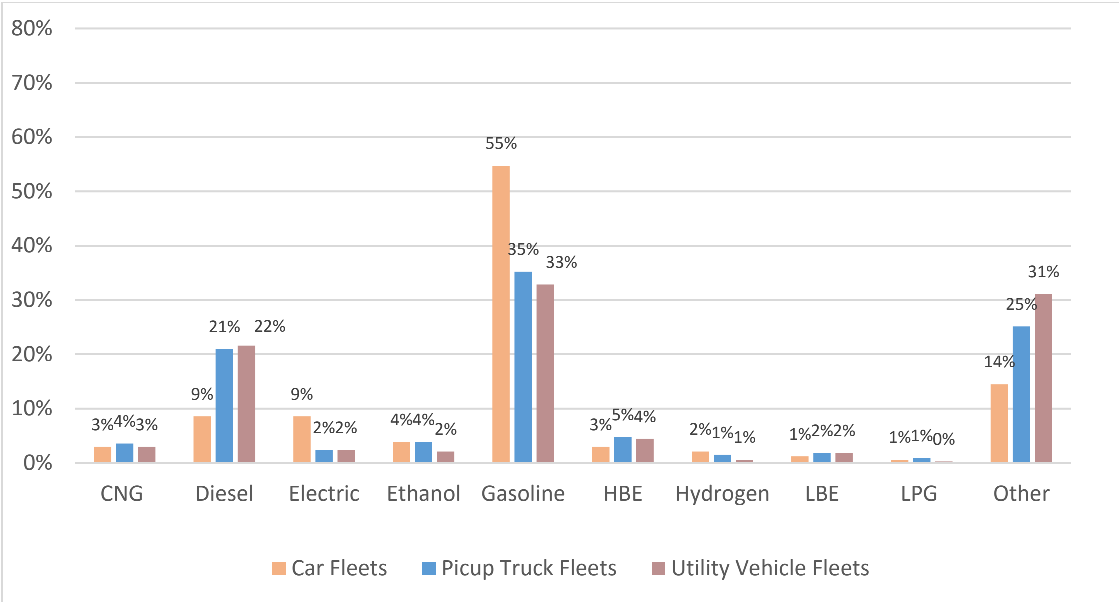


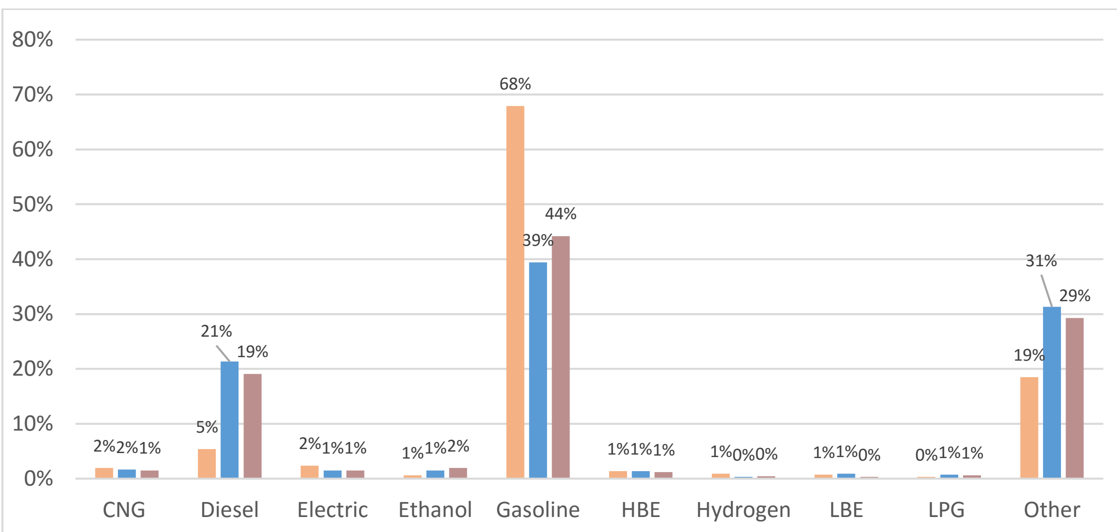
Figure 5-1 Spatial distribution of surveyed entities by Province

Table 5-1 Acquisition timeframe and acquisition condition of BEVs

Time Frame	**Share**	**Condition**	**Share**
In the next 2 years	201 (20%)	New	309 (31%)
In the next 5 years	159 (16%)	Used	70 (7%)
In the next 7 years	35 (3%)	Not sure	38 (4%)
Not sure when	52 (5%)	Mixed	30 (2%)
No plans	561 (56%)	N/A	561 (56%)
Total	1,008 (100%)		1,008 (100%)



(a)



(b)

Note: CNG: Compressed Natural Gas; HBE: High Blend Ethanol; LBE: Low Blend Ethanol; LPG: Liquefied Petroleum Gas

Figure 5-2 Fuel type distribution of surveyed fleets by organization type (a) government organizations and (b) corporate organizations

Figure 5-3 shows the existing charging infrastructure by the two broad categories of the surveyed organizations. The proportion of corporate' organizations that had charging stations at all fleet locations was more than double of government organizations (representing 'Federal', 'Municipal', 'Non-profit', 'Provincial' agencies and 'University/College'). However, the shares of government entities with most/some fleet locations having charging stations did not vary vastly from those of the corporate entities ('For-profit' firms) in the sample as shown in Figure 5-3. Finally, the proportion of corporate organizations that did not have any existing charging infrastructure was nearly three and half times more than those in the government sector.

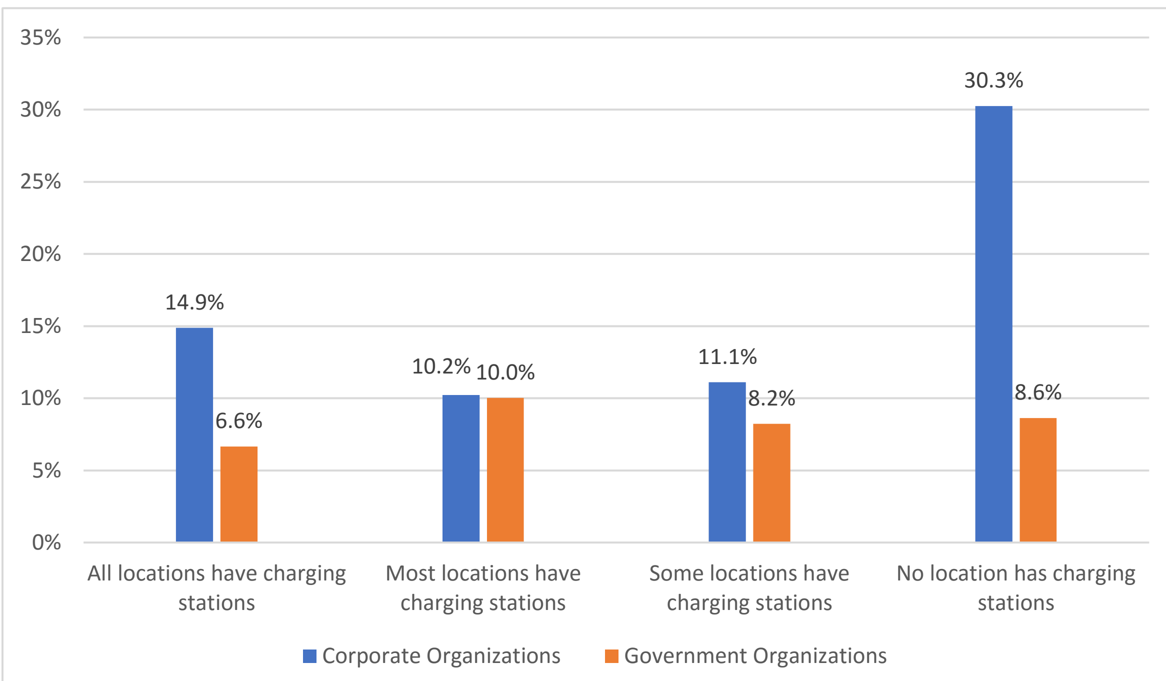


Figure 5-3 Existing charging infrastructure by broad categories of the surveyed organizations

Using a 7-point Likert scale, respondents were asked to express their opinion regarding factors that deter and support the acquisition of BEVs or PHEVs for their fleets.

Some of the key deterring factors included capital cost, battery replacement cost, charging infrastructure cost (i.e., charging outlets, garage upgrades etc.), operational reliability due to range limitation, and longer charging time. On the other hand, the supporting factors included reduced fuel and maintenance costs, monetary incentives including municipal and provincial incentives, access to high occupancy vehicles (HOV) lanes, and availability of free parking on municipal lots. Respondents were also presented with the 11 attitudinal statements (Section 3.3.4 of Chapter 3) in order to elicit a response from a 7-point Likert scale with 1 being 'Strongly Disagree', 4 being 'Neutral', and 7 being 'Strongly Agree'.

A summary result from the responses to these statements is presented in Figure 5-4. In general, the figure reveals consistency in terms of the participating organizations' agreement/disagreement to the above statements.

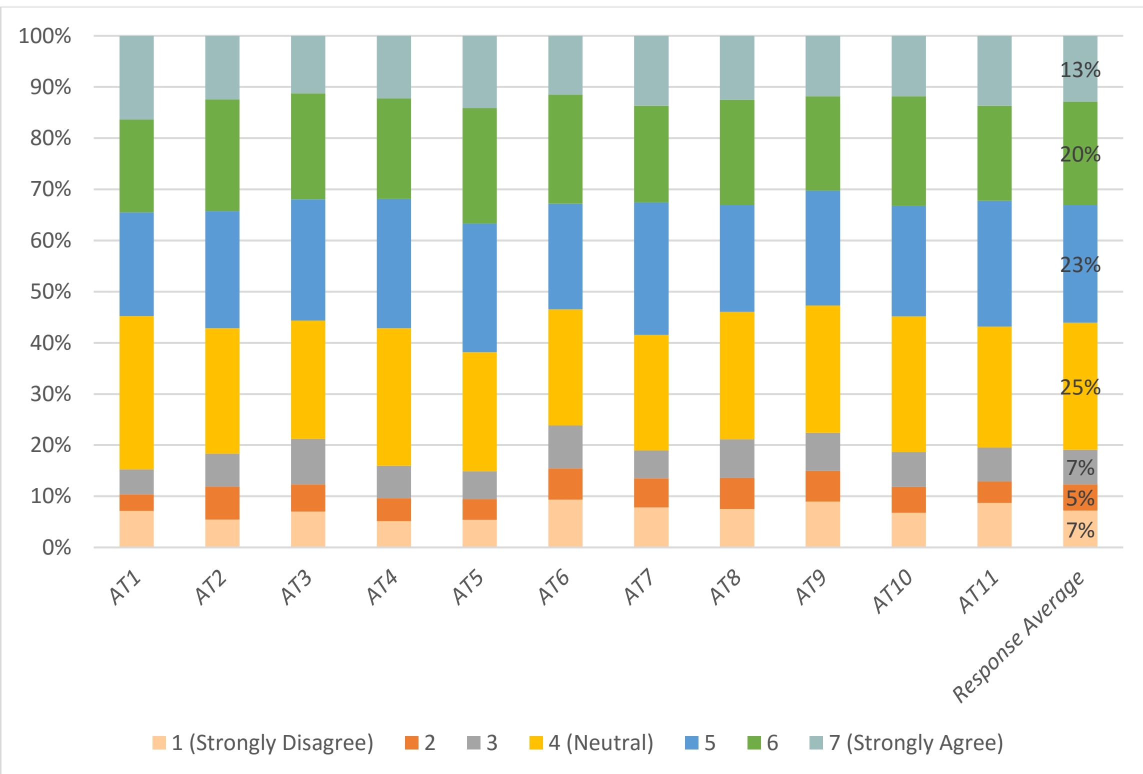


Figure 5-4 Agreement/disagreement with aspects influencing EV acquisition

5.4 Stated Preference Scenarios

This section of the survey was based on six separate stated preference (SP) scenarios that were presented to each respondent. Each SP scenario included four hypothetical, yet realistic vehicle powertrain choices with attributes that were categorized by four major categories namely 'Cost', 'Incentives', 'Performance', and 'Fueling/Charging Time and Infrastructure'. An illustration of the actual SP scenario is shown in Figure 5-5. The choice set for each scenario included ICEV, HEV, PHEV and BEV versions of the preferred vehicle size. After evaluating each vehicle powertrain based on its attributes and features, responding organizations were required to choose a vehicle powertrain that their organization would most likely acquire for its fleet.

The design of the SP section including the selection of the attributes and their levels were informed by the existing literature (for example, Bunch et al. 1993; Golob et al. 1997; Brownstone et al. 1996; Ewing and Sarigollu, 2000; Dagsvik et al. 2002; Batley et al. 2004 and; Potoglou and Kanaroglou, 2007). The attributes and their associated levels for the SP design are presented in Table 5-2. The SP choice scenarios were generated through a systematic process called 'experimental design'. The 'experimental design' allows manipulation of attributes and their levels to permit rigorous testing of certain hypothetical situations. A systematic construction of blocked Fractional Factorial Design (FFD) approach is utilized to constrain the choice scenarios to be presented to each respondent. The blocked approach groups the SP scenarios into small subsets, called blocks (for example, see the work by Ahn et al. 2008; Hess et al. 2011). The block design approach maintains orthogonality and ensures that respondents are presented with the whole range of each attribute's values such that the attribute level balance is maintained (Choice

Metrics, 2014). Our blocked FFD was designed to produce 144 unique choice scenarios for each vehicle class/size type. These scenarios were then grouped into 24 blocks, each consisting of six scenarios. The blocked FFD was generated using a specialized software program, Ngene 1.1.2 (Choice Metrics, 2014). The decision to limit the number of scenarios to six was taken in consideration to reduce respondent's cognitive burden and fatigue when completing the SP section of the survey.

University of Windsor

Social Sciences and Humanities Research Council of Canada

McMaster University

Fleet Acquisition Survey

33%

Scenario 1 of 6

Compact Sedan Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$17,000	$38,300	$29,800	$29,800
Annual Maintenance Cost ($)	$1,000	$600	$500	$800
Annual Fueling/Charging Cost ($)	$2,000	$1,800	$900	$800
Incentives				
Government Cash Incentive ($)	None	None	$3,000	$7,000
Other Monetary Incentives	None	None	No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Parking at Municipal Lots	Access to Bus and HOV Lanes
Performance				
Range per Refuel/Recharge (km)	400	500	700	550
Annual Depreciation Cost ($)	$2,650	$2,920	$2,920	$2,650
Extended Battery Warranty	N/A	N/A	6 Years / 120,000 km	5 Years / 100,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	10% Reduction	50% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	5 mins	10 mins	10 mins	30 mins
Number of Public Fueling/Charging Stations in a Typical 5km Radius	3	5	5	3
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

Cancel | << Previous | Next >>

Figure 5-5 An illustration of the CFAS stated preference scenario

Table 5-2 Attributes and levels used in the SP scenario design

Attributes	ICEV (Base)	HEV	PHEV	BEV
Cost				
Purchase Price ($)	Base	+50% of base	+50% of base	+50% of base
		+25% of base	+25% of base	+25% of base
		Base	Base	Base
		-25% of base	-25% of base	-25% of base
Annual Maintenance Cost ($)	Base	+25% of base	+25% of base	+25% of base
		Base	Base	Base
		-25% of base	-25% of base	-25% of base
		-50% of base	-50% of base	-50% of base
Annual Fueling/Charging Cost ($)	Base	Base	-15% of base	-30% of base
		-10% of base	-25% of base	-40% of base
		-20% of base	-35% of base	-50% of base
		-30% of base	-45% of base	-60% of base
Incentives				
Government Cash Incentive ($)	None	None	$3,000	$3,000
			$5,000	$5,000
			$7,000	$7,000
			$9,000	$9,000
Other Monetary Incentive	None	Manufacturer's rebate	Manufacturer's rebate	Manufacturer's rebate
		No purchase tax	No sales tax on purchase price	No sales tax on purchase price
		No annual registration fee	No annual registration fee	No annual registration fee
Non-monetary Incentive	None	None	Free charging station installation	Free charging station installation
		Free parking on municipal lots	Free municipal parking	Free municipal parking
		Access to bus and HOV lanes	Access to Bus and HOV lanes	Access to Bus and HOV lanes

Table 5-2 – continued

Attributes	ICEV (Base)	HEV	PHEV	BEV
Performance				
Range per Refuel/Recharge (km)	300	400	550	250
	400	500	600	400
	500	600	650	550
	600	700	700	700
Annual Depreciation Cost ($)	Base	+10% of base	+10% of base	+10% of base
		+7.5% of base	+7.5% of base	+7.5% of base
		+5% of base	+5% of base	+5% of base
		Base	Base	Base
Extended Battery Warranty	None	None	5 Years / 100,000 km	5 Years / 100,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Tailpipe Emission (%)	Base	-10% of base	-50% of base	-100% of base
		-20% of base	-60% of base	
		-30% of base	-70% of base	
		-40% of base	-80% of base	
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time (mins/hrs) (Cars and Light Truck Fleets)	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	4 hrs
	7 mins	7 mins	4 hrs	8 hrs
	10 mins	10 mins	8 hrs	12 hrs
Refueling/Recharging Time for Utility Fleets (mins/hrs) (Utility van, Bucket Truck and Large Walk-in Truck fleets)	7 mins	7 mins	15 mins	4 hrs
	10 mins	10 mins	1 hr	8 hrs
	12 mins	12 mins	6 hrs	12 hrs
	15 mins	15 mins	10 hrs	16 hrs
Number of Public Refueling/Recharging Stations in typical 5 km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

The shares of the choices pertaining to the four vehicle powertrains obtained from the SP section of the CFAS are presented in Figure 5-6. These choices, which were based on evaluating the potential trade-offs between attributes and features of the four powertrains, are broken-down by organization type. In general, the shares were similar between the two types of organizations. On average, Internal Combustion Engine Vehicles (ICEVs) had the highest market share of 34% among the four powertrains, followed by Hybrid Electric Vehicles (HEVs) with a share of 29%. The remaining two electrified powertrains, Plug-in Hybrid Electric Vehicles (PHEVs) and Battery Electric Vehicles (BEVs), had shares of 26% and 11%, respectively.

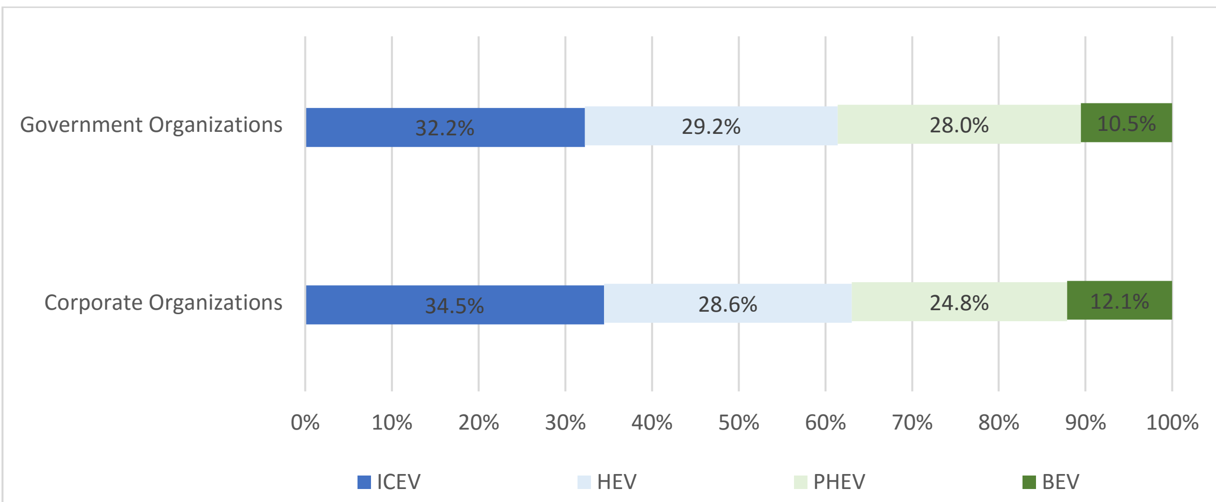


Figure 5-6 Stated preference shares of conventional and electric powertrains by organization type

5.5 Method of Analysis

The latent class (LC) model was used to identify the existence of discrete unobservable segments of population termed “classes” within the sample population. Class probabilities in the LC model are modeled via respondent’s characteristics, whereas choice probabilities for the available alternatives are dependent on alternative characteristics. The LC model offers a much better explanation of the decision maker's behavior when compared to the conventional multinomial logit (MNL) and mixed logit (ML) models, which to some extent can identify preference heterogeneity in the sampled population. More specifically, the LC model can reveal preference heterogeneity with respect to latent classes that exist within the sampled population, which are not visible to the analyst (McFadden and Train, 2000).

In contrast to continuous distribution of a parameter suspected to have preference heterogeneity among the sample population as specified in the ML model, the LC model assumes a discrete number of latent classes *s* where $s = 1,2, 3.....S$. Bierlaire (2010) defines the term latent as "*something that potentially exists but not presently evident or realized*". These classes are also referred to as support points that explain the joint density function of a given parameter. As such, the LC model can be considered as a special case of the ML model.

Following Louviere et al. (2000), if the probability of a FOE *n* being in class *s* is given by A_{ns} , the unconditional probability of choosing alternative *i* by *n* is given as:

$$P_{ni} = \sum_{s=1}^{S} P_{ni/s} \, . A_{ns} \qquad (5.1)$$

where $P_{ni/s}$ is the conditional probability of selecting alternative *i* by *n* when belonging to class s. The choice for specifying a certain number for classes is subject to the analyst's discretion. However, the classes must portray a realistic depiction of ground reality.

When applying the LC model to SP data, each FOE n is subjected to C consecutive SP choice scenarios (i.e., $c = 1, 2, \ldots, C$). For a given choice scenario c that pertain to FOE n, the probability $P_{nci|s}$ of choosing alternative i from a set of alternatives can be formulated using the traditional MNL model:

$$P_{nci|s} = \frac{\exp\,(\beta_s X_{nci})}{\sum_{i=1}^{I} \exp\,(\beta_s X_{nci})} \tag{5.2}$$

Assuming zero correlation among the C sequential choice situations, the joint probability $P_{ni|s}$ for the C choice scenarios presented to FOE n belonging to class s can be expressed as:

$$P_{ni|s} = \prod_{c=1}^{C} P_{nci|s} \tag{5.3}$$

The class assignment model probability A_{ns} of FOE n belonging to class s is estimated as:

$$A_{ns} = \frac{\exp\,(\theta_s Z_n)}{\sum_{s=1}^{S} \exp\,(\theta_s Z_n)} \tag{5.4}$$

where θ_s is the class-specific parameter vector associated with the vector of observable attributes Z_n of FOE n. One of the s parameter vectors is normalized to zero to ensure model's identification and class interpretation (Greene and Hensher, 2003). In terms of model diagnostics, minimized Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) can be used to identify the appropriate number of classes. However, AIC could lead to overestimation of the number of classes in the sampled population (Celeux and Soromenho, 1996).

Willingness-to-pay (WTP) estimates can be generated to evaluate FOE's willingness to spend a monetary amount to see improvements in a certain feature of the four powertrain alternatives available for each vehicle type in the SP scenarios. The WTP estimate is calculated by comparing a class-specific vehicle attribute coefficient β_{sx} and a class-specific cost attribute coefficient β_{sp} :

$$WTP = -\frac{\beta_{sx}}{\beta_{sp}} \tag{5.5}$$

WTP can be thought of as the trade-off between the acquisition cost that the FOE is willing to make to obtain a specific type of benefit when selecting a specific vehicle powertrain. It is worth noting that in order to have meaningful WTP estimates, it is imperative that both coefficients in the WTP ratio are statistically significant. WTP estimates in this research can be used in a sensitivity analysis framework to simulate the social cost and benefits of EV adoption by Canadian fleet operators.

5.6 Model Estimation Results

The final specification of the latent class (LC) model featured four latent classes. The validation criterion and the associated values used to select the specification are shown in Table 5-3. Minimized BIC and AIC were used to identify the appropriate number of classes. The chosen specification resulted in sensible Chi-square, AIC, and BIC values. Another consideration in selecting the final specification included the estimated class probabilities. The chosen specification yielded no identical classes (similar parameter estimates in magnitude and sign) and none of the classes was "too large" or "too small". Usually, any class with probability larger than 50% or smaller than 5% is considered "*too large*" or *"too small"*, respectively.

The estimated parameters of the final models are presented in Tables 5-4 and 5-5. Results pertaining to the conventional MNL model are included in Table 5-4 as a general benchmark for comparison purposes. According to the MNL model, there is less preference for BEVs as discerned from the alternative specific constant. All cost-related parameters under the **Cost ($)** category namely purchase price, annual operating cost, and annual depreciation cost are intuitive and significant. Purchase price was specified as an alternative specific variable for ICEVs, (HEVs), and Plug-in Electric Vehicles (i.e., PHEVs and BEVs), to explore sensitivity of the surveyed organizations towards these powertrains. As seen in the results, FOEs appear to be more sensitive to the price of conventional gasoline-based vehicles (i.e., ICEV) as oppose to the hybrid or fully electric versions.

Corporate FOEs are more concerned about operating cost when compared to the government FOEs as evident from the parameter for '*Operating Cost for Corporate Fleets'* variable. This is understandable as these fleets operate on the premise of profit maximization. *'Annual Depreciation Cost'* in the BEV utilities is highly significant implying that higher depreciation of BEVs is a concern. Under **Operations** category, range is an important attribute for FOEs planning to acquire EVs for their fleets, as discerned by the parameter for '*Range per Recharge (km)'*. FOEs perceive charging time as a disutility such that as the charging time increases the probability of acquiring PHEVs and BEVs decreases. On the other hand, the availability of more public charging stations in a typical 5 km radius has a positive effect on the probability of PHEV and BEV acquisition.

To explore the presence of preference heterogeneity among the surveyed organizations for acquisition of EVs for a specific fleet (i.e., car, pickup truck, and utility vehicles), variables representing the existing characteristics of the organizations were included in the model specification under **Fleet/Organization Specific** category. The *'Car Fleet'* parameter implies that FOEs are less likely to acquire plugin hybrid and battery electric cars compared to pickup truck and utility vehicles. A likely reason for this result could be attributed to the fact that an overwhelming majority of the surveyed FOEs operated pickup truck and utility fleets, which are 30% and 42%, respectively. Non-profit FOEs who do not have technical capabilities (i.e., mechanics that can perform EV repairs and maintenance) show disinterest in acquiring BEVs. Also, non-profit FOEs with locations lacking charging infrastructure seem to be less willing to acquire PHEV and BEVs for their fleets as the acquisition would require investing in charging infrastructure where these vehicles will be charged. Under **Attitudes** category, entities operating conventional gasoline-based vehicles tend to agree to the idea that adopting EVs in fleets is a high-risk decision. It is worth mentioning that results for all variables pertaining to incentives, both, monetary and non-monetary have no significant effects on the acquisition decision of EV by the surveyed entities, in both MNL and LC models.

The results for the LC model, namely *Class Utility* (Table 5-4) and *Class Assignment* (Table 5-5) models, are used to determine the orientation of the four latent classes forming the modeled entities and their preference towards acquiring a specific powertrain for their fleet operations. The parameters in bold are significant at 90% confidence interval or higher. Based on the results, the four classes were labeled as follows: Class 1 – ICEV Oriented FOEs, Class 2 – Cost Sensitive FOEs, Class 3 – EV Curious FOEs, and Class 4 – BEV Leaning FOEs.

Table 5-3 Validation of number of classes for the latent class model

S	***N***	***k***	***LL***	***AIC***	***BIC***	***Chi Squared***	ρ^2 ***Adj.***	***Class Probabilities***	***Identical Classes***	**Classes too big or too small**	**% Predicted Correct**
2	4536	40	- 27,344	54,767	54,767	15,598	0.22	58%, 42%	No	Yes	43
3	4536	66	- 25,256	50,644	25,377	19,773	0.28	42%, 16%, 42%	Yes	No	56
*4	4536	92	- 23,756	47,695	23,924	22,774	0.32	15%, 13%, 23%, 49%	No	No	63
5	4536	118	- 22,943	46,121	23,158	24,400	0.34	13%, 21%, 43%, 15%, 8%	Yes	No	65
6	4536	144	- 23,136	46,559	23,399	24,014	0.34	8%, 4%, 12%, 9%, 16%, 51%	Yes	Yes	71
7	4536	170	- 23,540	47,421	47,421	23,204	0.33	Not Feasible	N/A	N/A	69

**Selected model specification*

5.6.1 Class Utility (CU) Model

FOEs belonging to Class 1 appear to be significantly averse to acquiring BEVs. Given the large class probability value of 49% and the outcomes from the *Class Assignment* parameters, FOEs in this class could be labeled as *ICEV Oriented*. These FOEs appear to be concerned with the purchase price when acquiring ICEVs. With regards to their motivations for acquiring BEVs, this particular class places similar emphasis on trip range as does Class 4. Similar trends are noted for *'Charging Time'* and *'Number of public charging stations in a typical 5 km radius'.* FOEs belonging to this class seem to favor the acquisition of plugin hybrid and battery electric cars, as discerned by the '*Car Fleets*' parameter. This would suggest that these FOEs would prefer ICEVs when it comes to acquiring pickup trucks and utility vehicles. Interestingly, non-profit FOEs within this class show a preference towards BEV acquisition despite of lacking technical capabilities or means to repair or maintain EVs.

FOEs belonging to Class 2 could be labelled as *Cost Sensitiv*e given the results pertaining to the cost variables. FOEs in this class are sensitive to the *'Purchase Price'* of all four powertrains as well as other costs including annual operating and depreciation costs. Also, this class is most sensitive to the operating cost compared to all other classes in the model. Corporate fleets within this class appear to be very concerned with the cost for operating their fleets. The statement under the **Attitudes** category reinforce the idea that *'Adopting EVs in fleets is a high risk'.* This is understandable since cost sensitive entities are normally reluctant to embrace new technologies given their initial overhead cost.

Class 3 of the LC model could be labelled as *EV Curious* as evident from the significantly large positive constant for the BEV among the four latent classes. FOEs in this class, however, are noted to be concerned with the purchase price of all four available powertrains. Contrary to Class 2, FOEs in this class appear to be concerned with the *'Annual Depreciation Cost'*, suggesting that the operated fleets are likely to be replaced more often (i.e., have shorter replacement cycles). As in the case of the Class 2, corporate fleets within this class seem to be concerned with the operating cost of their fleets.

FOEs belonging to Class 4 could be labelled as *BEV Leaning*. The results indicate that these entities do not see *'Purchase Price'* or *'Operating Cost'* as a major deterrent in acquiring EVs. While these results might come across as counter intuitive, a likely explanation for them could be the following: first, this class of FOEs collectively represent a mindset whereby the participating FOEs believe that the initial high capital cost needed to acquire BEVs will be recovered through the various benefits that could be attained by fleet electrification. Additionally, relative to the other identified latent classes, the FOEs in this class probably disregarded or did not weigh the operating cost and perhaps also the purchase price the same way they valued other attributes when evaluating the SP scenarios. A less likely explanation could be due to the presence of multicollinearity that might exist in the SP responses provided by this class participants. According to the results, FOEs belonging to this class are more concerned with the *'Annual Depreciation Cost'* as evident by the estimated parameter. This class values higher trip range and lower charging time, as well as the availability of public charging stations. Non-profit FOEs lacking the technical capability to maintain EVs within this class are less likely to acquire BEVs. FOEs in this class do not think that adopting EVs is a high risk, which suggests that these entities are more likely to acquire EVs over ICEVs for their fleets' operations.

5.6.2 Class Assignment (CA) Model

The variables included in the CA model pertain to the general characteristics of the surveyed FOEs, as well as their manifested attitudes towards certain aspects of EVs. The results are interpreted relative to Class 1 (i.e., *ICEV Oriented FOEs*), which is used as the reference class.

Large corporate entities employing more than 500 fleet operators (C_1) are more likely to be assigned to Class 4 (*BEV Leaning FOEs)* compared to the two remaining classes (i.e., Class 2 and Class 3) relative to Class 1. This is intuitive given that mega organizations are often at the forefront of embracing new technologies and have the capital to invest in such technologies a much earlier stage than the smaller organizations. Our findings are in line with those reported by Globisch et al. (2018). The authors found that early EV adopting organizations are larger than average.

Reducing dependency on foreign oil is essential to the future of sustainable mobility, and the surveyed FOEs belonging to Class 2 (i.e., *Cost Sensitive FOEs)* are in agreement with the notion that operating Plug-in Electric Vehicles (i.e., BEV and PHEV) will help replace foreign-oil with made in Canada electricity (AT_1). Perhaps this is the case because this class of FOEs thinks that foreign oil reliance would prove to be too costly in the long run. On the contrary, Class 4 (i.e., *BEV Leaning FOEs)* and Class 3 (*EV Curious FOEs*) are skeptical about this notion. However, FOEs from the same two classes appear to confer with the statement that using Plug-in EVs in their organizations' fleets is a cost-effective decision (AT_2). FOEs belonging to Class 3 seem to be less willing to spend more money to adopt Plug-in EVs in their fleet in the near future (AT_3). However, the FOEs from the same class are noted to agree that the inclusion of plug-in EVs in their fleet is a prudent decision (AT_4).

Adoption of EVs in fleets is often seen as a measure to promote organization's image in terms of reducing the amount of carbon footprint and contributing to a more environmentally friendly and sustainable future. Interestingly, Class 4 seems to align themselves with this idea (AT_5). Furthermore, FOEs from the same class believe that EVs can meet the operational demands of their fleets (AT_7). Further, adopting emerging technologies is often associated with the so called "*guinea pig syndrome*", whereby there is an inherent risk of losing the investment made towards embracing a new technology as part of the existing infrastructure. Within this realm, *Cost Sensitive FOEs* oppose the idea that using plug-in EVs in their fleet is not a risky decision (AT_8) and by the same account, these FOEs do not feel pressured towards adopt EVs in their fleets (AT_9).

The lack of charging infrastructure is often seen as a major deterrent in EV adoption and understandably, *BEV leaning FOEs* seem to be willing to install additional infrastructure to adopt EVs in their fleets (AT_{10}). Critically, *Cost Sensitive FOEs* are also seen to be willing to install additional infrastructure to adopt plug-in EVs in their fleets. This disparity in acquisition behavior could be attributed to the fact that some of these Class 2 FOEs in some way do see EVs as a mean to save operating costs in the long run, other things being equal.

Table 5-4 Latent Class - Class Utility model results

Variable		MNL	Latent Class 1 ICEV Oriented FOEs (Prob. 49%)	Latent Class 2 Cost Sensitive FOEs (Prob. 23%)	Latent Class 3 EV Curious FOEs (Prob. 13%)	Latent Class 4 BEV Leaning FOEs (Prob. 15%)
	Utility	Co-eff. (t-stat)	Co-eff. (t-stat)	Co-eff. (t-stat)	Co-eff. (t-stat)	Co-eff. (t-stat)
Constant	*BEV*	-0.210 (-3.59)	-2.003 (-18.74)	–	6.462 (4.08)	3.239 (28.58)
Cost ($)						
Purchase Price	*ICEV*	**-0.022 (-8.48)**	**-0.017 (-3.82)**	**-0.142 (-3.30)**	**-0.403 (-18.46)**	**0.037 (2.46)**
Purchase Price	*HEV*	**-0.010 (-4.52)**	**0.009 (2.15)**	**-0.225 (-5.71)**	**-0.346 -(17.92)**	**0.033 (4.04)**
Purchase Price	*PHEV, BEV*	**-0.004 (-2.18)**	-0.004 (-1.32)	**-0.066 (-2.06)**	**-0.180 (-9.89)**	**0.023 (3.22)**
Annual Operating Cost	*PHEV, BEV*	**0.026 (1.96)**	-0.024 (-1.23)	**-0.915 (-2.61)**	-0.084 (-0.44)	**0.491 (8.67)**
Annual Depreciation Cost	*BEV*	**-0.145 (-12.31)**	**0.080 (3.61)**	**-0.371 (-2.43)**	**-2.051 (-5.74)**	**-0.309 (-16.39)**
Operating Cost for Corporate Fleets	*PHEV, BEV*	-0.036 (-1.27)	**0.490 (12.26)**	**-4.618 (-6.88)**	**-4.830 (-11.97)**	**2.251 (5.34)**
Operations						
Range per Recharge (km)	*PHEV, BEV*	**0.054 (8.35)**	**0.145 (16.61)**	-0.030 (-0.22)	**-0.482 (-5.04)**	**0.145 (4.42)**
Charging Performance						
Charging Time	*PHEV, BEV*	**-0.157 (-20.6)**	**-0.154 (-11.78)**	-0.275 (-1.43)	**-2.811 (-7.97)**	**-0.214 (-10.78)**
Number of Public Charging Stations in a Typical 5km Radius	*PHEV, BEV*	**0.053 (9.69)**	**0.079 (8.97)**	**-0.268 (-2.04)**	**-0.227 (-1.74)**	**0.210 (9.71)**
Fleet/Organization Specific						
Car Fleets	*PHEV, BEV*	**-0.001 (-5.61)**	**0.003 (13.41)**	-0.012 (-1.41)	**-0.053 (-3.11)**	-0.001 (-0.37)
Non-profit organizations with no technical capabilities	*BEV*	-0.017 (-0.38)	**1.167 (16.04)**	-5.126 (-0.03)	-8.163 (-0.01)	**-2.617 (-21.22)**
Non-profit organizations with no charging locations	*PHEV, BEV*	**-0.981 (-6.8)**	-0.360 (-0.75)	-8.179 (0.00)	-5.622 (-0.97)	10.292 (0.00)
Attitudes						
Adopting EVs in fleets is a high risk	*ICEV*	**0.524 (15.77)**	**-0.136 (-1.87)**	**2.111 (8.26)**	**-0.603 (-5.22)**	-6.053 (-0.08)

Table 5-5 Latent Class - Class Assignment model results

	Class Assignment Model	Latent Class 1 ICEV Oriented FOEs (Prob. 49%)	Latent Class 2 Cost Sensitive FOEs (Prob. 23%)	Latent Class 3 EV Curious FOEs (Prob. 13%)	Latent Class 4 BEV Leaning FOEs (Prob. 15%)
			Co-eff. (t-stat)	Co-eff. (t-stat)	Co-eff. (t-stat)
	Constant	Reference	**0.383 (4.30)**	**-1.723 (-8.45)**	**-7.760 (-15.01)**
C_1	Corporate organizations with more than 500 employees responsible for the vehicle fleet		-19.629 (0.00)	0.195 (0.71)	**1.118 (5.04)**
AT_1	Our organization thinks that operating Plug-in Electric vehicles (BEV or PHEV) will help replace foreign-oil with made in Canada electricity		**0.506 (2.43)**	**-0.448 (-2.13)**	-0.364 (-1.58)
AT_2	Our organization is confident that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a cost-effective decision		-0.184 (-0.78)	**1.445 (7.80)**	**4.009 (8.79)**
AT_3	Our organization is willing to spend more money to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet in the near future		0.076 (0.31)	**-0.407 (-1.75)**	-0.070 (-0.30)
AT_4	Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a prudent decision		**-0.432 (-1.84)**	**0.925 (3.59)**	**-2.483 (-11.87)**
AT_5	The decision to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet will promote our image, it is a good decision		**-0.320 (-1.64)**	**-1.043 (-5.66)**	**1.301 (3.75)**
AT_6	Our organization has the technical capabilities (i.e., specialized mechanics) to operate a fleet of Plug-in Electric vehicles (BEV or PHEV)		-0.217 (-0.97)	0.024 (0.10)	0.030 (0.14)
AT_7	Our organization is confident that a fleet of Plug-in Electric vehicles (BEV or PHEV) will meet our operational demands		**-1.418 (-6.64)**	-0.104 (-0.42)	**3.919 (7.02)**
AT_8	Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is not a risky decision		**-0.777 (-3.48)**	0.212 (0.93)	0.232 (1.03)
AT_9	Following the emerging trend in the industry, we feel pressure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet		**-1.255 (-5.80)**	0.371 (1.52)	**-0.866 (-4.64)**
AT_{10}	Our organization is willing to install additional infrastructure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet		**0.701 (3.40)**	**-0.523 (-2.27)**	**1.359 (5.31)**

5.6.3 Willingness-to-Pay for Fleet Electrification

The willingness-to-pay (WTP) estimates for the MNL and LC models are presented in Table 5-6. The estimates presented herein are based on using the '*Purchase Price'* of a BEV as the β_{sp} value. The estimated monetary measures are in dollars and imply the willingness of a FOE to pay a certain amount on top of the purchase price to obtain an improvement in the attribute of the BEV. Varying levels of WTP estimates reflect the taste variation among the four latent classes for improving a certain attribute of the BEV. It is worth noting that the WTP estimates for improvement in certain attributes could not be calculated as either the price parameter for PHEV and BEV was not statistically significant or the sign of the coefficient associated with the attribute and/or the price parameter was counter intuitive.

EV Curious FOEs would be willing to spend as much as $15,587 in purchase price for a decrease of an hour in charging time. Intuitively, *Cost Sensitiv*e *FOEs* would be willing to pay only about 25% of what *EV Curious FOEs* would be willing to pay for the same improvement. On the other hand, *EV Curious FOEs* would be willing to pay way less ($466) than *Cost Sensitiv*e *FOEs* to save $1,000 per year in the operating cost. This significant variation in the WTP could be attributed to the fleet replacement cycle of the two classes. Perhaps certain *EV Curious FOEs*, namely those operating cars, tend to have shorter replacement cycles and as such would be operating newer fleets compared to their cost sensitive counterparts.

EV Curious FOEs are also seen to be more concerned with the depreciation cost of their fleets and as such would be willing to pay $11,374 in purchase price to see a saving of $1,000 per year in the depreciation cost of their fleets. This could be tied to FOEs operating utility vehicles, which are usually associated with significantly longer replacement cycles. By comparison, *Cost Sensitive FOEs* would be willing to pay only about 50% of that amount to save $1,000 per year in depreciation cost. This could be attributed to the operational mindset of these *Cost Sensitive FOEs*. That is, Class 2 FOEs do not seem to be concerned about the depreciation cost since they tend to have longer replacement cycles in general.

Table 5-6 Willingness-to-pay estimates

		Latent Class Model			
Willingness to pay for/to	**MNL**	**Class 1** ***ICEV Oriented***	**Class 2** ***Cost Sensitive***	**Class 3** ***EV Curious***	**Class 4** ***BEV Leaning***
100 km increase in trip range	$13,751	–	–	–	–
one extra charging station	$13,528	–	–	–	–
60 min decrease in charging time	-$39,848	–	-$4,183	-$15,587	–
save $1,000 per year in operating cost	$6,647	–	-$13,895	-$ 466	–
save $1,000 per year in depreciation cost	-$36,789	–	-$5,638	-$11,374	–
attractiveness for EV, all else being equal	-$53,305	–	–	$35,830	–

5.7 Conclusions

This chapter modeled the factors affecting the acquisition of Electric Vehicles (EVs) in Canadian fleet operating entities (FOEs). The estimated model identified four latent FOE classes, namely *BEV leaning*, *EV curious*, *Cost sensitive* and *ICEV oriented* with class probabilities of 15%, 13%, 23% and 49%, respectively. As expected, purchase price is the most critical factor and heavily influences the acquisition decisions of all types of vehicle powertrains. Annual operating and depreciation costs also bear a significant influence on all the acquisition choices. However, corporate organizations in both *EV Curious* and *Cost sensitive* classes place strong emphasis on operating cost. Also, *BEV leaning FOEs* seem to place high value on extended trip range. Further, *Cost sensitive FOEs* consider the adoption of EVs a high-risk decision, which is not surprising given the cost saving mindset of these entities.

The results from the *Class Assignment model* provide novel insights to commonly perceived attitudes towards EVs. The perception that operating EVs will help organizations reduce foreign oil dependency by replacing it with electricity produced in Canada is mixed among the analyzed FOEs. *Cost sensitive FOEs* seem to side with this notion, while both *BEV leaning* and *EV Curious FOEs* object to it. It is likely that the latter FOEs are concerned with the methods used to produce the electricity needed to power EVs and do not see its well-to-wheel production to be totally emission free. Additionally, these organizations might not consider Canada to be totally dependent on the foreign-oil, after all Canada is the fifth-largest crude oil producer in the world (Natural Resources Canada, 2019). Not surprisingly, *BEV leaning FOEs* think that adopting EVs will promote their image relative to the *ICEV oriented* class. However, FOEs belonging to *EV curious* and *Cost sensitive* classes do not share this view. Most likely these classes do not see EVs as an effective panacea for reducing harmful air pollution. Also, they are not concerned with their public image at all. The popular notion that EVs require specialized mechanics for repairs and maintenance is not supported by our model. Further, *BEV leaning FOEs* side with the idea that a fleet of EVs is capable of meeting their operational demands; however, this is not the case for *Cost sensitive FOEs.* Perhaps the latter class use their fleets for intra- or inter-provincial operations, and the trip range offered by current EVs falls short for such tasks.

5.7.1 Policy Implications

The Stated Preference (SP) share of Plug-in Electric Vehicles in our sample is 38% which by far exceeds the minuscule shares that exist in the Canadian fleet market. The information brought on by our SP data points to a high potential for EVs in fleets. However, the right conditions must be put in place to exploit this potential. Some of the key policy implications arising from our empirical findings are as follows:

Investment in Public Charging Infrastructure

Both corporate and government FOEs placed high value on charging time in all four latent classes. Obviously, EVs with lower charging times could lead to substantive savings while enhancing on-road utilization of their fleets' operations. Further, the *BEV leaning FOEs* tend to be more concerned with the availability of public charging infrastructure. With a rather significant class probability of 15% for this class, policy instrument geared towards the expansion of public charging infrastructure especially in areas with cleaner electricity generation profile could entice EV acquisition.

Awareness Campaign highlighting EV Cost-effectiveness

Cost-effectiveness of any new technology is always a hugely debated issue, and there are no exceptions to that when it comes to the acquisition of EVs in fleets. In line with past studies, we also see differences among the four latent classes towards their evaluation of this issue. The variation could partly be due to the inherent belief that the EV technology is not matured enough to qualify as cost-effective (Seitz et al. 2015). Interestingly, while *EV curious* FOEs perceive EVs as cost-effective, they tend to be less willing to spend more money to adopt them in the near future. We believe these FOEs require more information to steer them from being curious to becoming highly interested. To that end, campaigns from various government platform to highlight the maturity and cost-effectiveness of EVs along with their potential cost saving can help achieve such goal.

Incentivize FOEs with climate action plan

With the increased interest in reducing greenhouse gas (GHG) emissions to combat climate change, many mega organizations have been moving towards adopting low carbon technologies in recent years. Organizations with climate action plan and access to renewable energy recourses could be potential adopters as EVs represent strong environmental appeal (Lemme et al. 2019). While *BEV leaning FOEs* demonstrated concerns about their social responsibility and image in the public domain, this was not the case for *EV curious FOEs*. Therefore, incentives will be needed to change the mindset of the latter FOEs and encourage them to adopt EVs in the near future.

Incentivizing on-site charging infrastructure

The availability of charging infrastructure is seen as a significant barrier affecting the acquisition of EVs in fleets. It should be noted that about 19% of all organizations in our sample indicated that they have some form of the charging infrastructure at their fleet locations. Both *BEV leaning* and *Cost sensitive FOEs* are willing to invest in additional on-site infrastructure. The implications are obvious for the former class. However, the attitudes displayed by the latter class could be tied to their belief about replacing foreign oil with made in Canada electricity. Hence, policies geared towards incentivizing FOEs to build on-site charging infrastructure could accelerate EV adoption in Canadian markets.

5.7.2 Directions for Future Research

The seminal effort made in this research offered new insights to bridge some of the knowledge gaps regarding the demand and prospects of EV adoption in Canadian corporate and government fleets. It did so by investigating the factors and conditions that could potentially accelerate the adoption of EVs in the Canadian fleets. However, in order to fully assess the feasibility of electric mobility in Canadian fleets in present day eco-friendly and cost-competitive environment, more data collection efforts focusing on the acquisition behavior of specific types of vehicle fleets will be needed in future research work.

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CHAPTER 6

DETERMINANTS OF BATTERY ELECTRIC VEHICLE ACQUISITION TIMEFRAME IN CANADIAN CORPORATE AND GOVERNMENT FLEETS - AN ORDERED LOGIT MODEL APPROACH

6.1 Introduction

Advancements in the manufacturing of Electric Vehicle (EV) battery technology are paving way for a rapid transition to a greener transportation system. It is widely believed that the high cost of battery has been a major hurdle in the widespread adoption of EVs. However, newer batteries which instead of relying on the traditional lithium-ions technology, make use of nickel-based cathode systems. The latter technology is significantly cheaper and provides higher energy density and longer cycle life (Hall, 2020). Also, authorities are acknowledging the strategic importance of EV battery manufacturing and are devising policies to support mega manufacturing plants to significantly lower the cost of producing batteries (Hall, 2020). Over time, the reduction in battery cost is expected to contribute to capital cost parity between EVs and their conventional counterparts (i.e., internal combustion engine vehicles). Overall, recent developments in the manufacturing of reliable battery technology are resulting in EVs with extended trip range, reduced charging time and lower capital cost.

The availability of high capacity public charging infrastructure and tighter tail-pipe emission controls have also renewed private sector's interest in EV adoption in fleets (IEA, 2016). Further, authorities at various levels are supporting policies that encourage different entities to consider EV adoption on a more substantial scale. In this respect, both the public and commercial sectors are responsible for the majority of global EV purchases, as reported by Sierzchula (2014). According to the literature, higher vehicle acquisition rates, intensive utilization and readiness to invest in refueling/charging infrastructure are the key reasons which makes fleets ideal candidates for EV adoption (see for example: Dijk et al. 2013; Nesbitt and Davies, 2013). Also, large organizations are often at the forefront of embracing new technologies as they are more willing to invest earlier than smaller organizations (Globisch et al. 2018). This is evident from Amazon Inc.'s recent decision to acquire 100,000 all-electric vans for its delivery operations, an initiative which is in line with its vision to become carbon-neutral by 2040 (CNBC, 2019). Such massive uptakes underline the potential of larger than average fleet operating entities (FOEs) as being the front runners in early EV adoption.

Many organizations in both the public and private domains often have large fleets with extensive daily usage that includes activities such as transporting employees, delivering goods, and/or providing services. These commercial activities, with the majority of them transpiring in urban areas, contribute significantly to the overall carbon footprint of the transportation sector. Many North American jurisdictions are enforcing limits to motivate greenhouse gas (GHG) emitters to decrease their levels. As a result, tighter regulations have led to an increase in the adoption of low-carbon vehicle technologies (Government Technology, 2019). To this end, the discussions on the benefits and costs of adopting such technologies, including all-electric powertrains, is drawing the attention of the fleet industry. Since 2013, the share of EVs in Canada has been increasing at a faster pace (FleetCarma, 2019). More specifically, the total numbers of EVs have grown substantially from 3,254 in 2013 to 34,357 in 2018. However, new fleet registrations for cars and light pickup truck in 2018 in Canada had negligible shares of 1.0% and 0.8%, respectively.

We contend that the Canadian fleet market has the potential to adopt EVs at a large scale given the cost savings that these vehicles offer considering the recent battery technology enhancements. The question here is: "what conditions are needed to help corporate and government organizations lean towards early fleet electrification in Canada?". The work in this chapter addresses this question by examining the determinant of the battery electric vehicle (BEV) acquisition timeframe in Canadian fleets. Several ordered logit models are estimated using data collected by the Canadian Fleet Acquisition Survey (CFAS). The CFAS data pertain to a sample of over 1,000 random organizations that owned and operated cars, pickup trucks and utility vehicle fleets in Canadian cities. The research is the first of its kind to collect and analyze revealed data on the acquisition timeframes of EVs in fleets. The collected data included organization's general characteristics, existing fleet characteristics, future acquisition plans and EV fleet prospects. It also included attitudinal statements to understand the latent perceptions that might exist among the responding FOEs that could influence EV acquisition in fleets.

The remainder of this chapter is organized as follows: a literature review of previous studies on the subject is provided in Section 6.2. Next, description of the variables derived from the CFAS and used in the analysis is included in Section 6.3. The analytical method used to model BEV acquisition timeframe is described in Section 6.4. Section 6.5 presents and discusses the results of the estimated models. Lastly, a conclusion section is provided to highlight the takeaway lessons and the steps for future research.

6.2 Literature Review

One of the most critical factors influencing the success or failure of a new technology is users' acceptance (Davis, 1993). A thorough review of past studies on Electric Vehicles (EV) adoption indicates that there are stark differences between private consumers and organizations' motivations and their decision-making process regarding the EV technology (Globisch et al. 2018). Although EVs have come a long way since their inception, their acceptance is still affected by their unfavorable historical traits of lack of performance, range limitation and functionality issues (Wikstrom et al. 2016).

Typically, budget and cost considerations influence the acquisition or purchase decisions of organizations. In fleets, vehicle purchase policies are based on rational decisions such that the acquired vehicle will require less efforts in integration and lead to improvement in the performance and productivity of the existing fleets (Seitz et al. 2015). However, empirical research on processes involved in organizational buying shows that purchase decisions are not always based on cost-benefit measures alone (Zehetner, 2011). For instance, if a rational evaluation of purchasing alternatives is not possible, personal feelings might come into play when arriving at the final purchasing decision. In this vein, non-cognitive factors such as trust matters in supplier relationships, cultural influence, intuition and individually implied social responsibility and perceptions also impact professional decision-making (Zehetner, 2011).

The vast majority of past studies on EV acquisition has focused on consumers belonging to private households (Potoglou and Kanaroglou, 2007; Hjorthol, 2013; Rezvani et al. 2015, Ferguson et al. 2018). On the other hand, the studies by Golob et al. (1997), Nesbitt and Davies, (2013) Koetse and Hoen (2014), Wikstrom et al. (2014), (2016), Sierzchula (2014), and Seitz et al. (2015), Globischa et al (2018), Dimatulac et al. (2018) are the few noticeable exceptions that looked at the acquisition of EVs in fleets. The overarching finding from these studies suggests that typically, private consumers prefer vehicle comfort and performance when choosing EVs, whereas, FOEs value environmental benefits and enhanced corporate image that could be accrued through the adoption of EVs. To that effect, constructs such as subjective norms are found to be quite important in influencing the acquisition of EVs in commercial fleets (Globisch et al. 2108). Environmental benefits and perceived ease of use are identified as relevant antecedents to EV acceptance in fleets (Globisch et al. 2108). This finding is in fact partly corroborated by Seitz et al. (2015) whereby early adoption of EVs in larger than average organizations is driven by non-economic considerations such as corporate image and social responsibility in public domain.

An efficient fleet replacement strategy is essential for ensuring upfront and operating costs as well as fleet performance. The existing literature indicates that acquisition condition and operational barriers such as annual mileage and average age are important considerations affecting the replacement cycle of fleets (Jabali and Erdogan, 2015; MAI, 2014; Beirnes, 2012). Aside from financial barriers, operational barriers play a pivotal role in the acquisition decisions of new technologies aimed at the decarbonization of the transportation sector. Research by Skippon and Chappel (2018) and Wikström et al. (2016) identified potential barriers and challenges and that could hinder the adoption of BEV in commercial fleets, if not tackled. These challenges pertained to issues such as deployment, handling failures, and promotion of usage. In a similar vein, Wikström et al. (2016), through their focus-group based research findings, further suggested that the introduction of BEV to fleets should be supported through assistance and commitment, from external sources such as government initiatives and policies.

6.3 Fleet Operating Entities (FOEs) Data

The data used in this chapter was collected through a web-based Canadian Fleet Acquisition Survey (CFAS) that was conducted in December 2016. The survey obtained information from over 1,000 randomly selected organizations that owned and operated cars, pickup trucks and utility vehicle fleets in Canadian cities. The sampled fleet operating entities (FOEs) were categorized into corporate (66%) and government (34%) entities. The revealed portion of the collected data included organization's general characteristics, existing fleet characteristics, future acquisition plans and Electric Vehicle (EV) fleet prospects. More specifically, information regarding fuel type, acquisition condition and ownership status of the existing fleet was acquired. Furthermore, information regrading the geographical extent (i.e., intercity, inter province, intra province) of fleet operations for the three types of fleets was also obtained. Finally, the responding organizations were asked to provide the fleet usage information such annual mileage, replacement cycle and average age of their existing fleet.

An EV acquisition outlook section was included in the CFAS to gauge the success and growth prospects of EVs in the Canadian fleet market. Respondents in this section were subjected to policy questions such as having any regulatory imperatives or policies (internal or external) in fleet procurement, for example '*made in Canada'*. An overwhelming majority (92%) of the all organizations in our sample indicated that they do not have any regulatory imperatives in their fleet procurement process. The section also collected information regarding FOEs' plans to acquire battery electric vehicles (BEVs) for their fleets. This included obtaining information related to the number of vehicles to be acquired, timeframe, and condition and acquisition strategy. This information was collected to understand the nature of FOEs and their associated transportation needs in a geographical context. Information about the best descriptor of the respondent's organization, location, total number of employees, total fleet locations, total number of Canada-wide employees with daily responsibilities related to the vehicle fleet, and availability of on-site charging infrastructure at all fleet locations was also collected.

In terms of geographic representation, almost 40% of the 1,008 surveyed organizations in our sample were from Ontario. Quebec accounted for 20% and ranked 2nd, while British Columbia ranked 3rd with 12% of the organizations that participated in the survey. Manitoba accounted for 4% of the total sample while New Brunswick and Nova Scotia had the same representation in the survey with each accounting for 2% of the total sample. Finally, the provinces of Saskatchewan and Newfound Land and Labrador each accounted for 1% of the sample. Table 6-1 shows the characteristics of the full sample of FOEs that was used in the estimated ordered logit model.

Table 6-1 Characteristics of full sample used in the Ordered Choice Logit model

FOE Characteristics	Variable	Count (%)
Number of employees		
	1-5 employees	109(11%)
	6-10 employees	103(10%)
	11-25 employees	138(14%)
	26-50 employees	137(14%)
	51-100 employees	154(15%)
	101-250 employees	106(11%)
	251 – 500 employees	119(12%)
	Greater than 500 employees	141(14%)
Employees dedicated to fleets		
	1-5 employees	273(27%)
	6-10 employees	155(15%)
	11-25 employees	142(14%)
	26-50 employees	136(13%)
	51-100 employees	142(14%)
	101-250 employees	77(8%)
	251 – 500 employees	41(4%)
	Greater than 500 employees	41(4%)
On-site charging infrastructure		
	All location feature on-site charging	217(22%)
	Most location feature on-site charging	204(20%)
	Some location feature on-site charging	195(19%)
	No location feature on-site charging	391(39%)
Number of fleet sites		
	Only one site	323(11%)
	2 sites	194(14%)
	3-5 sites	272(11%)
	5-10 sites	127(12%)
	Greater than 10 sites	92(14%)
Regulatory imperatives		
	Yes	948(94%)
	No	60(6%)

Table 6-1 - continued

FOE Characteristics	Variable	Count (%)
Decision-making roles		
	Director	200(20%)
	Chief Executive Officer)	187(19%)
	Fleet Manager	147(15%)
	Other Manager	138(14%)
	President	109(11%)
	Chief Administrative Officer	68(7%)
	Fleet Supervisor	59(6%)
	Chief Financial Officer	58(6%)
	Elected Official	42(4%)

6.3.1 Characteristics of Corporate and Government FOEs

Fleet operating entities (FOEs) were categorized into corporate and government entities with shares of 66% and 34% of the total sample. Figure 6-1 shows the breakdown of the 9 vehicles types by the two broad categories of FOEs in the full sample. For the most part, the shares of each vehicles type in the two categories are consistent, though corporate FOEs are noted to have slightly more *Large walk-in truck* (3% to be precise) compared to the *government* FOEs.

The distribution of the extent of existing charging infrastructure of corporate and government FOEs is presented in Figure 6-2. Nearly twice as many corporate FOEs are noted to have charging stations at every fleet location they own. Similar shares are noted for the two types of FOEs for the '*most locations have charging stations'* and '*some locations have charging stations'*. On the other hand, corporate FOEs with no existing charging stations are nearly three times of the entities that belong to the government sector.

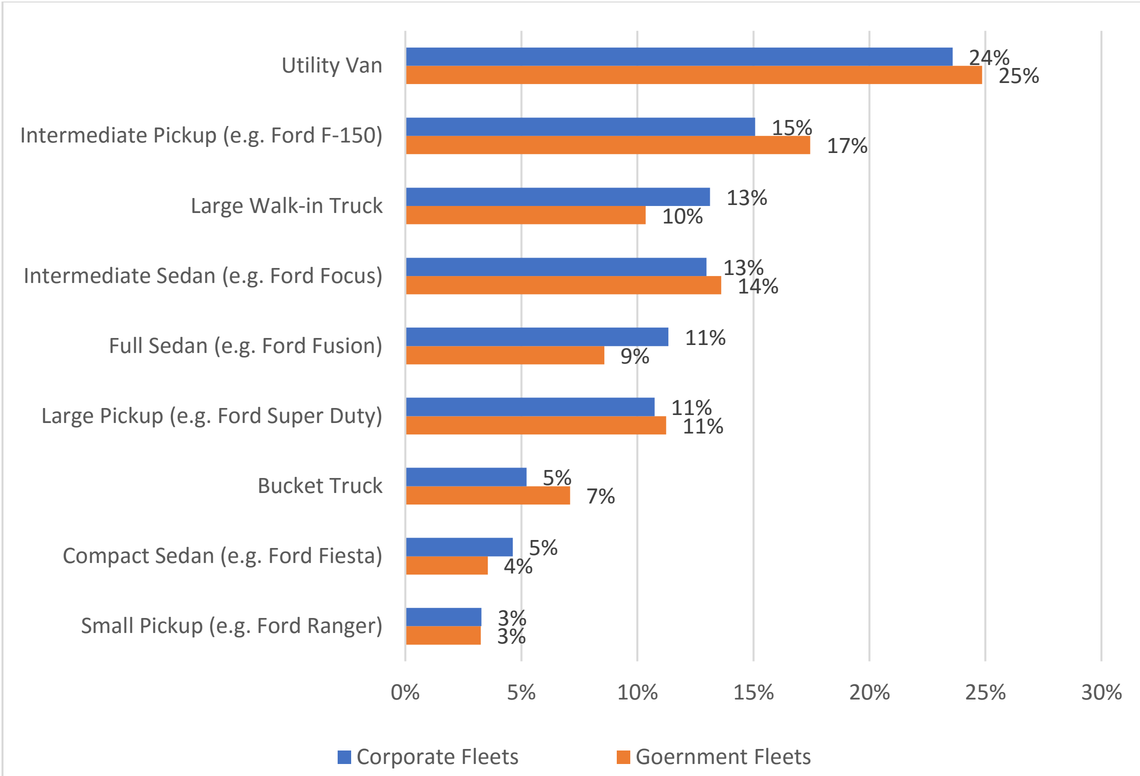
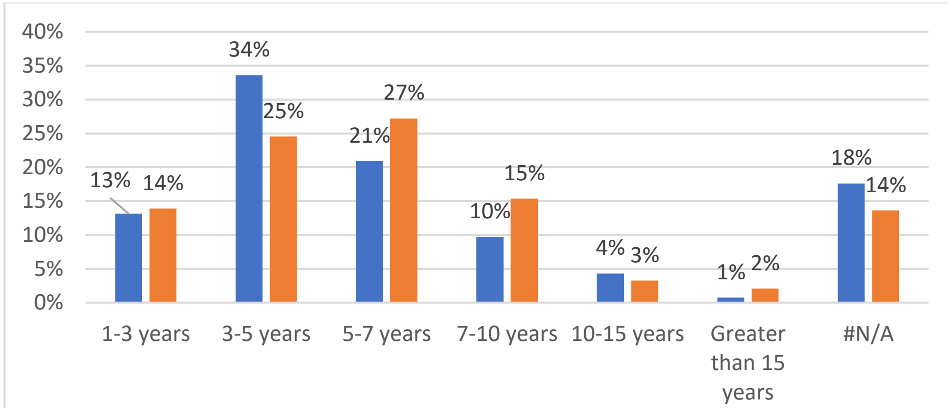


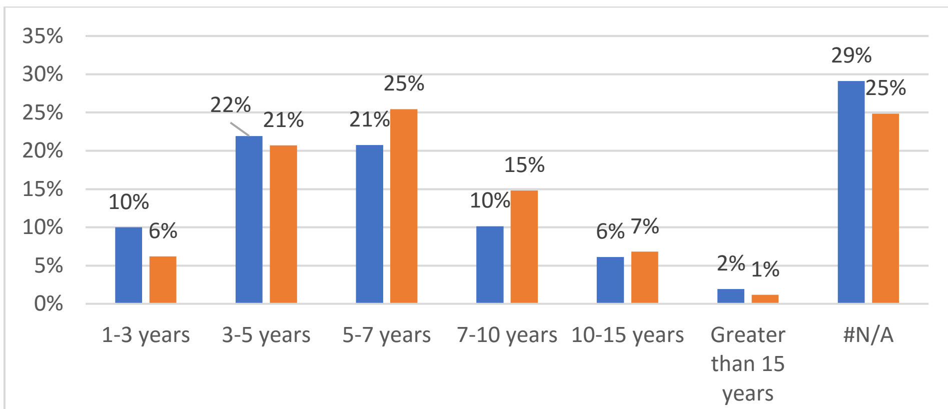
Figure 6-1 Distribution of dominant vehicle type in the sampled FOEs

Figure 6-2 Distribution of existing charging infrastructure in the sampled FOEs

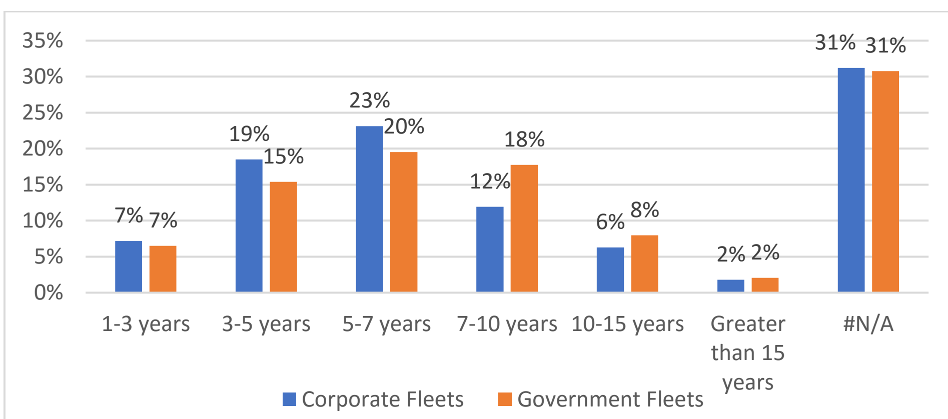
Figure 6-3 presents the replacement cycle ranges for cars, pickup truck and utility vehicles fleets for corporate and government FOEs. The highest share of car fleets, represented by nearly 34%, in corporate FOEs is associated with a 3-5 years replacement cycle. Likewise, the highest share for pickup truck fleets (22%) was acquired under the same replacement cycle category. The second highest share for both cars and pickup trucks for the corporate sector is associated with a replacement cycle of 5-7 years with a share of 21%, each. Interestingly, the highest share of the utility vehicle fleets (23%) that were acquired by corporate organizations have a relatively longer replacement cycle of 5-7 years, while the second highest share (19%) for these types of vehicles is associated with a replacement cycle of 3-5 years. By comparison, the most dominant replacement cycle category for car, pickup truck and utility vehicle fleets among government organizations is 5-7 years. This indicates that government fleets are generally acquired for longer periods. The last category, i.e., #NA in Figure 6-3 implies unavailability of replacement cycle data for the corresponding proportion of the sampled FOEs.



(a)



(b)



(c)

Figure 6-3 Replacement cycle distribution (a) – car fleets, (b) pickup truck fleets (c) utility vehicle fleets

6.3.2 Characteristics of FOEs by Vehicle Types

The characteristics of the existing fleets of the sampled FOEs by vehicle types are presented in Table 6-2. Under 'Acquisition Condition', we see, that a significant proportion of all three types of fleets are acquired as 'New'. Under 'Geography', nearly 42% of the car fleets are used for 'within city' operations while more than 50% of both the pickup truck and utility vehicles fleets are utilized for 'within Province' operations. Under 'Purpose', car fleets are equally utilized to transporting employees and providing serveries with each share of 37% of the total car fleet vehicles. The share of providing services using pickup trucks and Utility vehicles is very similar. (i.e., 40% and 41%, respectively). As for the 'Annual Mileage', we see that the' 25,001 - 50,000 km' range to be the most significant with nearly 37% of car fleets operating within this range. Pickup truck and utility vehicle fleets are noted to have shares of 20% and 58%, respectively.

Table 6-2 Characteristics of different fleet types of CFAS sample

Characteristics	Fleet Type		
	Cars	Pickup Trucks	Utility Vehicles
Acquisition Condition			
New	69%	83%	80%
Used	4%	6%	2%
Mixed	27%	11%	18%
Geography			
Within a Site	10%	8%	6%
Within a City	42%	26%	35%
Within a Province	37%	56%	53%
Between Provinces	11%	10%	7%
Purpose			
Transporting Employees	37%	24%	16%
Providing Services	37%	40%	41%
Delivering Goods	26%	36%	43%
Annual Mileage			
Less than 25,000 km	17%	26%	5%
25,001 - 50,000 km	37%	20%	58%
50,001 - 75,000 km	23%	28%	11%
75,001 - 100,000 km	15%	18%	15%
Greater than 100,000 km	8%	8%	10%

6.4 Method of Analysis

An ordered discrete choice model was specified and estimated to investigate the factors affecting the acquisition timeframe of BEVs in the sampled FOEs. The ordered modeling approach is suited when the dependent variable is of ordered nature with more than two levels (Greene and Hensher, 2003). The dependent variable τ_n for each modeled FOE n in our case is ordinal with 4 observed levels: 0, 1, 2, and 3. The first level 0 represents the (1 – 3) years BEV acquisition timeframe for FOE *n*. Likewise, levels 1, 2 and 3 represent the (3 – 5), (5 – 7) and (7 – 10) years timeframes, respectively. Table 6-3 shows the different categories of the dependent variable. More than 60% of the participating FOEs indicated that they do not have any plans to acquire BEVs for their fleet of vehicles. FOEs that are likely to acquire BEVs for their fleet in the next 2 years have a share of 20% in the total sample. As the timeframe to acquire BEVs is projected further in the future, the share of FOEs that are likely to acquire BEVs drops, i.e., from 16% for the 5 – 7 years timeframe to 3% for the 7 – 10 years timeframe.

Table 6-3 Shares of the dependent variable categories

BEV Acquisition Timeframe	Ordered Logit Coding	Full Sample	Corporate FOEs	Government FOEs
(1 – 3) years	0	200 (20%)	127 (19%)	73 (22%)
(3 – 5) years	1	159 (16%)	102 (15%)	57 (17%)
(5 – 7) years	2	34 (3%)	19 (3%)	15 (4%)
(7 – 10) years	3	612 (61%)	420 (63%)	192 (57%)

The specified model estimates the marginal effect of different independent variables on the dependent variable τ_n, such that the observed dependent variable τ_n is linked to the unobservable latent variable τ_n^* by the following rules:

$$\tau_n = \begin{cases} 0 & -\infty < \tau_n^* \leq 0 \\ 1 & \mu_1 < \tau_n^* \leq \mu_2 \\ 2 & \mu_2 < \tau_n^* \leq \mu_3 \\ 3 & \mu_3 < \tau_n^* \leq +\infty \end{cases}$$

Where μ's are the cut-points or thresholds to be estimated along with the other parameters of the model. The latent acquisition timeframe measure τ_n^* is obtained by the following utility expression:

$$\tau_n^* = V_n + \varepsilon_n \tag{6.1}$$

Where τ_n^* is a latent and continuous measure of BEV acquisition timeframe for organization n, V_n is the observable utility for FOE n, and ε_n is the random error term for FOE n. Assuming ε_n follows the Gumbel distribution, then the model becomes an ordered logit in which we can calculate the probabilities associated with the acquisition timeframe categories. In the above expression, τ_n^* can be thought of as the utility of delaying the acquisition of a BEV. That is, as the value of τ_n^* increases the probability of delaying the acquisition will also increase. Figure 4 represents the distribution of the utilities and associated probabilities for the modeled acquisition timeframes. According to Figure 6-4, the utility can be used to calculate the probability of each of the 4 BEV acquisition timeframes. More specifically, the probability of a (1 – 3) years acquisition timeframe can be formulated as follows:

$$P(0) = \Pr(\tau_n^* < \mu_1) = \Pr(\varepsilon_n < \mu_1 - V_n) \tag{6.2}$$

The probability of each of the acquisition timeframes (3 – 5), (5 – 7) and (7 – 10) years can be formulated according to the following three respective equations:

$$P(1) = \Pr(\mu_1 < \tau_n^* < \mu_2) = \Pr(\varepsilon_n < \mu_2 - V_n) - \Pr(\varepsilon_n < \mu_1 - V_n) \tag{6.3}$$

$$P(2) = \Pr(\mu_2 < \tau_n^* < \mu_3) = \Pr(\varepsilon_n < \mu_3 - V_n) - \Pr(\varepsilon_n < \mu_2 - V_n) \tag{6.4}$$

$$P(3) = \Pr(\tau_n^* > \mu_3) = 1 - \Pr(\tau_n^* < \mu_3) = 1 - \Pr(\varepsilon_n < \mu_3 - V_n) \tag{6.5}$$

It is worth noting that for the ordered logit model, the probability $\Pr(\varepsilon_n < \mu_k - V_n)$ is formulated as follows:

$$\Pr(\varepsilon_n < \mu_k - V_n) = \frac{\exp(\mu_k - V_n)}{1 + \exp(\mu_k - V_n)} \quad (6.6)$$

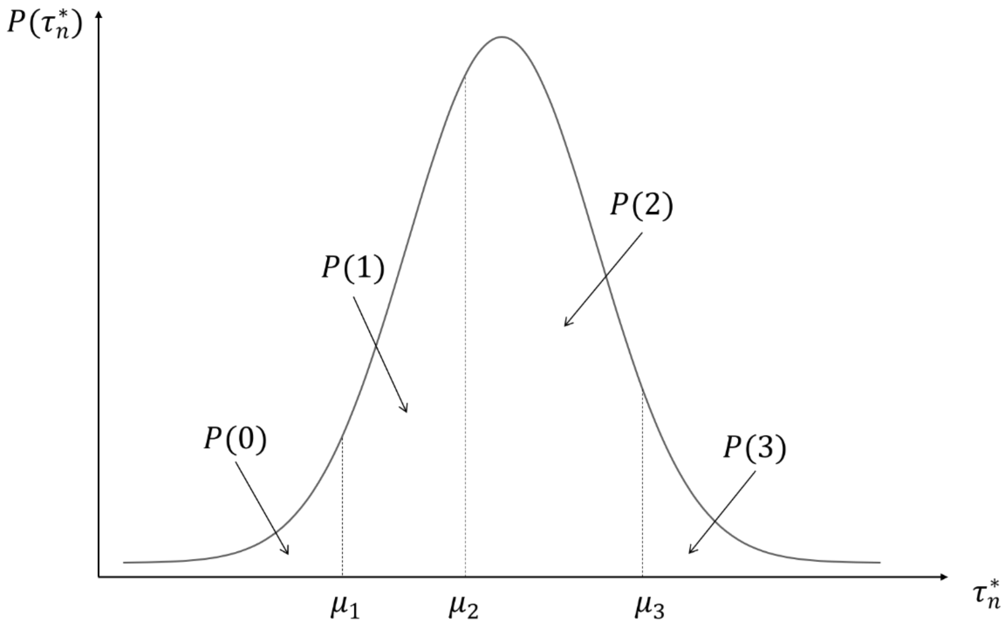


Figure 6-4 Distribution of utility and probability based on BEV acquisition timeframe

If the threshold parameters μ_1, μ_2 and μ_3 are known and the observed utility V_n represented by the independent variables and associated parameters are also known, then equation 6.6 can be employed in equations 6.2 to 6.5 to calculate the probability of the 4 acquisition timeframe levels. Usually, V_n is formulated as a linear-in-parameters function that depends on several independent variables. Typically, fleets with higher mileage and age are more likely to be replaced/renewed sooner due to the increased cost incurred in maintaining aging vehicles. The independent variables also included measures characterizing the existing fleets such as vehicle type, vehicle class, acquisition condition, fleet usage and fleet operations. Finally, the outputs from the Exploratory Factors Analysis (EFA) conducted on the responses to the attitudinal statements of the CFAS were also included as independent variables in the estimated models. More specifically, the four labeled latent factors in Table 6-4 were included as continuous variables with each factor providing a combined effect of the 11 statements for each of the sampled organizations. The detailed description of the statements in the table can be found in Section 3.3.4 of Chapter 3 of this dissertation.

Table 6-4 Explanatory Factor Analysis results for attitudinal statements

Observed variable	Early adopter attitude	Economically driven attitude	Obligatory attitude	Technology believer attitude
AT1	-0.01	**0.78**	0.07	-0.04
AT2	0.12	**0.78**	0.04	0.02
AT3	0.24	**0.51**	0.11	0.14
AT4	0.24	0.42	0.07	**0.30**
AT5	0.20	0.34	0.13	**0.30**
AT6	**0.69**	0.01	0.08	0.06
AT7	**0.72**	0.16	0.00	0.08
AT8	**0.75**	0.12	0.12	-0.07
AT9	0.45	0.06	**0.44**	-0.04
AT10	0.25	0.22	**0.50**	0.02
AT11	0.14	0.21	**0.56**	0.06

Note: The loadings ≥ 0.3 are shown in bold.

6.5 Model Estimation Results

NLOGIT 5.0 is used to estimate the ordered logit models presented in this section. NLOGIT sets the value for the threshold parameter μ_1 to zero in the model as it is not possible to simultaneously estimate the overall model constant and all the thresholds. As such, the software estimates the values for the μ_2 and μ_3 parameters. Table 6-5 presents the results of the ordered logit models estimated using the full sample and sub-samples of corporate and government organizations. The parameters in bold are significant at 90% confidence interval or higher. The parameters for the three models are largely consistent in terms of sign and magnitude. The model fit and predictive power of all three models is satisfactory. The lower values for the '*Constant'* for the three models suggest that the estimated models accounted for much of the unobserved effects of explanatory variables. The positive results for smaller organizations (with employees less than 25) imply that these organizations are likely to delay the acquisition of battery electric vehicles (BEVs) . The impact of size is more pronounced for the smallest category of organizations (i.e., 6 to 10 employees). Also, organizations with only one site as base, are likely to have a longer acquisition timeframe for BEVs. Organizations located in Quebec seem to have a higher tendency for acquiring BEVs under relatively shorter timeframes although the impact is only marginally significant. In contrast, FOEs in the prairie province of Saskatchewan are likely to delay the acquisition of BEVs. With respect to vehicle classes, FOEs with compact sport utility vehicles in their exiting fleets are noted to show propensity to acquire BEVs under shorter acquisition timeframes. This effect is slightly more pronounced in corporate fleets.

FOEs using cars in their fleets to provide services are more likely to have a shorter acquisition timeframe for BEVs. Similarly, corporate FOEs with compact SUVs are more likely to have a shorter acquisition timeframe for BEVs. Not surprisingly, the odds for acquiring BEVs in a short timeframe increases for FOEs with a short vehicle replacement cycle of 1 to 7 years. Availability of on-site charging infrastructure tend to have a significant influence on the acquisition timeframe of BEVs. For instance, FOEs with on-site charging at all locations in the full sample are likely to acquire BEVs under shorter timeframes. Interestingly, the effect is more pronounced in the case of government FOEs as oppose to their corporate counterparts. Overall, the results suggest that the availability of on-site charging infrastructure increases the probability of early BEV acquisition even if the charging infrastructure is only available at some of the fleet locations. Regulatory imperatives in fleet procurement also tend to influence acquisition timeframe for BEVs in fleets. FOEs with regulatory imperatives both in the full sample, and in the government sector, show a higher propensity for acquiring BEVs under shorter timeframes.

The results related to the acquisition conditions of the BEVs from the full sample suggest that relative to acquiring a mix of new/used batch of BEVs, FOEs that acquire cars in 'New' and 'Used' condition for use in their fleets have a higher probability of shorter BEV acquisition timeframes, other things being equal. However, FOEs who rely on leased cars for their fleets are associated with a longer BEV acquisition timeframe. Further, the results related to the *attitudes and perception* variables in all three estimated models suggest that FOEs with economically driven attitudes are likely to acquire BEVs under shorter acquisition timeframe. This could be the case because these FOEs are likely to believe that using BEVs in fleets would lead to economic benefits. With regards to the effect of the role of decision-making authority on BEV acquisition timeframe, higher hierarchy role such as 'Director' in governmental organizations is associated with longer timeframes. The same effect is also observed in the case of 'Other managerial level authority' in corporate FOEs.

Table 6-6 presents the results of the estimated ordered logit models for the FOEs that operate Car fleets, Pickup truck fleets and Utility vehicle fleets. All three estimated models have acceptable explanatory and predictive powers. All things being equal, FOEs operating the three types of vehicle fleets are less likely to acquire BEVs in near future. The propensity of acquiring BEVs in the near future decreases for small FOEs using cars, pickup trucks and utility vehicles in their fleets. FOEs with pickup trucks fleets located in Quebec show a higher propensity for early BEV acquisition. This is not surprising given that Quebec is the leading jurisdiction in clean energy in Canada with lowest GHG emissions and toxic waste in hydro generation (Hydro Quebec 2019). More specifically, nearly 95% of electricity in Quebec is generated from hydro (Canada Energy Regulator, 2019). On the other hand, Organizations using utility vehicles in their fleets in Ontario show low propensity of acquiring BEVs in a short timeframe. As in the case of the models reported in Table 6-5, availability of existing on-site charging infrastructure increases the probability of a shorter BEVs acquisition timeframe for all three types of vehicle fleets, other things being equal. Further, FOEs that operate cars and pickup trucks from only one base site are less likely to acquire BEVs in the short run. In contrast, FOEs that operate utility vehicle fleets and have two or more sites available for their fleet operations have a shorter BEV acquisition timeframe.

FOEs operating pickup truck fleets to provide services have a shorter BEV acquisition timeframe. The same could be said about FOEs operating cars to provide services, although the impacts are not significant. In line with the result obtained from the models provided in Table 6-5, the existence of regulatory imperatives contributes to the early acquisition of BEVs especially in the case of FOEs operating pickup trucks. The same could be said about the other two classes of fleets although the results are not as significant.

FOEs that acquire used cars for their fleets tend to have shorter BEV acquisition timeframes. Similarly, FOEs acquiring used pickup trucks also have a shorter acquisition timeframe, although the effects are not as significant for this fleet class.

FOEs with compressed natural gas (CNG) utility vehicles have a lower propensity of acquiring BEVs under shorter timeframes. This result is sensible since CNG-based utility vehicles are typically larger in size and cost more money to acquire. As such, these types of vehicles would be associated with longer replacement cycles let alone the much higher purchase cost of battery electric-based utility vehicles. Surprisingly, there is no significant associations between the nature of fleet operations and the acquisition timeframe in all three estimated models. The probability of a shorter timeframe acquisition increases for small organizations (11 – 25 employees) operating utility vehicles. The same is observed for larger organizations with 51 – 100 employees. FOEs with *economically driven attitude* have the tendency to acquire BEVs for their car fleets under shorter timeframes. A similar behavior is observed for certain entities operating utility vehicles. That is, *economically driven* government entities and corporate entities *with early adopter attitude*. Not surprisingly, corporate entities operating pickup truck and exhibiting obligatory attitudes towards electric mobility have a lower BEV acquisition timeframe. Lastly, the results pertaining to higher hierarchy roles (i.e., director or other managerial level authority) in the three vehicular fleet models are consistent with the findings presented in Table 6-5.

Table 6-5 Estimated parameters of the Ordered Logit models

Variable Description	Full Sample	Corporate FOEs	Government FOEs
	Coefficient (t-stat)	Coefficient (t-stat)	Coefficient (t-stat)
Constant	**2.910 (12.21)**	**2.594 (9.13)**	**3.695 (7.83)**
Establishment Characteristics			
Organizations with 6 to 10 employees	**0.912 (3.33)**	**0.842 (2.57)**	**1.144 (2.21)**
Organizations with 11 to 25 employees	**0.354 (1.69)**	**0.469 (1.79)**	–
Organizations located in Quebec	-0.213 (-1.27)	-0.288 (-1.29)	–
Organizations located in Saskatchewan	**2.255 (2.06)**	**2.147 (1.81)**	–
Only one site used as a base of organization	**0.358 (2.09)**	**0.623 (2.88)**	–
Existing Fleet Characteristics			
Organizations using car fleets for providing services	-0.348 (-1.50)	-0.354 (-1.20)	-0.47 (-1.20)
Organizations using car fleets with replacement cycle of 1 to 7 years	-0.26 (-1.51)	-0.184 (-0.80)	-0.366 (-1.36)
Organizations with Compact SUVs in their fleets	**-0.424 (-1.63)**	**-0.798 (-2.42)**	0.238 (0.54)
Fleet Purpose			
Pickup truck fleet operations within a site	-0.234 (-0.8)	-0.193 (-0.48)	–
Pickup truck fleet operations within a city	-0.166 (-1.06)	-0.174 (-0.83)	-0.238 (-0.97)
On-site Charging Infrastructure			
All location feature on-site charging infrastructure	**-0.839 (-4.00)**	–	**-2.249 (-5.23)**
Most location feature on-site charging infrastructure	**-1.027 (-4.95)**	**-0.652 (-2.46)**	**-1.987 (-4.98)**
Some location feature on-site charging infrastructure	**-1.132 (-5.52)**	**-1.027 (-4.07)**	**-1.884 (-4.58)**
Fleet Acquisition Policy			
Regulatory imperatives in fleet procurement	**-0.729 (-2.43)**	-0.477 (-1.01)	**-0.919 (-2.33)**
Fleet Acquisition Strategy			
Car fleets acquired in NEW condition	**-0.507 (-2.42)**	**-0.528 (-1.91)**	**-0.412 (-1.21)**
Car fleets acquired in USED condition	**-0.794 (-3.03)**	**-0.929 (-2.64)**	**-0.59 (-1.45)**
Car fleets leased	**0.274 (1.73)**	**0.246 (1.22)**	**0.308 (1.15)**
Attitudes and Perceptions			
Organizations with economically driven attitude	**-0.351 (-2.03)**	**-1.005 (-7.85)**	**-0.329 (-2.28)**
Corporate organizations with economically driven attitude	**-0.614 (-2.91)**	–	–
Government organizations with early adopter attitude	-0.058 (-0.31)	–	–
		–	–
Role of Decision-making Hierarchy			
Director	–	–	**0.516 (1.69)**
Fleet manger	–	–	**0.304 (1.02)**
Other managerial level authority	**0.387 (1.69)**	**0.834 (2.62)**	–
Threshold parameter μ_2	**1.000 (15.96)**	**1.047 (12.89)**	**0.984 (9.48)**
Threshold parameter μ_3	**1.187 (17.79)**	**1.215 (14.18)**	**1.218 (10.82)**
No. of Observations	1,008	668	340
McFadden ρ^2	0.14	0.17	0.12
Percent Predicted Right	63%	68%	61%

Table 6-6 Estimated parameters of the Ordered Logit models for vehicular fleets

Variable Description	Car Fleet Organizations	Pickup Truck Fleets Organizations	Utility Vehicle Fleets Organizations
	Coefficient (t-stat)	Coefficient (t-stat)	Coefficient (t-stat)
Constant	**2.500 (7.29)**	**3.660 (5.89)**	**2.255 (7.14)**
Organizations with 6 to 10 employees	**1.535 (2.96)**	—	**1.571 (3.05)**
Organizations with 11 to 25 employees	**0.667 (2.04)**	—	**0.535 (1.64)**
Organizations located in Quebec	—	**-0.614 (-1.87)**	—
Organizations located in Ontario	—	—	**0.428 (1.95)**
All location feature on-site charging infrastructure	**-0.835 (-2.8)**	**-1.093 (-2.46)**	**-1.031 (-3.48)**
Most location feature on-site charging infrastructure	**-0.875 (-2.89)**	**-1.042 (-2.44)**	**-0.913 (-3.00)**
Some location feature on-site charging infrastructure	**-1.204 (-3.7)**	**-1.262 (-3.17)**	**-1.213 (-3.78)**
Only one site used as a base of organization fleet	**0.715 (2.52)**	**0.625 (1.65)**	—
2 site(s) are used as a base of organization fleet	—	—	**-0.722 (-2.34)**
3-5 site(s) are used as a base of organization fleet	—	—	**-0.444 (-1.63)**
5-10 site(s) are used as a base of organization fleet	—	—	**-0.786 (-2.21)**
Fleets providing services	-0.401 (-1.06)	**-0.919 (-1.85)**	—
Fleets delivering goods	–	-0.519 (-1.07)	—
			—
Fleets with replacement cycle of 1 to 7 years	-0.026 (-0.09)	—	—
Fleets with replacement cycle of 7 to 10 years	–	-0.445 (-1.23)	—
Fleets with age between 10-15 years	–	—	0.667 (1.30)
Regulatory imperatives in fleet procurement	-0.631 (-1.38)	**-1.203 (-2.14)**	-0.605 (-1.29)
			—
Fleets acquired in new condition	-0.313 (-0.99)	-0.459 (-1.02)	—
Fleets acquired in used condition	**-1.205 (-2.95)**	-0.68 (-1.32)	—
Fleets acquired through lease	0.286 (1.21)	-0.251 (-0.80)	—
Organizations with compact SUV in their fleets	-0.541 (-1.49)	—	—
Organizations with CNG fleets	—	—	**1.992 (2.62)**

Table 6-6 - continued

Variable Description	**Car Fleet Organizations**	**Pickup Truck Fleets Organizations**	**Utility Vehicle Fleets Organizations**
	Coefficient (t-stat)	Coefficient (t-stat)	Coefficient (t-stat)
Fleet operations are within a site	-0.532 (-1.16)	—	—
Fleet operations are within a city	-0.316 (-1.31)	—	—
Fleet operations are within a province	—	0.032 (0.11)	—
Fleet operations are within a city as well as a province	—	—	0.293 (1.28)
Canada-wide 11-25 employees responsible for vehicle fleets	—	—	**-0.852 (-2.72)**
Canada-wide 51-100 employees responsible for vehicle fleets	—	—	**-0.554 (-1.87)**
Organizations with economically driven attitude	**-0.747 (-3.35)**	-0.266 (-1.03)	—
Corporate organizations with Early adopter attitude	-0.320 (-1.17)	—	**-0.868 (-4.75)**
Corporate organizations with Obligatory attitude	—	**-0.928 (-2.63)**	—
Government organizations with Early adopter attitude	0.197 (0.72)	—	—
Government organizations with Economically driven attitude	—	—	**-0.763 (-2.17)**
Government organizations with Obligatory attitude	—	-0.067 (-0.21)	0.279 (0.74)
Director	**0.653 (2.37)**	—	**0.614 (2.26)**
Other Managerial Level Authority	—	**0.822 (1.85)**	—
Threshold parameter μ_2	**1.168 (11.57)**	**1.029 (8.18)**	**1.178 (11.59)**
Threshold parameter μ_3	**1.335 (12.62)**	**1.377 (9.84)**	**1.345 (12.64)**
No. of Observations	280	302	423
McFadden ρ^2	0.15	0.19	0.15
Percent Predicted Right	64%	68%	65%

6.6 Conclusions

This chapter investigated the determinants of the battery electric vehicle (BEV) acquisition timeframe among Canadian fleet operating entities (FOEs). A number of ordered logit models were estimated based on the two key sectors to which FOEs belong to, and the type of operated fleets. The analysis was based on the revealed portion of the Canadian Fleet Acquisition Survey that collected data from over 1,000 randomly selected corporate and government organizations that owned and operated car, pickup truck and utility vehicle fleets in Canadian cities. The contributions in this chapter are twofold: 1) the conducted analysis explains the behavior governing the acquisition timeframe for BEVs in FOEs, and 2) the work highlights the heterogeneity in the factors affecting the acquisition timeframe of BEVs. To our knowledge, the work in this research is the first of its kind and has never been conducted in the past.

The factors explaining the acquisition timeframe for BEVs included organization's employment size and location, nature of operation (i.e., providing services or delivering goods), operational spatial scale, availability of on-site charging stations, availability of dedicated staff for fleets, regulatory imperatives in fleet procurement, and role of decision-making hierarchy. Another set of factors that affects the acquisition timeframe included attitudes and perceptions of the modeled FOEs towards electric mobility. A third set of factors were related to vehicle fleet characteristics and included replacement cycle, acquisition condition and ownership status, fuel type and vehicle size.

In addressing the research question posed in the introduction section, the achieved findings provide evidence that could help formulate specific policy instruments to entice certain types of FOEs to adopt BEVs in their fleets. For example, policies targeting small

FOEs that use cars or utility vehicles in both government and corporate sectors could lead to early BEV acquisition. Also, policies aimed at subsidizing on-site infrastructure especially for FOEs located in jurisdictions with cleaner electricity generation profile could trigger early acquisition among them. Similarly, policies that provide fiscal subsidies to FOEs that incorporate regulatory imperatives (for example, *going green, sustainable mobility,* and *climate action plan*) in their fleet procurement could also lead to an uptake of BEVs among such entities. Finally, FOEs, especially in the corporate sector, that have economically driven attitude towards fleet electrification can be targeted with policies that further harvest these attitudes. That is, policies aimed at engaging such entities through awareness campaigns and discussions forums to further inform them of the various cost saving benefits of BEVs could lead to a higher share of early fleet electrification. The same could be said about corporate entities that exhibit early adoption or obligatory attitudes towards electric mobility in fleets. Here, future surveys could engage different FOEs to characterize their attitudinal identity with respect to fleet electrification. Furthermore, responses to questions on how EVs can help FOEs reduce their fleet size and/or the kilometers travelled while meeting their operational obligations can provide further understating of the viability and acquisition timeframes of these vehicles.

The research contends that in the absence of a benchmark or true population estimate of the FOEs in Canada, developing a representative sample could be an issue. And, since the costs for panel surveys is quite high ($30 per respondent in our case), a more focused recruitment of FOEs from the key provinces of Ontario, Quebec and British Columbia that have significantly clean energy generation profiles would be beneficial for future analyses on the subject.

6.7 Chapter 6 References

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CHAPTER 7

CONCLUSIONS

7.1 Objectives Achieved

This dissertation investigated the adoption of electric mobility in Canadian fleets. While the feasibility electric vehicles (EVs) among household consumers has been addressed extensively in the literature, there has been a clear lack of knowledge regarding its adoption by fleets. As such, the research conducted in this dissertation filled the knowledge gap by examining the factors and conditions that could deter or support fleet electrification among various corporate and government entities in Canadian jurisdictions. It also investigated the prevailing attitudes and perceptions regarding various aspects of EVs as they relate to its feasibility in Canadian fleets. The following specific objectives were achieved by the work conducted in this dissertation.

7.1.1 Current State of Fleet Operations in Canada

The data needed to achieve the objectives of this dissertation did not exist. A comprehensive online survey titled Canadian Fleet Acquisition Survey (CFAS), which included a stated preference (SP) component as well as an extensive suite of attitudinal statements, was designed to collect data that was subsequently used to fulfil the objectives of this research.

The collected data records, which pertained to over 1,000 Canadian fleet operating entities (FOEs), provided valuable information regarding the current state of fleet operations that did not exist before. The information included fuel type, usage, age and replacement cycles of Canadian car, light truck and utility vehicle fleets (objective 1.2.1). The CFAS also provided valuable information regarding the ownership status and acquisition condition under which FOEs typical procure their fleets. It also provided insights to the planning horizons of the sampled FOEs to acquiring EVs for their fleets.

7.1.2 Underlying Behavioral Constructs Influencing the Acquisition of EVs

The information collected through the CFAS included a Likert based assessment of the prevailing factors, attitudes, perceptions and concerns of the sampled FOEs towards the feasibility of different EV powertrains in fleets. An Exploratory Factor Analysis (EFA) of the responses towards common EV aspects provide evidence of latent constructs in the sampled organizations (objective 1.2.2). *Technological Concerns* and *Monetary Concerns* were identified as the two most dominant constructs accounting for more than 25% of the total variance in the collected responses on the factors that deter EV adoption. On the other hand, latent constructs for the supporting factors, included *Monetary Considerations* and *Non-monetary Considerations*. The former construct was primarily informed by lower maintenance and fuel cost whereas the latter was associated with access to High Occupancy Vehicle (HOV) lanes and availability of free parking.

The EFA model on the attitudes relating to various EV aspects identified four latent constructs of behavior. The two key constructs were *Early Adopter Attitudes* and *Economically Driven Attitudes*. Together, the two groups of constructs accounted for nearly 36% of the total variance in the sampled responses. The FOEs in the *Early Adopter Attitude* construct believe that adopting emerging technologies is not a risky decision and that a fleet of EVs can meet their operational needs, while the FOEs in the *Economically*

Driven Attitude construct have a positive attitude towards the economic benefits of adopting EVs in their fleets.

The variation of attitudes in the corporate and government FOEs towards adopting EVs was investigated by estimating separate EFA models. The four latent factors identified for the deterring factors for both subsamples had high correlations implying that the overall responses to the deterring factors are quite similar between the two types of FOEs. However, slight variation in the response to some of the deterring factors that included electricity/hydro rate, higher insurance rates and operational reliability due to range limitation and longer charging time was also noted.

The EFA analysis on the supporting factors yielded two factors for both sub-samples with near perfect correlation (i.e., 98% for each factor). The high correlation reflects similar attitudes and perceptions towards the factors that support the adoption of EVs in fleets among the sampled corporate and government FOEs. Similar results were obtained for the first three factors of the EFA performed using the responses to the attitudinal statements. Here, the correlations were above 90% implying strong relationship in the attitudes and perceptions of the two sectors towards the various issues affecting the viability of EVs in fleets.

Further EFA was performed for corporate FOEs belonging to *Transportation and Warehousing, and Retail Trade* sectors. These FOEs accounted for 42% of all corporate FOEs. A fair level of a consistency in the responses of the FOEs from the two industries was noted in the estimated EFA models covering the deterring and the supporting factors. However, weaker correlations among the four factors emerging from the EFA of the attitudinal statements reflect variation in attitudes and perceptions towards the various issues affecting the viability of EVs in fleets among the two industries.

Finally, the results of the Analytical Hierarchy Process (AHP) analysis conducted for the full and sub-samples of FOEs demonstrate that the obtained responses for a set of pairwise comparisons on the key factors affecting EV adoption in fleets were logical and consistent. The risk of implementing new technology was perceived with relatively higher importance with an average weighting score of 60%. The results obtained are convergent with the findings of previous studies where risk of implementing a new technology (guinea-pig syndrome) is often regarded as one of the most critical elements in acquisition decisions of any new product.

7.1.3 Investigation of Factors Affecting EV Adoption in Fleets using SP Data

The research used revealed and stated preference data to estimate a latent class (LC) model to investigate factors affecting the acquisition of EVs in Canadian FOEs and thereby accomplished objective 1.2.3 set out in section 1.2 of the first chapter of this dissertation. The estimated LC model identifies four latent classes, namely BEV leaning FOEs, EV curious FOEs, Cost sensitive FOEs, and ICEV oriented FOEs with class probabilities of 15%, 13%, 23% and 49%, respectively. A variety of factors are found to affect the acquisition choice of the four powertrains among the four latent classes. The key takeaways from the conducted analysis are as follows:

- *BEV leaning FOEs* seem to place high value on extended trip range and are found to agree with the notion that adopting EVs will promote their public image.

- Relative to the *ICEV oriented class*, *BEV leaning*, and *EV curious FOEs* agree with the idea that using EVs would be a cost-effective decision.

- *BEV leaning FOEs* are found not to be concerned with trip range anxiety but concur with the idea that a fleet of EVs can meet their operational demands.

- Corporate FOEs relative to their governmental counterparts, in both *EV curious* and *cost sensitive* classes, are found to be more concerned with operating cost than any other cost.

- The high potential of EV adoption in Canadian FOEs requires the formulation of adequate policy instruments geared towards investing in public charging infrastructure, incentivising FOEs with on-site charging infrastructure, engaging FOEs in climate action plan, and launching awareness campaigns to highlight the cost-effectiveness of EVs.

7.1.4 Determinants of BEV Acquisition Timeframe

This dissertation is first of its kind to investigate the determinants of the battery electric vehicle (BEV) acquisition timeframe for FOEs in Canadian corporate and government. The results from the estimated ordered logit models, presented in Chapter 6 (section 6.5) accomplish objective 1.2.4 of this research. The results indicate that government organizations, all else being equal, are likely to acquire BEVs under longer acquisition timeframes. Smaller corporate organizations, and corporate organizations with only one fleet site as base are also found to follow the same trend. Also, corporate FOEs from Quebec, in general, have a higher tendency for acquiring BEVs under relatively shorter timeframes.

FOEs in both corporate and government sectors, with on-site charging infrastructure at most locations are likely to acquire BEVs in short periods of time. A higher propensity is noted for fleets operated by government organizations as oppose to corporate organizations. Regulatory imperatives in fleet procurement seems to influence BEV acquisition strategy positively with FOEs belonging to the government showing a higher propensity for early BEVs adoption. This implies that imperatives such as 'going green', 'made in Canada' stemming from enforcement of sustainable mobility and climate action plans could lead to the early adoption of the BEVs in Canadian fleets.

FOEs with economically driven attitude are noted to acquire BEVs for their car fleets under a shorter timeframe. Corporate FOEs with an early adopter attitude have a higher tendency of a shorter BEV acquisition timeframe for their utility vehicles fleets. Similarly, a shorter BEV acquisition timeframe for pickup truck fleets is associated with corporate FOEs with obligatory attitude. Interestingly, government FOEs with economically driven attitude are the only FOEs in this attitudinal category to show a higher propensity of shorter BEV acquisition timeframe for their utility vehicles.

7.2 Policy Guidelines

Informed by the findings from the conducted research, a set of policy guidelines is proposed below, thereby accomplishing objective 1.2.5 of this dissertation.

7.2.1 Investment in Public Charging Infrastructure

The results from the LC model suggest that the *BEV leaning FOEs* tend to be more concerned with the availability of public charging infrastructure. With a rather significant class probability of 15% for this group of FOEs, policy instrument geared towards the expansion of public charging infrastructure especially in areas with cleaner electricity generation profile could entice EV acquisition among these entities.

7.2.2 Incentivising On-site Charging Infrastructure

The availability of on-site charging infrastructure is seen as a significant barrier affecting the acquisition of EVs in fleets. About 19% of all sampled FOEs in the CFAS indicated that they have some form of the charging infrastructure at their fleet locations. Both *BEV leaning* and *Cost sensitive FOEs* are willing to invest in additional on-site infrastructure. The implications are obvious for the former class. However, the attitudes displayed by the latter class could be tied to their belief about replacing foreign oil with made in Canada electricity. Hence, policies geared towards incentivising FOEs to build on-site charging infrastructure could accelerate EV adoption in Canadian fleet markets.

7.2.3 Incentivize FOEs with Climate Action Plan

With the increased interest in reducing greenhouse gas emissions to combat climate change, many mega organizations have been moving towards adopting low carbon technologies in recent years. Organizations with climate action plan and access to renewable energy recourses could be potential adopters as EVs represent strong environmental appeal (Lemme et al. 2019). While *BEV leaning FOEs* demonstrated concerns about their social responsibility and image in the public domain, this was not the case for *EV curious FOEs*. Therefore, incentives will be needed to change the mindset of the latter FOEs and encourage them to move towards fleet electrification in the near future.

7.2.4 Harvesting Positive Attitudes Towards Fleet Electrifications

Cost-effectiveness of any new technology is always a hugely debated issue, and there are no exceptions to that when it comes to the acquisition of EVs in fleets. In line with past studies, we observed differences among the four latent classes of the modeled FOEs towards their evaluation of this issue. The variation could be partly due to the inherent belief that the EV technology is not matured enough to qualify as cost-effective (Seitz et al. 2015). Interestingly, while *EV curious* FOEs perceive EVs as cost-effective they tend to be less willing to spend more money to adopt them in the near future. This implies that these FOEs require more information to steer them from being curious to becoming highly interested. To that end, campaigns from various government platform to highlight the maturity and cost-effectiveness of EVs along with their potential cost saving can help achieve such goal. Further, FOEs in the corporate sector, that have economically driven attitude towards fleet electrification can be targeted with policies that further harvest these attitudes. That is, policies aimed at engaging such entities through discussions forums to further inform them of the various cost saving benefits of BEVs could lead to a higher share of early fleet electrification. The same could be said about corporate entities that exhibit early adoption or obligatory attitudes towards electric mobility in fleets. Here, future surveys could engage different FOEs to characterize their attitudinal identity with respect to fleet electrification.

7.3 Scholarly Contributions

The research developed a robust online survey to collect valuable data from over 1,000 randomly selected fleet operating entities (FOEs), Canada wide. The data included revealed and stated preferences of these FOEs as they relate to their existing fleets as well as to the prospects of EV adoption and fleet electrification. The collected data also included an extensive suite of attitudinal statements relating to various aspects of EVs. The detailed micro information (including FOEs general characteristics such as geographical location, details of existing fleets, and Likert based assessment of EV prospects) did not previously exist.

The dissertation by virtue of achieving its objectives provides the following scholarly contributions to the transportation literature on EVs and fleet electrification:

a) *Better understanding of the Canadian fleet operations in general including usage and replacement cycles of existing car, light truck and utility vehicle fleets.*

b) *Evaluation of prospects of EV adoption for use in fleet operation in Canada.*

c) *Evaluation of prevailing attitudes, perceptions and concerns of Canadian fleet operators regarding EV powertrains.*

d) *Identification of underlying factors influencing acquisition of EVs with willingness-to-pay measures.*

e) *Identification of conditions needed for an early EV adoption in Canadian fleet.*

f) *Identification of appropriate modelling techniques and methods to investigate relationships and latent constructs in stated preference and attitudinal data.*

7.4 Research Limitations

A key limitation of the research is rooted in the extent of its coverage of different fleet types, both in terms of organization type and vehicle type. More specifically, the research investigated the adoption of EVs in three different fleet vehicles types namely: car fleets, pickup truck fleets and utility vehicles fleets. For perspective respondents, the research casted a wider net and sampled for two main types of organizations namely corporate and government fleets. This added to the complexity of the survey design. Subsequently, the stated preference component of the survey had to be designed to cater nine different vehicle classes, with three classes each for three different fleet vehicles types. In the end, the budgetary constraints restricted the final sample size to a set of 1,000 randomly selected fleet operating entities as the cost per observation turned out to be significantly higher than what was anticipated.

With the benefit of hindsight, a better approach would have been to just focus on a specific fleet type, preferably utility vehicles fleets as these types of fleets are the most common on roads. With larger and more focused sample size, the estimated models are likely to yield more stable willingness-to-pay estimates that could be used in the simulation of EV adoption scenarios through a sensitivity analysis. Despite the sample size limitation, the work presented in the dissertation is the first of its kind to analyze the conditions that could lead to fleet electrification in Canada.

The various analyses conducted in this dissertation focused on the tail-pipe emissions of EVs which in the case of BEVs are zero. However, the manufacturing of EVs has consequential greenhouse gas emissions externalities which must be considered while assessing the environmental benefits of EVs. This involves all aspects of the EV emissions, from the manufacturing process of the vehicle, its usage once produced and its recycling once it becomes unusable. Emissions from the manufacturing process entails the production of the different parts of the vehicle as well as the batteries that are used to power them. In a broader sense, for global greenhouse gas reductions, the entire lifecycle of vehicles would need to be accounted for. Additional factors that could affect the positive environmental benefits of EVs include energy generation profile, driving conditions and charging patterns (Requia et al. 2018). However, in our research we focused only on tailpipe emissions by specifying a 100% reduction for BEVs as it was imperative for the participating fleet operating organizations to fully understand the core of the BEV proposition.

7.5 Future Research

The global Electric Vehicle (EV) market has seen sharp uptake in recent years, and it is expected to grow even faster in the coming years. It reached a total stock of 5.1 million in 2018, a growth of about 67% from the previous year (IEA, 2019). Technological advancements in the battery component have improved EV trip range and operational reliability and are fuelling this growth.

EVs accounted for only 1.0 % in the Canadian car fleets and a miniscule 0.8% in the light truck fleets as reported in the 2018 national registrations (CAF, 2019). Such minimal market shares of EVs provided the motivation for this research to explore and investigate the factors responsible for the status quo shares and those that could potentially accelerate the adoption of EVs in the Canadian fleets. The seminal effort made in this research sought and successfully managed to bridge the knowledge gap regarding the broader picture of fleet operations and the prospects of EV adoptions in Canadian corporate and government fleets. However, in order to fully assess the feasibility of electric mobility in Canadian fleets in present day cost-competitive yet environmental conscious environment, more data collection efforts are needed. As mentioned earlier, focusing on one type of vehicle fleets and increasing the sample size for a specific industry especially within the corporate sector could prove to be beneficial. Also collecting information about the life cycle costs of EVs are needed. Further, future surveys could engage different fleet operating entities (FOEs) to characterize their attitudinal identity with respect to fleet electrification.

7.6 Chapter 7 References

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APPENDIX A – Canadian Fleet Acquisition Survey (CFAS) Forms

University of Windsor

Social Sciences and Humanities Research Council of Canada

McMaster University

Fleet Acquisition Survey

Dear Participant,

This survey is a significant component of a five year research project funded by the *Social Science and Humanities Research Council of Canada* (SSHRC) to evaluate the future of Electric Mobility in Canada. The project is being led by McMaster Institute for Transportation and Logistics (MITL) in partnership with University of Windsor, Ford Motor Company of Canada, Ontario Ministry of Transportation, Canadian Automobile Association, Electric Mobility Canada, and Burlington Hydro.

This survey is directed at professionals who make, or influence, decisions related to acquisition of their organization's fleet vehicles. The survey consists of the following sections:

1. **Existing Fleet Characteristics**
2. **Fleet Acquisition Choice**
3. **Stated Preference Scenarios**
4. **Electric Vehicle Fleet Prospects**
5. **Organization General Characteristics**
6. **Attitudinal Statements**

The survey requires approximately 15-20 minutes to complete. Before completing the survey, please note the following:

The survey does not collect any specific identifiable information such as name and exact location of your organization. All information provided will be kept strictly confidential and will be used for academic research only. Your participation in this survey is voluntary. For further details, please read the **Letter of Information for Consent to Participate in Research**.

Please click here to complete the survey

Sincerely,

Dr. H. Maoh
Associate Professor
Department of Civil and Environmental Engineering
University of Windsor

University of Windsor

Social Sciences and Humanities Research Council of Canada

McMaster University

Fleet Acquisition Survey

◯ This is the first time I am attempting the survey

◯ I have the access code that I saved from my previous attempt

Start Survey

Note: During the survey please do not use the Next/Previous buttons of your web browsers, instead use the buttons provided at the end of each survey form.

University of Windsor

Social Sciences and Humanities Research Council of Canada

McMaster University

Fleet Acquisition Survey

Record the access code shown in red below if you wish to complete the survey at a later time. You will be able to resume from where you left.
Your access code is: Q7D2L8V7

0%

Screening Questions

1. Is it part of your job to influence or make decisions about the acquisition of vehicles for your organization? ○ Yes ○ No
2. Does your organization operate some combination of at least 5 vehicles that are a good match for one or more of the pictured vehicle types? ○ Yes ○ No

Cancel Next >>

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Record the access code shown in red below if you wish to complete the survey at a later time. You will be able to resume from where you left.
Your access code is: Q7D2L8V7

6%

Screening Questions

1. Select the type of organization you represent
   - For-profit firm
   - Non-profit organization
   - University/college
   - Municipal
   - Provincial
   - Federal

2. Choose the best fitting job title for your role in your organization
   - Chief Executive Officer (CEO)
   - President
   - Chief Administrative Officer (CAO)
   - Chief Financial Officer (CFO)
   - Director
   - Fleet Manager
   - Fleet Supervisor
   - Other Manager
   - Elected Official
   - Other, specify

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Your access code is: Q7D2L8V7

12%

1. Existing Fleet Characteristics

Provide the composition of your vehicle fleet considering only the vehicles over which you have influence

0 Cars

0 Pickup Trucks

0 Vans/Light Trucks/Utility

Cancel << Previous Next >>

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20%

1.1 Existing Car Fleet Characteristics

1. Select the vehicle class and fuel type that is most dominant in your fleet of 5 Cars

Vehicle Class **Fuel Type**

2. Select the acquisition condition of your existing Car fleet — New / Used / Mixed
3. Select the ownership status of your existing Car fleet — Leased / Rented / Purchased / Mixed
4. How important are the following uses for your Car fleet (select and quantify all that apply)?
   - Transporting Employees 1 %
   - Providing Services 1 %
   - Delivering Goods 1 %
5. Select the best option that describes the typical geography of your Car fleet operations
   - Within a Site (for example, University Campus) / Within a City / Within a Province / Between Provinces
6. Indicate the average annual mileage of your existing Car fleet — Please Choose:
7. Choose the replacement cycle of your existing Car fleet — Please Choose:
8. Indicate the average age of your existing Car fleet — Please Choose:

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Fleet Acquisition Survey

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25%

1.2 Existing Pickup Truck Fleet Characteristics

1. Select the vehicle class and fuel type that is most dominant in your fleet of 10 Pickup Trucks

Vehicle Class | **Fuel Type**

2. Select the acquisition condition of your existing Pickup Truck fleet — New / Used / Mixed
3. Select the ownership status of your existing Pickup Truck fleet — Leased / Rented / Purchased / Mixed
4. How important are the following uses for your Pickup Truck fleet (select and quantify all that apply)?
   - Transporting Employees 1 %
   - Providing Services 1 %
   - Delivering Goods 1 %
5. Select the best option that describes the typical geography of your Pickup Truck fleet operations
   - Within a Site (for example, University Campus) / Within a City / Within a Province / Between Provinces
6. Indicate the average annual mileage of your existing Pickup Truck fleet — Please Choose:
7. Choose the replacement cycle of your existing Pickup Truck fleet — Please Choose:
8. Indicate the average age of your existing Pickup Truck fleet — Please Choose:

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Record the access code shown in red below if you wish to complete the survey at a later time. You will be able to resume from where you left.
Your access code is: Q7D2L8V7

30%

1.3 Existing Vans/Light Trucks/Utility Fleet Characteristics

1. Select the vehicle class and fuel type that is <u>most dominant</u> in your fleet of 15 Vans/Light Trucks/Utility Vehicles

Vehicle Class	Fuel Type

2. Select the <u>acquisition condition</u> of your existing Vans/Light Trucks/Utility Vehicle fleet ○ New ○ Used ○ Mixed

3. Select the <u>ownership status</u> of your existing Vans/Light Trucks/Utility Vehicle fleet ○ Leased ○ Rented ○ Purchased ○ Mixed

4. How <u>important</u> are the following uses for your Vans/Light Trucks/Utility Vehicle fleet (select and quantify all that apply)?
   - ☐ Transporting Employees 1 %
   - ☐ Providing Services 1 %
   - ☐ Delivering Goods 1 %

5. Select the <u>best option</u> that describes the typical geography of your Vans/Light Trucks/Utility fleet operations
   ○ Within a Site (for example, University Campus) ○ Within a City ○ Within a Province ○ Between Provinces

6. Indicate the average <u>annual mileage</u> of your existing Vans/Light Trucks/Utility Vehicle fleet Please Choose:

7. Choose the <u>replacement cycle</u> of your existing Vans/Light Trucks/Utility Vehicle fleet Please Choose:

8. Indicate the <u>average age</u> of your existing Vans/Light Trucks/Utility Vehicle fleet Please Choose:

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30%

2. Fleet Acquisition Choice

Here you will be asked to make a very important vehicle selection which will affect the next major section of the survey. <u>Please make this decision very carefully.</u> Of the nine vehicles on display below, choose the one that would most likely be acquired or be most prominent for your organization's next fleet renewal purchase.

CARS

○ Compact Sedan (e.g. Ford Fiesta)

○ Intermediate Sedan (e.g. Ford Focus)

○ Full Sedan (e.g. Ford Fusion)

PICKUP TRUCKS

○ Small Pickup (e.g. Ford Ranger)

○ Intermediate Pickup (e.g. Ford F-150)

○ Large Pickup (e.g. Ford Super Duty)

VANS/LIGHT TRUCKS/UTILITY

○ Utility Van

○ Bucket Truck

○ Large Walk-in Truck

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Your access code is: Q7D2L8V7

35%

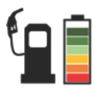
3. Stated Preference Scenarios

This section is based on 6 separate choice scenarios that will be presented to you one at a time. Please carefully review the instructions below.

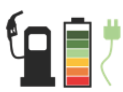
1. Each scenario will feature 4 different powertrains and associated attributes.
2. After evaluating each vehicle powertrain based on its attributes and features, choose a vehicle powertrain that you would most likely acquire.
3. You can click on ⓘ icon to obtain detailed description on any vehicle attribute.

The following describes the available powertrain options for each scenario:

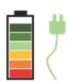
Internal Combustion Engine Vehicles (ICEs) - are the most common type of vehicles. They are usually powered by gasoline or diesel fuel.



Hybrid Electric Vehicles (HEVs) - are more fuel-efficient than ICEs, 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. An example of HEV is the Toyota Prius.



Plug-in Hybrid Electric Vehicles (PHEVs) - run on both battery and gasoline/diesel. The battery allows short range travel without emissions, while the conventional engine could be used for longer distance traveling. Chevrolet Volt is an example of PHEV.



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. An example of BEV is the Tesla Model S.

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40%

Scenario 1 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$38,500	$46,900	$50,300
Annual Maintenance Cost ($)	$1,300	$650	$260	$200
Annual Fueling/Charging Cost ($)	$5,000	$4,000	$3,250	$2,000
Incentives				
Government Cash Incentive ($)	None	None	$10,000	$12,000
Other Monetary Incentives	None	None	No Annual Registration Fee	No Sales Tax on Purchase Price
Non-monetary Incentives	None	None	Free Charging Station Installation	Access to Bus and HOV Lanes
Performance				
Range per Refuel/Recharge (km)	400	500	600	400
Annual Depreciation Cost ($)	$3,300	$3,630	$3,630	$3,470
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	6 Years / 120,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	20% Reduction	60% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	7 mins	7 mins	30 mins	1 hr
Number of Public Fueling/Charging Stations in a Typical 5km Radius	2	5	3	5
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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Fleet Acquisition Survey

Record the access code shown in red below if you wish to complete the survey at a later time. You will be able to resume from where you left.
Your access code is: Q7D2L8V7

45%

Scenario 2 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$40,200	$46,900	$46,900
Annual Maintenance Cost ($)	$1,300	$1,040	$390	$330
Annual Fueling/Charging Cost ($)	$5,000	$3,000	$2,750	$2,000
Incentives				
Government Cash Incentive ($)	None	None	$10,000	$12,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Municipal Parking	Free Charging Station Installation
Performance				
Range per Refuel/Recharge (km)	300	500	500	500
Annual Depreciation Cost ($)	$3,300	$3,550	$3,550	$3,300
Extended Battery Warranty	N/A	N/A	6 Years / 120,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	30% Reduction	60% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	5 mins	5 mins	2 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	5	5	3	1
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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Fleet Acquisition Survey

Record the access code shown in red below if you wish to complete the survey at a later time. You will be able to resume from where you left.
Your access code is: Q7D2L8V7

50%

Scenario 3 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$38,500	$50,300	$43,600
Annual Maintenance Cost ($)	$1,300	$1,040	$260	$590
Annual Fueling/Charging Cost ($)	$5,000	$4,500	$1,750	$1,500
Incentives				
Government Cash Incentive ($)	None	None	$12,000	$10,000
Other Monetary Incentives	None	None	No Sales Tax on Purchase Price	Manufacturer's Rebate
Non-monetary Incentives	None	None	Access to Bus and HOV Lanes	Free Municipal Parking
Performance				
Range per Refuel/Recharge (km)	500	500	400	400
Annual Depreciation Cost ($)	$3,300	$3,300	$3,470	$3,550
Extended Battery Warranty	N/A	N/A	8 Years / 150,000 km	5 Years / 100,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	40% Reduction	50% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	10 mins	5 mins	2 hrs	30 mins
Number of Public Fueling/Charging Stations in a Typical 5km Radius	2	1	1	3
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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55%

Scenario 4 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$36,900	$43,600	$40,200
Annual Maintenance Cost ($)	$1,300	$780	$390	$590
Annual Fueling/Charging Cost ($)	$5,000	$4,500	$2,750	$1,500
Incentives				
Government Cash Incentive ($)	None	None	$11,000	$9,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Municipal Parking	Free Charging Station Installation
Performance				
Range per Refuel/Recharge (km)	500	700	500	200
Annual Depreciation Cost ($)	$3,300	$3,550	$3,470	$3,470
Extended Battery Warranty	N/A	N/A	6 Years / 120,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	40% Reduction	60% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	3 mins	5 mins	30 mins	1 hr
Number of Public Fueling/Charging Stations in a Typical 5km Radius	2	2	1	0
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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60%

Scenario 5 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$35,200	$40,200	$46,900
Annual Maintenance Cost ($)	$1,300	$1,040	$650	$330
Annual Fueling/Charging Cost ($)	$5,000	$3,000	$1,750	$2,000
Incentives				
Government Cash Incentive ($)	None	None	$12,000	$11,000
Other Monetary Incentives	None	None	No Sales Tax on Purchase Price	Manufacturer's Rebate
Non-monetary Incentives	None	None	Access to Bus and HOV Lanes	Free Municipal Parking
Performance				
Range per Refuel/Recharge (km)	400	600	600	400
Annual Depreciation Cost ($)	$3,300	$3,470	$3,630	$3,300
Extended Battery Warranty	N/A	N/A	8 Years / 150,000 km	5 Years / 100,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	30% Reduction	50% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	3 mins	7 mins	10 mins	1 hr
Number of Public Fueling/Charging Stations in a Typical 5km Radius	2	2	5	1
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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65%

Scenario 6 of 6

Utility Van Attributes	ICE	HEV	PHEV	BEV
COST				
Purchase Price ($)	$33,500	$38,500	$43,600	$40,200
Annual Maintenance Cost ($)	$1,300	$650	$650	$590
Annual Fueling/Charging Cost ($)	$5,000	$4,000	$1,750	$1,250
Incentives				
Government Cash Incentive ($)	None	None	$12,000	$10,000
Other Monetary Incentives	None	None	No Annual Registration Fee	No Sales Tax on Purchase Price
Non-monetary Incentives	None	None	Free Charging Station Installation	Access to Bus and HOV Lanes
Performance				
Range per Refuel/Recharge (km)	300	700	400	400
Annual Depreciation Cost ($)	$3,300	$3,470	$3,470	$3,470
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	6 Years / 120,000 km
Reduction in Tailpipe Emissions (%)	No Reduction	10% Reduction	80% Reduction	100% Reduction
Fueling/Charging Time and Infrastructure				
Refueling/Recharging Time	5 mins	7 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	1	1
Please choose the option that your organization would most likely acquire for its fleet of vehicles.	○	○	○	○

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70%

4. Electric Vehicle Fleet Prospects

1. Does your organization have any regulatory imperatives or policies (internal or external) in fleet procurement (for example 'Made in Canada')?
   - No
   - Yes, please describe briefly

2. Do you plan to purchase Battery Electric Vehicles (BEVs) for your fleet?
   - No
   - Yes

Time Frame	In the next 2 years	In the next 5 years	In the next 7 years	Not sure when
Condition	New	Used	Mixed	Not sure
Acquisition Strategy	Lease	Purchase	Rent	Not sure

3. Do you plan to purchase Plug-in Hybrid Electric Vehicles (PHEVs) for your fleet?
   - No
   - Yes

Time Frame	In the next 2 years	In the next 5 years	In the next 7 years	Not sure when
Condition	New	Used	Mixed	Not sure
Acquisition Strategy	Lease	Purchase	Rent	Not sure

4. For the specific vehicle type (Utility Van) used in the just completed six scenarios how many vehicles of this type would you expect to acquire in the next years

   0

5. For the 3 major vehicle categories that have been used in this survey, quantify the number of vehicles by category that are likely to be acquired for your fleet in the next years

   Cars 0 Pickup Trucks 0 Vans/Light Trucks/Utility 0

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75%

5. Organization General Characteristics

1. Please choose the type of industry which best characterizes your organization — Please Choose:
2. Please provide 3 digits postal code of your office location
3. Please indicate the approximate total number of Canada-based employees in your organization — Please Choose:
4. How many Canada-wide sites/locations are used as a base for your fleet? — Please Choose:
5. Please indicate the total number of employees at your current location whose daily responsibilities are related to the vehicle fleet — Please Choose:
6. Please indicate the total number of employees Canada-wide whose daily responsibilities are related to the vehicle fleet — Please Choose:
7. Please indicate the availability of on-site charging infrastructure at your fleet locations — Please Choose:

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80%

6.1 Attitudinal Statements

a. **How important are the following in deterring the acquisition of plug-in electric vehicles (BEV or PHEV) for your fleet**

	1 Not at all Important	2	3	4 Moderately Important	5	6	7 Extremely Important
Capital cost	○	○	○	○	○	○	○
Battery Replacement cost	○	○	○	○	○	○	○
Cost of human resources (i.e. mechanics)	○	○	○	○	○	○	○
Charging Infrastructure cost (i.e. chargers, garage upgrade, etc.)	○	○	○	○	○	○	○
Electricity (Hydro) rates	○	○	○	○	○	○	○
Higher insurance rates	○	○	○	○	○	○	○
Operational reliability due to range limitation and longer charging time	○	○	○	○	○	○	○
Integration with current fleet	○	○	○	○	○	○	○
Cold/Hot weather impacts	○	○	○	○	○	○	○
Concerns on the maturity of electric vehicle technology	○	○	○	○	○	○	○
"Technology Anxiety" and fear of obsolescence	○	○	○	○	○	○	○
High risk of being an early adopter of new technologies	○	○	○	○	○	○	○

b. **How important are the following in supporting the acquisition of plug-in electric vehicles (BEV or PHEV) for your fleet**

	1 Not at all Important	2	3	4 Moderately Important	5	6	7 Extremely Important
Reduced fuel cost	○	○	○	○	○	○	○
Lower maintenance cost	○	○	○	○	○	○	○
Monetary incentives including municipal & provincial financial support	○	○	○	○	○	○	○
Access to HOV lanes	○	○	○	○	○	○	○
Availability of free parking	○	○	○	○	○	○	○
Availability of public charging stations	○	○	○	○	○	○	○

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85%

6.2 Attitudinal Statements

Rate your level of agreement with each of the following statements

	1 Strongly Disagree	2	3	4 Neutral	5	6	7 Strongly Agree
Our organization thinks that operating Plug-in Electric vehicles (BEV or PHEV) will help replace foreign-oil with made in Canada electricity	○	○	○	○	○	○	○
Our organization is confident that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a cost-effective decision	○	○	○	○	○	○	○
Our organization is willing to spend more money to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet in the near future	○	○	○	○	○	○	○
Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is a prudent decision	○	○	○	○	○	○	○
The decision to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet will promote our image, it is a good decision	○	○	○	○	○	○	○
Our organization has the technical capabilities (i.e. specialized mechanics) to operate a fleet of Plug-in Electric vehicles (BEV or PHEV)	○	○	○	○	○	○	○
Our organization is confident that a fleet of Plug-in Electric vehicles (BEV or PHEV) will meet our operational demands	○	○	○	○	○	○	○
Our organization thinks that using Plug-in Electric vehicles (BEV or PHEV) in our fleet is not a risky decision	○	○	○	○	○	○	○
Following the emerging trend in the industry, we feel pressure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet	○	○	○	○	○	○	○
Our organization is willing to install additional infrastructure to adopt Plug-in Electric vehicles (BEV or PHEV) in our fleet	○	○	○	○	○	○	○
Our organization feels socially obliged to use Plug-in Electric vehicles (BEV or PHEV) to support environmental causes	○	○	○	○	○	○	○

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90%

6.3 Attitudinal Statements

In each statement below, how important is the second underlined aspect relative to the first underlined aspect?

	1 Not at all Important	2	3	4 Equally Important	5	6	7 Extremely Important
Relative to its environmental benefits, the total cost of ownership of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○
Relative to its operational feasibility, the total cost of ownership of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○
Relative to the risk of implementing new technology, the total cost of ownership of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○
Relative to its operational feasibility, the environmental benefit of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○
Relative to the risk of implementing new technology, the environmental benefit of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○
Relative to the risk of implementing new technology, the operational feasibility of Plug-in Electric vehicles (BEV or PHEV) is:	○	○	○	○	○	○	○

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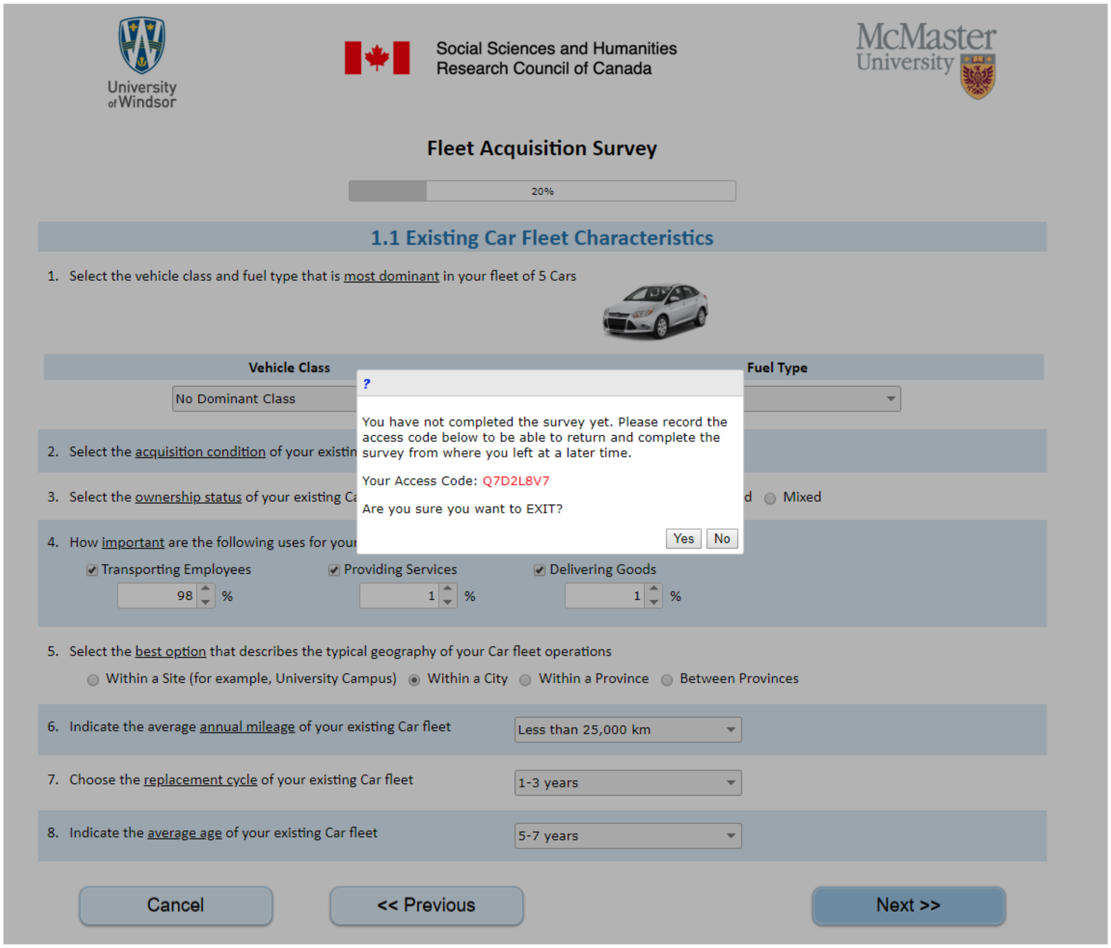

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20%

1.1 Existing Car Fleet Characteristics

1. Select the vehicle class and fuel type that is most dominant in your fleet of 5 Cars

Vehicle Class	Fuel Type
No Dominant Class	

?

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Are you sure you want to EXIT?

Yes No

2. Select the acquisition condition of your existin

3. Select the ownership status of your existing Ca d Mixed

4. How important are the following uses for your

- [x] Transporting Employees 98 %
- [x] Providing Services 1 %
- [x] Delivering Goods 1 %

5. Select the best option that describes the typical geography of your Car fleet operations

- ○ Within a Site (for example, University Campus)
- ● Within a City
- ○ Within a Province
- ○ Between Provinces

6. Indicate the average annual mileage of your existing Car fleet: Less than 25,000 km

7. Choose the replacement cycle of your existing Car fleet: 1-3 years

8. Indicate the average age of your existing Car fleet: 5-7 years

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95%

Congratulations!
You have successfully completed the survey. Your help is highly appreciated.

Best regards,
Survey Team

Please use the space below to provide any additional comments.

Contact Information

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APPENDIX B – Attributes and Values used in the Stated Preference Design

Base Value Table for SP Design

Vehicle Class	Purchase Price	Maintenance Cost	Fuel Cost	Life Cycle (Years)	Total Depreciation Rate	Average Depreciation Cost
Compact	$17,000	$1,000	$2,000	3	47%	$2,650
Intermediate	$21,500	$1,100	$2,500	3	47%	$3,350
Full-size	$28,000	$1,150	$3,000	3	47%	$4,400
Small Pickup Truck	$24,000	$1,250	$4,200	5	63%	$3,000
Medium Pickup Truck	$36,500	$1,350	$5,500	5	63%	$4,600
Large Pickup Truck	$41,000	$1,450	$6,800	8	79%	$4,050
Utility Van	$33,500	$1,300	$5,000	8	79%	$3,300
Bucket Truck	$111,000	$2,000	$7,500	10	86%	$9,550
Walk-in Truck	$66,000	$1,500	$8,100	8	79%	$6,500

Compact Sedan				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 17,000	$ 20,400	$ 25,500	$ 25,500
		$ 19,600	$ 23,800	$ 23,800
		$ 18,700	$ 22,100	$ 22,100
		$ 17,900	$ 20,400	$ 20,400
Annual Maintenance Cost ($)	$ 1,000	$ 800	$ 500	$ 450
		$ 700	$ 400	$ 350
		$ 600	$ 300	$ 250
		$ 500	$ 200	$ 150
Annual Fueling/Charging Cost ($)	$ 2,000	$ 1,800	$ 1,300	$ 800
		$ 1,600	$ 1,100	$ 700
		$ 1,400	$ 900	$ 600
		$ 1,200	$ 700	$ 500
Government Cash Incentive ($)	None	None	$ 3,000	$ 3,000
			$ 4,000	$ 4,000
			$ 5,000	$ 5,000
			$ 6,000	$ 6,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 2,650	$ 2,920	$ 2,920	$ 2,920
		$ 2,850	$ 2,850	$ 2,850
		$ 2,780	$ 2,780	$ 2,780
		$ 2,650	$ 2,650	$ 2,650
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Intermediate Sedan				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 21,500	$ 25,800	$ 32,300	$ 32,300
		$ 24,700	$ 30,100	$ 30,100
		$ 23,700	$ 28,000	$ 28,000
		$ 22,600	$ 25,800	$ 25,800
Annual Maintenance Cost ($)	$ 1,100	$ 880	$ 550	$ 500
		$ 770	$ 440	$ 390
		$ 660	$ 330	$ 280
		$ 550	$ 220	$ 170
Annual Fueling/Charging Cost ($)	$ 2,500	$ 2,250	$ 1,630	$ 1,000
		$ 2,000	$ 1,380	$ 880
		$ 1,750	$ 1,130	$ 750
		$ 1,500	$ 880	$ 630
Government Cash Incentive ($)	None	None	$ 6,000	$ 6,000
			$ 7,000	$ 7,000
			$ 8,000	$ 8,000
			$ 9,000	$ 9,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 3,350	$ 3,690	$ 3,690	$ 3,690
		$ 3,600	$ 3,600	$ 3,600
		$ 3,520	$ 3,520	$ 3,520
		$ 3,350	$ 3,350	$ 3,350
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Full-size Sedan				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 28,000	$ 33,600	$ 42,000	$ 42,000
		$ 32,200	$ 39,200	$ 39,200
		$ 30,800	$ 36,400	$ 36,400
		$ 29,400	$ 33,600	$ 33,600
Annual Maintenance Cost ($)	$ 1,150	$ 920	$ 580	$ 520
		$ 810	$ 460	$ 400
		$ 690	$ 350	$ 290
		$ 580	$ 230	$ 170
Annual Fueling/Charging Cost ($)	$ 3,000	$ 2,700	$ 1,950	$ 1,200
		$ 2,400	$ 1,650	$ 1,050
		$ 2,100	$ 1,350	$ 900
		$ 1,800	$ 1,050	$ 750
Government Cash Incentive ($)	None	None	$ 9,000	$ 9,000
			$ 10,000	$ 10,000
			$ 11,000	$ 11,000
			$ 12,000	$ 12,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 4,400	$ 4,840	$ 4,840	$ 4,840
		$ 4,730	$ 4,730	$ 4,730
		$ 4,620	$ 4,620	$ 4,620
		$ 4,400	$ 4,400	$ 4,400
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Small Truck				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 24,000	$ 28,800	$ 36,000	$ 36,000
		$ 27,600	$ 33,600	$ 33,600
		$ 26,400	$ 31,200	$ 31,200
		$ 25,200	$ 28,800	$ 28,800
Annual Maintenance Cost ($)	$ 1,250	$ 1,000	$ 630	$ 560
		$ 880	$ 500	$ 440
		$ 750	$ 380	$ 310
		$ 630	$ 250	$ 190
Annual Fueling/Charging Cost ($)	$ 4,200	$ 3,780	$ 2,730	$ 1,680
		$ 3,360	$ 2,310	$ 1,470
		$ 2,940	$ 1,890	$ 1,260
		$ 2,520	$ 1,470	$ 1,050
Government Cash Incentive ($)	None	None	$ 6,000	$ 6,000
			$ 7,000	$ 7,000
			$ 8,000	$ 8,000
			$ 9,000	$ 9,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 3,000	$ 3,300	$ 3,300	$ 3,300
		$ 3,230	$ 3,230	$ 3,230
		$ 3,150	$ 3,150	$ 3,150
		$ 3,000	$ 3,000	$ 3,000
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Medium Truck

Attribute	ICEV (BASE)	HEV	PHEV	BEV
Purchase Price ($)	$ 36,500	$ 43,800	$ 54,800	$ 54,800
		$ 42,000	$ 51,100	$ 51,100
		$ 40,200	$ 47,500	$ 47,500
		$ 38,300	$ 43,800	$ 43,800
Annual Maintenance Cost ($)	$ 1,350	$ 1,080	$ 680	$ 610
		$ 950	$ 540	$ 470
		$ 810	$ 410	$ 340
		$ 680	$ 270	$ 200
Annual Fueling/Charging Cost ($)	$ 5,500	$ 4,950	$ 3,580	$ 2,200
		$ 4,400	$ 3,030	$ 1,930
		$ 3,850	$ 2,480	$ 1,650
		$ 3,300	$ 1,930	$ 1,380
Government Cash Incentive ($)	None	None	$ 9,000	$ 9,000
			$ 10,000	$ 10,000
			$ 11,000	$ 11,000
			$ 12,000	$ 12,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 4,600	$ 5,060	$ 5,060	$ 5,060
		$ 4,950	$ 4,950	$ 4,950
		$ 4,830	$ 4,830	$ 4,830
		$ 4,600	$ 4,600	$ 4,600
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Large Truck				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 41,000	$ 49,200	$ 61,500	$ 61,500
		$ 47,200	$ 57,400	$ 57,400
		$ 45,100	$ 53,300	$ 53,300
		$ 43,100	$ 49,200	$ 49,200
Annual Maintenance Cost ($)	$ 1,450	$ 1,160	$ 730	$ 650
		$ 1,020	$ 580	$ 510
		$ 870	$ 440	$ 360
		$ 730	$ 290	$ 220
Annual Fueling/Charging Cost ($)	$ 6,800	$ 6,120	$ 4,420	$ 2,720
		$ 5,440	$ 3,740	$ 2,380
		$ 4,760	$ 3,060	$ 2,040
		$ 4,080	$ 2,380	$ 1,700
Government Cash Incentive ($)	None	None	$ 12,000	$ 12,000
			$ 13,000	$ 13,000
			$ 14,000	$ 14,000
			$ 15,000	$ 15,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 4,050	$ 4,460	$ 4,460	$ 4,460
		$ 4,350	$ 4,350	$ 4,350
		$ 4,250	$ 4,250	$ 4,250
		$ 4,050	$ 4,050	$ 4,050
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Utility Van

Attribute	ICEV (BASE)	HEV	PHEV	BEV
Purchase Price ($)	$ 33,500	$ 40,200	$ 50,300	$ 50,300
		$ 38,500	$ 46,900	$ 46,900
		$ 36,900	$ 43,600	$ 43,600
		$ 35,200	$ 40,200	$ 40,200
Annual Maintenance Cost ($)	$ 1,300	$ 1,040	$ 650	$ 590
		$ 910	$ 520	$ 460
		$ 780	$ 390	$ 330
		$ 650	$ 260	$ 200
Annual Fueling/Charging Cost ($)	$ 5,000	$ 4,500	$ 3,250	$ 2,000
		$ 4,000	$ 2,750	$ 1,750
		$ 3,500	$ 2,250	$ 1,500
		$ 3,000	$ 1,750	$ 1,250
Government Cash Incentive ($)	None	None	$ 9,000	$ 9,000
			$ 10,000	$ 10,000
			$ 11,000	$ 11,000
			$ 12,000	$ 12,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 3,300	$ 3,630	$ 3,630	$ 3,630
		$ 3,550	$ 3,550	$ 3,550
		$ 3,470	$ 3,470	$ 3,470
		$ 3,300	$ 3,300	$ 3,300
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Walk-in Truck				
Attribute	**ICEV (BASE)**	**HEV**	**PHEV**	**BEV**
Purchase Price ($)	$ 66,000	$ 79,200	$ 99,000	$ 99,000
		$ 75,900	$ 92,400	$ 92,400
		$ 72,600	$ 85,800	$ 85,800
		$ 69,300	$ 79,200	$ 79,200
Annual Maintenance Cost ($)	$ 1,500	$ 1,200	$ 750	$ 680
		$ 1,050	$ 600	$ 530
		$ 900	$ 450	$ 380
		$ 750	$ 300	$ 230
Annual Fueling/Charging Cost ($)	$ 8,100	$ 7,290	$ 5,270	$ 3,240
		$ 6,480	$ 4,460	$ 2,840
		$ 5,670	$ 3,650	$ 2,430
		$ 4,860	$ 2,840	$ 2,030
Government Cash Incentive ($)	None	None	$ 12,000	$ 12,000
			$ 13,000	$ 13,000
			$ 14,000	$ 14,000
			$ 15,000	$ 15,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 6,500	$ 7,150	$ 7,150	$ 7,150
		$ 6,990	$ 6,990	$ 6,990
		$ 6,830	$ 6,830	$ 6,830
		$ 6,500	$ 6,500	$ 6,500
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

Bucket Truck

Attribute	ICEV (BASE)	HEV	PHEV	BEV
Purchase Price ($)	$ 111,000	$ 133,200	$ 166,500	$ 166,500
		$ 127,700	$ 155,400	$ 155,400
		$ 122,100	$ 144,300	$ 144,300
		$ 116,600	$ 133,200	$ 133,200
Annual Maintenance Cost ($)	$ 2,000	$ 1,600	$ 1,000	$ 900
		$ 1,400	$ 800	$ 700
		$ 1,200	$ 600	$ 500
		$ 1,000	$ 400	$ 300
Annual Fueling/Charging Cost ($)	$ 7,500	$ 6,750	$ 4,880	$ 3,000
		$ 6,000	$ 4,130	$ 2,630
		$ 5,250	$ 3,380	$ 2,250
		$ 4,500	$ 2,630	$ 1,880
Government Cash Incentive ($)	None	None	$ 12,000	$ 12,000
			$ 13,000	$ 13,000
			$ 14,000	$ 14,000
			$ 15,000	$ 15,000
Other Monetary Incentives	None	None	Manufacturer's Rebate	Manufacturer's Rebate
			No Sales Tax on Purchase Price	No Sales Tax on Purchase Price
			No Annual Registration Fee	No Annual Registration Fee
Non-monetary Incentives	None	None	Free Charging Station Installation	Free Charging Station Installation
			Free Municipal Parking	Free Municipal Parking
			Access to Bus and HOV Lanes	Access to Bus and HOV Lanes
Range per Refuel/Recharge (km)	300	400	400	200
	400	500	500	300
	500	600	600	400
	600	700	700	500
Annual Depreciation Cost ($)	$ 9,550	$ 10,510	$ 10,510	$ 10,510
		$ 10,270	$ 10,270	$ 10,270
		$ 10,030	$ 10,030	$ 10,030
		$ 9,550	$ 9,550	$ 9,550
Extended Battery Warranty	N/A	N/A	5 Years / 100,000 km	5 Years / 100,000 km
			6 Years / 120,000 km	6 Years / 120,000 km
			8 Years / 150,000 km	8 Years / 150,000 km
Reduction in Tailpipe Emission (%)	0%	10% less	50% less	100%
		20% less	60% less	
		30% less	70% less	
		40% less	80% less	
Refueling/Recharging Time	3 mins	3 mins	10 mins	30 mins
	5 mins	5 mins	30 mins	1 hr
	7 mins	7 mins	2 hrs	2 hrs
	10 mins	10 mins	4 hrs	4 hrs
Number of Public Fueling/Charging Stations in a Typical 5km Radius	1	1	0	0
	2	2	1	1
	3	3	3	3
	5	5	5	5

APPENDIX C – NGENE Code for the Fractional Factorial Design

```
/*ICVE: Internal Combustion Engine Vehicles*/
/*HEV:  Hybrid Electric Vehicles*/
/*PHEV: Plug-in Hybrid Electric Vehicles*/
/*BEV: Battery Electric*/
/*time: Refueling/Recharging Time*/
/*range: Range per Refuel/Recharge (km)*/
/*pprice: Purchase Price ($)*/
/*main: Annual Maintenance Cost ($)*/
/*fuel: Annual Fueling/Charging Cost ($)*/
/*depr: Annual Depreciation Cost ($)*/
/*emis: Reduction in Tailpipe Emissions (%)*/
/*pstat: Number of Public Fueling/Charging Stations in a Typical 5km
Radius*/
/*gov: Government Cash Incentive ($)*/
/*monet: Other Monetary Incentives*/
/*nmoent: Non-monetary Incentives*/
/*batt: Extended Battery Warranty*/

Design
; alts = ICEV, HEV, PHEV, BEV
; rows = 144
; orth = sim
; block = 24
; model:
U(ICEV) =
b7*range[-3,-1,1,3]
+ b11*time[-3,-1,1,3] + b12*pstat[-3,-1,1,3] /
U(HEV)  = b13 + b1*pprice[-3,-1,1,3] + b2*main[-3,-1,1,3] + b3*fuel[-
3,-1,1,3]                                                          +
b7*range            + b8*depr[-3,-1,1,3]                  + b10*emis[-
3,-1,1,3] + b11*time            + b12*pstat            /
U(PHEV) = b14 + b1*pprice            + b2*main            + b3*fuel
+ b4*gov[-3,-1,1,3] + b5*monet[-1,0,1] + b6*nmonet[-1,0,1] + b7*range
+ b8*depr            + b9*batt[-1,0,1] + b10*emis            + b11*time
+ b12*pstat           /
U(BEV)  = b15 + b1*pprice            + b2*main            + b3*fuel
+ b4*gov            + b5*monet         + b6*nmonet         + b7*range
+ b8*depr            + b9*batt                             + b11*time
+ b12*pstat
$
```

VITA AUCTORIS

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