Viability of Electric Vehicles within the Vancouver Police Department Fleet

by

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Abstract

Emissions from gas vehicles negatively impact the environmental wellbeing of a city. Green initiatives that aim to reduce greenhouse gas (GHG) emissions by replacing ageing internal combustion engine vehicles (ICEVs) with more environmentally friendly alternatives have been launched in numerous municipalities across Canada. The purpose of this project is to examine the feasibility of replacing the ageing 4-door administrative and detective fleet of Ford Fusions with electric vehicle (EV) alternatives at the Vancouver Police Department (VPD). The fuel efficiency and maintenance cost data of 112 fleet vehicles were compiled and used to construct the total ownership cost ($6,119,456). The 8-year total cost of ownership (TCO) of a complete 112-vehicle fleet using the proposed Ford Focus EVs is estimated to be significantly less (up to $1.04 million) than the TCO of the existing ICEVs. Furthermore, an online survey was conducted to determine the VPD detective and administrative employees' perception of this class of vehicle and to investigate whether their operational needs would still be met if they were to use one. A total of 96 participants (n=200) responded to the survey over a three-week period in June. Over 75% of survey respondants indicated that if their trip destination is within 80 kms and either car is available, they would prefer to use an EV over a ICEV. In addition, 79% of respondants believed that the majority of all vehicle trips conducted while on duty fall within the 80 kilometre range of what a fully charged EV is capable of travelling without refuelling. In summary, the fuel efficiency, maintenance cost, and survey response data suggest that it is both financially feasible and operationally possible to replace a proportion of the current ICEVs with similarly equipped EVs at the VPD.

Preface

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1. Introduction

In 2010, the City of Vancouver's municipal council adopted the long term goals recommended by the Greenest City Action Team (GCAT) and set in motion a series of activities that would transform the way in which the city would achieve its economic and social objectives for the next 10 years ("Greenest City 2020 Action Plan" 7). As a result of this decision, a Vancouver Police Department (VPD) project was approved for funding to investigate how Vancouver could become a world leader in 1) eliminating its dependence on fossil fuels and 2) minimizing the release of GHG emissions from vehicle traffic ("Viability of Electric Vehicles Within the VPD" 1). Specifically, this project aims to explore the possibility of reducing fossil fuel consumption by replacing the Ford Fusion administrative and detective vehicles at the VPD with EV alternatives. Over the course of 4 months, data were gathered and analyzed to determine if EVs could be used to replace the existing Ford Fusion vehicles without suffering from any reduction in service efficacy. In other words, could the same organizational requirements be met when using a vehicle that consumes electricity for fuel rather than using a vehicle that consumes gasoline? This project concludes that it is both financially and operationally possible to replace ICEVs with EVs.

Section one of this report describes the history of EVs, their current implementation at the municipal level in various jurisdictions across North America, and provides an analysis of the different psychological and environmental impacts that this type of vehicle can have. Section two of this report describes the methodology taken to determine the feasibility of replacing ICEVs with EVs at the VPD and section three finishes with the results, limitations, conclusion and recommendations.

1.1 Current Vehicles Used by the Vancouver Police Department

Constables and sergeants currently use fleet vehicles for a variety of purposes including but not limited to investigation, surveillance, traffic stops, meetings, person interviews, and couriering. However, many of these ICEVs are ageing and scheduled to be retired. Based on data provided by the City of Vancouver's Department of Engineering, 92% of the detective and administrative vehicle fleet is comprised of 4-door, 4-cylinder Ford Fusions with a production year between 2008 and 2013 with the remaining 8% comprised of 4-door, 4 cylinder Ford Focuses with a production year between 2001 and 2006. All vehicles except one are equipped with a standard set of emergency lights and a majority of the vehicles are used on a daily basis. On average, the vehicle keys are usually returned to the department key desk before 5pm on same day. There are, however, some outliers. For example, there may be an instance where a vehicle may need to be driven far outside of the city, accumulating more than 200 kms in a single trip, with the key not being returned for days.

Based on internal department documents, in 2011 the VPD's fleet of Crown Victoria police cars travelled a cumulative distance of 3.4 million kms and had consumed a staggering 850,000 litres of gasoline. Vehicle emissions that are produced by the day-to-day operations of the VPD therefore contribute a substantial amount of pollutants such as sulphur dioxide (SO_2) and carbon dioxide (CO_2) into the environment. A simple reduction in a proportion of these emissions could result in improved air quality and thus contribute to the City of Vancouver's Greenest City 2020 Action Plan goal #9 of breathing the cleanest air of any major city in the world.

1.2 Introduction to Electric Vehicles

Several decades ago, the idea of using electricity to power a motor vehicle was something that could only be seen in science fiction movies. Interestingly, EVs were actually conceptualized before the first ICEVs (Dings 9). In the late 19th century, France and Britain were the first to see the widespread development of these vehicles, and America followed with its first large-scale commercial fleet of New York Taxis in 1897 (Dings 8). The production of EVs began to decline shortly after 1912 due to several factors, such as improved road networks requiring vehicles capable of longer-range transportation, the advent of the electric car starter thus replacing the hand crank, the discovery of cheaply available crude oil in Texas as an energy source, and Henry Ford’s mass production of ICEVs for under $1000 (Dings 9). The reemergence of an EV sector did not occur until the OPEC oil embargo of the 1970’s and has continued with external pushes like stricter air pollution laws and climate change (Dings 10).

Today, electric engines are used in a wide variety of applications, ranging from aeronautics to personal road transportation (Edison Tech Centre, 2012). Many of the current EVs used for personal transportation have very similar range, performance, and fuel efficiency ratings. However, they are widely recognized by consumers as being more environmentally friendly when compared to their ICEV counterparts, due to their lower vehicle emissions, reduction in environmentally damaging gasoline engine lubricants, and decrease in fossil fuel consumption (Frenken, Hekkert, and Per 486). EVs have the potential to revolutionize the automotive industry through their lower per kilometre driving cost, reduced number of internally moving parts, regenerative breaking, and recaptured waste heat energy (Yang 171). Reducing the tailpipe emissions problem that is the primary cause of big city downtown smog can be achieved when a sufficient number of vehicles convert to EVs. The electricity required to fuel the vehicle can also be sourced from renewable resources or less polluting nonrenewable resources such as natural gas or nuclear. For example, 95% of the electricity generated in British Columbia comes from its 31 hydroelectric dams, with the remaining 5% from natural gas ("Hydroelectricity Powers BC Forward"). More and more vehicles are being powered either partially or completely by electricity (Baum 2; Dubin *et al*. 8). It is estimated that within the next five years, automakers across the world will introduce 30 different electric vehicle models, many of which have been predicted to gain rapid consumer acceptance (Dings 13). There is strong evidence that without taking in to account changes from external forces such as financial incentives to purchase, or major advances in battery technology, EVs will make modest market penetration by 2020 and be no more than 25% of new vehicle sales by 2050 (Trigg and Telleen 11; Dings 13). With further improvements in batteries, consumer concern over reliability should also begin to dissipate as EV range approaches the equivalent of one full tank of petroleum-based fuel.

Another benefit of using batteries as a fuel source for an engine is that they offer a good opportunity to store intermittent renewable energy from the sun and wind (Dings 31). Combining the use of renewable energy sources with zero tailpipe emissions will likely promote the rapid adoption of such technology by energy conscious consumers.

Several automakers have been closely watching the reemergence of a market demand for EVs. For example, Tesla's Model S vehicles are capable of driving over 500 kilometers on a single charge and have better engine performance than many mid-size luxury vehicles. They have been able to capture huge publicity and popularization (Tesla Go Electric). With pre-sale orders of 4600 vehicles in 2011 to delivery estimates of over 10000 vehicles in 31 countries in 2013 (Tesla Go Electric), further advances in EV engine and battery technology will only continue increase interest in this class of vehicle.

1.2.1 Electric Vehicle Use in Canada

There is a dearth of information regarding the use of EVs in Canada. In order to determine the breadth of their use in Canada, various police agencies across the country were contacted via telephone and informally questioned as to whether there are EVs used in their vehicle fleet. Upon completing this inquiry, it was discovered that out of the 15 Canadian police departments surveyed, only the Saanich Police Department (SPD) was using EVs[1]. Therefore, it was discovered that very little information pertaining to their use in police related duties is available. The lack of data may be due to the fact that EVs are relatively new in any police vehicle fleet program across the country. Nevertheless, data concerning their use are invaluable because these findings may influence the speed and scale in which the department chooses to implement an EV replacement program in their vehicle fleet. These findings may speak to their courage and willingness to innovate by combating vehicle emissions and looking for innovative long-term strategies to minimize their vehicle fleet operating costs.

Despite the absence of EV's in the majority of police departments, there are a number of cities across Canada that currently have a comprehensive EV fleet. Cities such as Toronto, Winnipeg, Edmonton, Vancouver and Victoria are all currently making use of these vehicles in their municipal fleet to complete tasks related to parking enforcement and routine administrative duties. The number of instances that a functioning EV is used in a municipal government vehicle fleet suggests that the feasibility of implementing such a program may be restricted to work of a similar capacity that does not require a specialized vehicle for transportation. Therefore, it may be seen as evidence to support the possibility of implementing an EV replacement program in a

[1] The SPD uses one Mutsubushi EV as a police court liaison vehicle.

police department, to perform routine detective and administrative duties. This finding is important because it demonstrates multiple working examples of EV fleets across the country, performing a similar role as what is envisioned by the VPD.

1.2.2 The United States of America

In order to determine the use of EVs in the United States (US), in late May 2014, selected west coast police agencies (San Jose, Las Angeles, Portland, and Seattle) were telephoned and informally surveyed as to whether EVs were used in their vehicle fleet. Out of the five police departments contacted, none of them were currently using electric vehicles in their vehicle fleet. Similar to the situation in Canada, most of the electric vehicles were registered in the municipal vehicle fleet for the sole purpose of parking enforcement and low-level administrative duties. For instance, the City of Seattle – Fleet Management Division was able to financially justify the purchase of electric scooters (See Table. 3) and successfully operationalize them in to various duties within the city. This finding is important because it demonstrates another working example of EVs performing a similar role as what is envisioned by the VPD.

1.3 Comparison between Electric Cars and Gas Vehicles

Electric vehicles are not a new phenomenon to the North American automobile market (Dings 9). A number of EV models were envisioned following the change of legal landscape of the US in the 1970s when the federal government launched the Federal Clean Car Incentive Program and the Electric and Hybrid Vehicle Research, Development and Demonstration Act, but these initiatives never materialized (Dings 9). The first known mass-produced[2] fully electric vehicles in North America had originated in California with the introduction of the Landmark Zero Emission Vehicle (ZEV) Mandate (Dings 9). Beginning in the 1990's, low-volume production ran for several years and was discontinued shortly after, due in part to the weakening of the ZEV mandate (Dings 9). In 2003, Toyota became the last major carmaker to stop producing them (Dings 9). It would seem that the gap in production years tended to coincide most with corporate interest and external pressures such as spikes in the price of oil, regulatory pressures to improve air quality, and legislation to cut CO_2 emissions (Dings 9). The variability in external pressures combined with the competition afforded by ICEVs, meant that the probability of a successfully mass-produced EV at the time, would be limited.

1.3.1 Environmental Impacts

The environmental impacts attributed to owning an EV can be calculated in a variety of ways. Variations in calculation methods can result in discrepancies depending on the type of measurement used and the number of variables included. It is not immediately apparent what should be included in the calculation of assessing the environmental impact. For example, Hawkins *et al*. uses a measurement called Global Warming Potential (GWP) in their assessment of the comparative environmental lifecycle between conventional ICEVs and EVs (53). While Hawkins *et al*. noted that although there are substantial gains in terms of a reduction in the overall life consumption of fuel like gasoline and diesel, the production and operation of EVs can lead to potential increases in human toxicity, freshwater eco-toxicity, freshwater eutrophication,

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[2] Production of this vehicle was limited to 1484 vehicles from 1997-2003

and metal depletion impacts, largely emanating from the vehicle supply chain (53). In 2008, Kendall used a well-to-wheel life-cycle analysis (WTW) in determining their environmental impacts. The WTW analysis included both the production of fuel and combustion of fuel resulting in the car's use (Kendall 156). Tracing the lifecycle back to emissions attributed to oil extraction and refining through the vehicle production to its end of life cycle can have a drastic increase in the total amount of emissions obtained (Kendall 156). However, how far exactly can or should one include in their calculation of the environmental impacts? Should the fuel extraction process and end of life treatment really be included when fuel and materials are a common variable included in both classifications of vehicle? The European Federation for Transport and Environment AISBL in 2009 entered the environmental impacts calculation foray by attempting to analyze exclusively the tank-to-wheel emissions and found that these represent approximately 90% of total emissions of ICEVs. The proportion of electric cars however, is different in that the majority of emissions come from the electricity production (well-to-tank) (Dings 22). Therefore, the environmental impacts are largely determined by the carbon intensity of the power generation used in its production and propulsion (Dings 22). It is important to note that regardless of the method used to estimate the environmental impacts, the overall amount of negative environmental impacts associated with ICEVs seem to outweigh those caused by EVs.

1.3.2 Psychology

Electricity has long been considered as a possible alternative energy source to the traditional petroleum based fuel that vehicles have been dependent on for the last century. However, widespread use of electricity as a fuel source for cars has encountered resistance. Specifically, the perceived limitations of an EV as a mobility resource (Bunch *et al*. 237; Franke *et al*. 2), electric battery systems (Hitamura and Hagiwara 2010), and general perceptions of user satisfaction (Francfort and Carroll 1) have acted as primary resisting factors. In addition, financial factors may also suppress their widespread adoption. Such factors can be related to the cost associated with the purchase of a new EV, the installation of electric vehicle charging stations for the home, the costs associated with publically available recharging stations outside of the home, and untraditional vehicle maintenance requirements such as infrequent battery replacements or other one-off repairs that require a higher degree of technological competence than what would be traditionally associated with an ICEV. These factors will cumulatively affect one's perception of EVs.

There has been a slightly stronger acceptance of passenger EVs in the early part of the 21st century. This small change in consumer preference begs the question: why are people choosing or not choosing to purchase electric cars? The answer may rest in current technological advances that have allowed electric cars to be a sufficiently viable option, such that consumers are no longer as concerned about their reliability, range, or safety. Specifically, advances in EV batteries have been a key limiter for the success of electric mobility systems (Kitamura & Hagiwara, 2010). Much research has been done through field trials (Bish and Tietmayer 81; Patil 15), but there are very little data published about the real user experience with range and how the vehicle occupants address this issue. Will there ultimately be a better user experience when driving in an EV or an ICEV? Scientific literature surrounding concepts like anxiety or fear that characterize the nature of the range experience (Botsford and Szczepanek 7; Skippon and Garwood 525) cannot yet definitively conclude one way or the other. Additional studies addressing factors like range optimization behavior (Gregersen *et al*. 302; Steg 148; Steg and Gifford 59), driving schedules, and perceptions of safety should be conducted.

1.4 Project Objectives

This project aims to determine the viability of EVs in the VPD fleet by conducting a limited scan of other police agencies, determining the needs within the VPD, determining the financial feasibility to the organization, and the optimal ratio of vehicles. This project also aims to determine the environmental benefits that would be derived through an estimation of the reduction of fuel consumption and corresponding GHG emissions that would occur from replacing the current ICEVs. Finally, this project makes a holistic recommendation for the viability of implementing EVs as part of the VPDs detective and administrative purposed Ford Fusion vehicle fleet.

2. Methodology

2.1 Operational Feasibility Survey

A survey was designed and distributed to senior detectives and administrative staff managers at the VPD via a secure in-house email system. The survey was developed after carefully considering the nature of possible responses that would be most valuable to the organization. In order to remain as impartial and unbiased in the wording of the questions as possible, questions were written in a non-leading fashion (see Table 4). In order to cover the complete range of possible answers, when possible, open-ended questions were used and the option of “other” was always available. For example, question number eight specifically inquired about the proportion of relevant fleet vehicle trips would be included in an eighty kilometer per day range by asking the following, “A total range of 80 kms would be adequate to serve what percentage of my daily VPD pool car needs?” Respondents were able to view and select one of the following responses “none, a little bit, half, a majority, all.” The email provided detailed instructions about whom the survey was intended for and what was its purpose.

2.2 Total Cost of Ownership (TCO) Analysis

The TCO analysis is based on data provided by the City of Vancouver’s Department of Engineering.

Data analysis were conducted using Microsoft excel version 2011. When examining the relationship between fuel efficiency (litre of fuel/kilometer) and mileage travelled, a linear correlation test was used. Similarly, a linear correlation analysis was used to determine the relationship between maintenance cost and the age of the vehicle. The eight-year lifecycle timeline is the proposed life of the vehicle and is determined by an equivalent annual cost calculation based on the American Public Works Association method of determining vehicle replacement life. An eight-year lifetime replacement estimation for the vehicles under consideration has been established because it is at this time when the City of Vancouver's Department of Engineering considers to be the benchmark equipment life for police use balances with the point where the equivalent annual cost is at a minimum.

The acquisition cost reflects the purchase price for a 2014 model of either the Ford Fusion gas model or Ford Focus EV. Models prior to 2014 are corrected for 2% annual inflation.

The lifetime fuel reflects the financial burden that the two classifications of vehicles place on the VPD for the duration of 8 years. Specifically, on average, a non-patrol vehicle travels 4,013 kms. This distance is determined by a randomly selected sample containing 17 non-patrol vehicles out of a population of 112 vehicles. For ICE Ford Fusion vehicles, the fuel efficiency is 0.13 litres per kilometer and the Ford Focus EV fuel efficiency is 0.25 kWh per kilometer. Currently, the VPD pays $1 per litre of gas and $0.09 per kW. Life fuel is computed by distance travelled multiplied by energy efficiency multiplied by the cost per unit of energy.

For ICE Ford Fusion vehicles, the lifetime maintenance cost is the average of maintenance costs incurred by the randomly selected sample of 17 ICE Ford Fusion vehicles. For the Ford Focus EVs, there is no data available to estimate the maintenance cost, nevertheless, the City of Vancouver's Department of Engineering estimates the annual maintenance budget for electric cars to be $1,200. Thus for the duration of 8 years, the estimated cost is eight times this number.

Salvage is 5% of the acquisition cost.

The TCO is calculated by combining the cost of vehicle acquisition, life fuel, life maintenance, subtracting salvage.

2.3 Environmental Impacts

In order to assess the environmental impacts by replacing 112 Ford Fusion ICEVs with EVs, data provided by the City of Vancouver Department of Engineering for 2013 were analyzed. GHG emissions estimations were calculated by multiplying litres of fuel by an emissions factor for the mass of CO_2 present in the type of fuel for that year.

3. Results and Discussion

The results of this project have been concluded from vehicle data provided by the City of Vancouver Department of Engineering, an online survey provided to both detectives and administrative employees of the Vancouver Police Department, and written articles (both scholarly and non-scholarly) that discuss various aspects of EVs as they relate to this project. The information disclosed within this section will advance the City of Vancouver's Greenest City 2020 Action Plan goals to 1) eliminate dependence on fossil fuels and 2) minimize the release of GHG emissions from its own vehicle traffic. Specifically, benefits that could be derived through the implementation of these vehicles as replacements for the traditional 4-door ICE models will only come about as a result of careful planning, staggered implementation and a host of other precautions such as charging station training for staff, the establishment of an effective, dedicated, and reliable charging station area for the vehicles to refuel, and a positive experience advertising campaign.

3.1 Survey

A total number of 96 civilian and sworn officers at the VPD responded to an online survey containing a combination of 10 multiple choice and fill-in the blank style survey questions (see Table 4). Based on the responses, it was determined that there are approximately 3 levels of use frequency for existing VPD Ford Fusion pool cars. There is an incidence of high frequency use on Tuesday, Wednesday, and Thursdays followed by an incidence of medium frequency use on Monday and Fridays with an incidence of low frequency use on Saturday and Sundays. Existing VPD Ford Fusion pool cars have a high incidence of user sign-outs occurring between the hours of 6am and 10am (9-32%) with a peak occurring at 7am and a trough occurring at 6am. Existing VPD Ford Fusion pool cars have a low incidence of user sign-outs occurring between the hours of 12pm and 7pm (1-2%) with a peak occurring at 12pm and a trough occurring at all other times between 1am to 7pm. Existing VPD Ford Fusion pool car users most frequently make use of the vehicle between the hours of 9am and 1pm with less frequent use during the hours of 5am to 8am and 2pm to 5pm. The highest frequency of existing VPD Ford Fusion pool cars being returned occurs between the hours of 1pm to 5pm exclusively and accounts for over 94% of vehicle returns.

Forty-four percent of respondents indicated that a total range of 80 kms would be adequate to serve the majority of their daily vehicle needs, 35% of respondents indicating that a total range of 80 kms would be adequate to serve all of their daily vehicle needs, 12% of respondents indicating that a total range of 80 kms would be adequate to serve half of their daily vehicle needs, 8%of respondents indicating that a total range of 80 kms would be adequate to serve a little bit of their daily vehicle needs and 1% of respondents indicating that a total range of 80 kms would be adequate to serve none of their daily vehicle needs. Seventy-five percent of respondents indicated that they would choose an EV over an ICEV to complete their trip if the total round-trip distance was within 80 kms, 22% of respondents indicated that they would choose an ICEV over an EV to complete their trip if the total round-trip distance was within 80 kms, and 3% respondents indicated that they would choose some other type of car to complete their trip if the total round-trip distance was within 80 kms.

Significantly, 45% of people had indicated that the most important factor to consider when choosing between a gas or electric vehicle was either the range or the reliability followed by 44% of respondents indicating that the most important factor to consider was one of availability of space, performance, battery capacity, and access to a refueling source, followed by

11% of respondents indicating that the most important factor to consider was one of charge time, safety or vehicle familiarity. Overall, two major themes had been observed. Specifically, concerns related to the EVs battery (including response selections like range, reliability, battery capacity, charge time, and refueling source) had accounted for over 42% of responses while concerns related to the vehicles attributes (including space, safety, performance, optics, and practicality) had accounted for 21% of responses. Two minor themes were also observed. Specifically, concerns related to the environment had accounted for 15% of responses and concerns related to the purchase or operating costs of the vehicle had accounted for 8%. Five percent of responses came back as "not sure".

3.2 Financial Analysis

The replacement of ICEVs with EV at the VPD is financially feasible (see Table 1). By replacing a single ICEV with a single EV the department will save $9,292 (see Table 1). The majority of these savings come from the difference in the lifetime fuel costs between. This finding is consistent with an American study where Anair and Mahmassani noted that the total ownership of an ICEV would be three times more than an EV (18). Furthermore, these calculations are supported by a study conducted by the City of Seattle, which compared the total cost of ownership for electric scooters against ICE scooters and found similar results (see Table 3).

The fuel consumption is not correlated with the mileage travelled (see Figure 1). In other words, mileage of the car cannot be used to predict fuel efficiency. Similarly, maintenance costs are not correlated with age (See Figure 2). In other words, age of the car cannot be used to predict what its maintenance costs will be.

3.3 Environmental Impacts

In order to assess the environmental impacts by replacing 112 Ford Fusion ICEVs with EVs, data provided by the City of Vancouver Department of Engineering for 2013 were analyzed. In total, the 112 fleet vehicles emit almost 228 tonnes of GHG emissions annually. Over the expected fleet lifetime of 8 years, approximately 1,824 tonnes of GHGs would be emitted[3]. This estimation does not include the potential environmental impacts caused by the electricity that would be used to fuel the car and the materials that would be used to produce the car. Because only GHG emissions attributed to the burning of fuel from the existing ICEV Ford Fusion vehicles were included for the purposes of this project, approximately 99% of the 1,824 tonnes of GHG would be removed from the environment by a complete EV replacement of all 112 fleet vehicles.

3.4 Limitations

There is a dearth of information regarding the use of electric vehicles in Canadian police departments. An approximate scan had been conducted by contacting the various police agencies across the country but in no way should the results of this scan be seen as being representative of the Canadian police forces across the country in general. Every city across the country is very individualized as far as geographical space covered, range of policing issues that they deal with, climate/environment, budget constraints, etc. Additionally, because of the fact that only vehicles assigned as VPD specific vehicles were included in the results of this survey, many areas of the

[3] Assuming a consistent 2013 emissions factor

country were considered to have not been using EVs when in fact they were using them in the city vehicle fleet.

There are a number of other important limitations to acknowledge when discussing the findings based in this project. These limitations pertain specifically to the survey and financial analysis that comprises the basis of the total cost of ownership calculation. For example, one of the limitations of the total cost of ownership calculation is that the calculation does not include the cost of charging stations that will be part of the capital infrastructure improvement costs required for the building. Another limitation to the calculation of the total cost of ownership is that it assumes a constant price of fuel, constant price of vehicle maintenance, and consistent patterns of vehicle usage throughout the duration of the 8-year vehicle lifecycle.

There are several important limitations to take in to consideration when analyzing the results provided by the survey such as questionnaires bias, limited number of respondents and the self-selecting nature of the respondents. These limitations were considered in advance of distributing the survey and reasonable steps were taken to try and ensure against these limitations. For example, every question was carefully worded using the simplest language possible while clearly articulating an open-ended question without leading the participant to select a certain response.

An additional limitation to this project was due to the scheduling constraints provided by the large scope and short project completion deadlines. Overall, this 4-month, student-led project was designed to be the first step towards the implementation of a successful ICEV to EV replacement program. These findings should therefore be considered only as hypothesis for further investigation.

4. Conclusion and Recommendations

The data uncovered by this project will advance the City of Vancouver's Greenest City 2020 Action Plan goals to 1) eliminate dependence on fossil fuels and 2) minimize the release of GHG emissions from its own vehicle traffic.

Overall, it is financially feasible to replace ICEV with EVs at the VPD. The more ICEVs that the department replaces, the more money the department will save. For example, by replacing the entire fleet with EVs, the department will save approximately $1.04 million (see Table 1).

Without any reduction in operational standards, it was found that the optimal number of electric vehicles could be most appropriately achieved by gradually increasing the EV proportion to a maximum number of 60, when the total fleet capacity is at 112 vehicles. This would work out to a roughly 1:1 proportion of electric: gas vehicles. Based on the survey responses of 96 participants at the VPD, this combination of vehicles would be sufficient to maintain the operational requirements, while saving the department an estimated $558,000 and removing 977 tonnes of GHGs from the atmosphere.

It is recommended that a gradual replacement of ICEV to EVs occur over a number of years, beginning in year zero with a maximum replacement of 10% of the total vehicle fleet. More data (i.e. life fuel, maintenance, operational feasibility) should then be collected. Subsequently, if demand exceeds availability, and the vehicles can still satisfy a majority of the operational needs, then additional ICEVs should be incrementally substituted.

Lastly, this project recommends the implementation of new policies within the VPD to ensure that the EVs are connected to a charging station as often as possible. For example, EVs should only be able to be reserved a maximum of 30 minutes in advance of the departure time, so that they remain at the charging stations and connected to the charging port for as long as possible. This may resolve the potential problem of key hogging and help to maintain the internet communications link between the vehicles and the central key desk.

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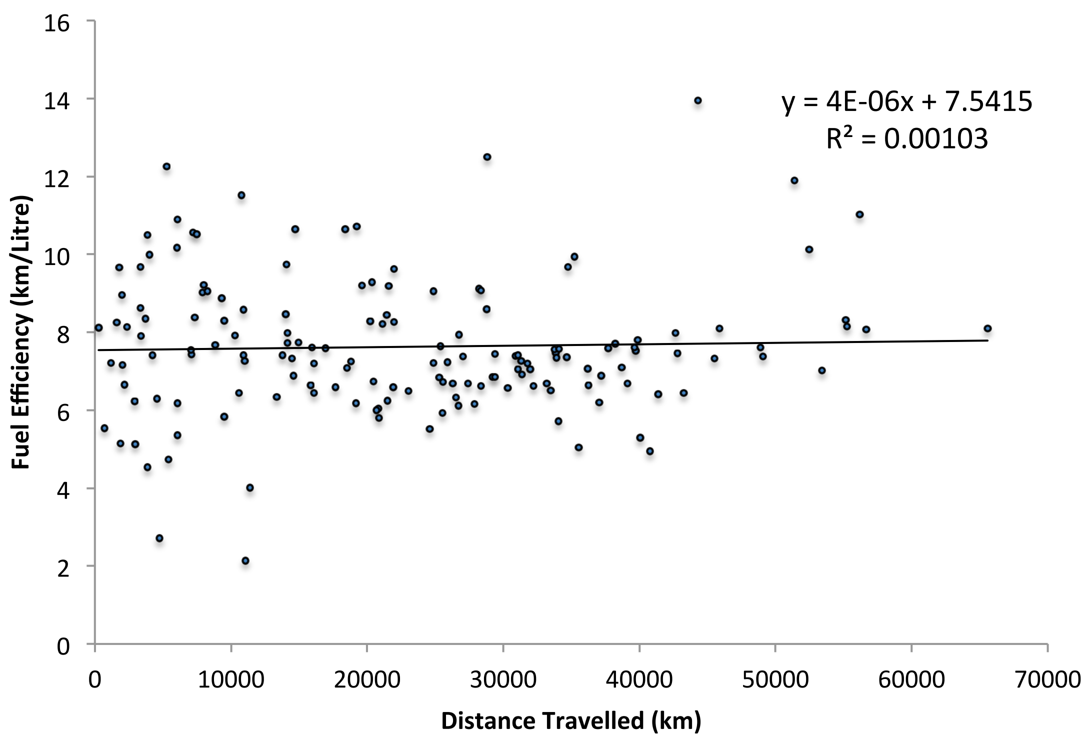

Figure 1. Fuel efficiency data describing fuel efficiency and total distance travelled.

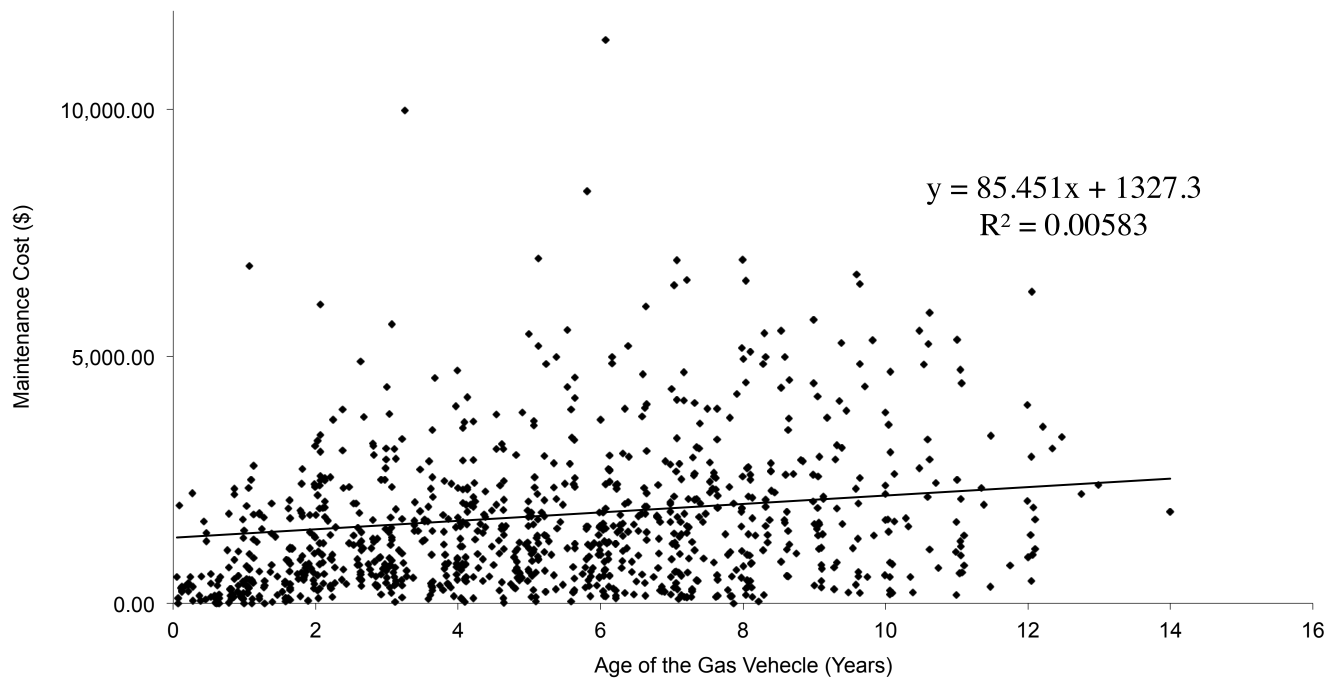

Figure 2. Maintenance cost data describing yearly maintenance cost of gas vehicles.

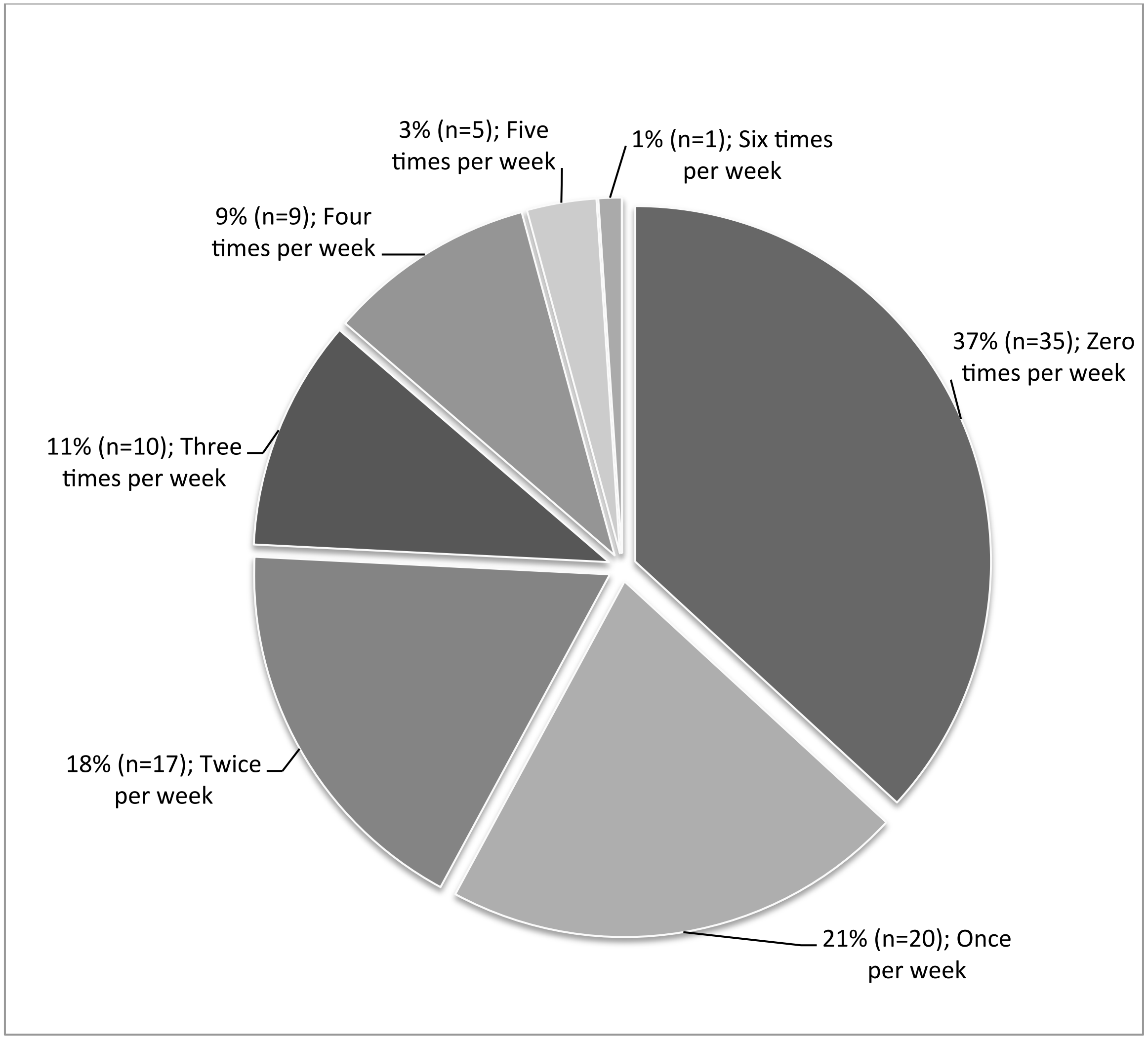

Figure 3. The frequency that each individual officer signs out a Ford Fusion fleet vehicle.

Table 1. Summary of Answers to the Question: When choosing between a gas or electric vehicle, what is the most important factor to consider?

Concerns	# Participants Expressed Concerns	Quotes from the Participants
Automobile Specification Related Concerns	19	**Range** • **"**Doesn't run out of energy in a remote location" • **"**Running out of power for electric vehicle" • **"**Will the electric charge last if I get stuck in a traffic jam" • "The ability for it to retain a charge so I am no stuck"
	8	**Access to Refuelling Source** • **"**The ease of finding a charging station vs. a gas station" • **"**Concerned about having to plug in the car" • **"**Ease of charging, availability of charging unit, convenience of charging (underground stall)"
	24	**Reliabilit**y • "I have not driven an electric car before so familiarity and reliability" • "As electric vehicles are relatively 'new' things, I would be concerned that it may not be as reliable as a gas vehicle" • "Dependability with flexibility of purpose and distance." • "Dependability, I do not want to be stranded" • "Getting stranded out on the road and having to ask for tow" • "That it runs"
	11	**Battery Capacity** • **"**Distance to be driven, without having access to power" • **"**Gas b/c sometimes things change on the road and a short trip turns into an all day affair"

Concerns	# Participants Expressed Concerns	Quotes from the Participants
Automobile Specification Related Concerns	3	**Battery Charge** • "Battery close to be fully charged" • "That the car is fueled and ready to go" • "Whether the electric vehicle is fully charged at the time of sign-out"
	10	**Comfort / Available Space** • "Interested only in EV with more cargo space that could hold all of the equipment needed for work" • "Comfort for a 6'1" frame wearing an operational uniform" • "Storage capacity" • "Size of the cabin (Big enough)"
	3	**Safety** • "Safety. Pedestrians don't hear electric car and the driver has to be extra vigilant that pedestrians will step in front of a moving EV more often"
	9	**Availability** • "That the car is fueled and ready to go" • "Which one is available" • "If the electric car is charged and ready to go"
	13	**Performance** • "The size and power of the car" • "Performance if required to assist on a call" • "Ability to perform emergency duties if/when required." • "Acceleration of the vehicle" • "Torque and handling"
Psychological Barriers	6	**Familiarly** • "The actual operation of the electric vehicle" • "I have not driven an electric car before so familiarity" • "I don't know enough about electric cars"

Concerns	# Participants Expressed Concerns	Quotes from the Participants
Psychological Barriers	3	**Optics** • **"**Generally I think use of electric vehicles yields excellent optics and is in line with the City and VPD's strategic goals" • **"**Does it look good."
	3	**Practicality** • **"**Role for using the car"
Environmental Concerns	22	**Fuel & Emissions** • **"**I would use the electric vehicle. It is better for the environment" • **"**Reduce emissions" • **"**Whichever is more environmentally friendly but will still work" • **"**Going green" • **"**I don't need an "operational" vehicle so electric is important for gas savings" • **"**Electric for the environment" • **"**No need for gas for short trips"
Financial Concerns	12	**Operating Cost** • **"**Cheaper to operate" • **"**The green benefits could be overshadowed by costs, etc., if indeed these vehicles are costly to operate" • **"**Cost to the city" • "Money"
Spoiled Response	8	**Spoiled Responses** • "Not sure" • **"**It is difficult to answer as I have never driven an electric vehicle before" • **"**The car itself" • "*" • **"**Purpose of trip - operational vs. meeting"

Table 2. VPD Total Cost of Ownership (TCO) Analysis

Type	Model	Life Cycle	Acquisition[1]	Life Fuel[4]	Life Maintenance	Salvage[6]	TCO[7]	Fleet Cost (112 vehicles)
Gas	Ford Fusion	8	$35,647[2]	$5426	$14,957	$1,392	$54,638	$6,119,456
EV	Ford Focus	8	$36,867[3]	$722	$9,600[5]	$1,843	$45,346	$5,078,752

[1] Up-fitting cost is not included. Models prior to 2014 are corrected for (2% annual) inflation.
[2] The price is established based on the department purchase of six 2013 Ford Fusion vehicles.
[3] The price is established based on the department purchase of two 2014 Ford Focus EV's.
[4] Fuel assumptions: 4013 km/year (the average distance driven by a non-patrol vehicle is determined by a randomly selected sample containing 17 cars, out of a population of 118); 0.13 liter/km of gas (the fuel efficiency value is determined by a randomly selected sample containing 17 cars, out of a population of 112); City of Vancouver most recent estimates for the cost of fuel for both vehicle types is $1.30/liter of gas; EVs kWh cost = $0.09/kWh; 0.25kWh/km. Currently, 112 internal combustion detective/administrative fleet vehicles are in operation at Vancouver Police Department.
[5] The City of Vancouver Department of Engineering estimates the annual maintenance cost for Ford Focus EV's to be $1200.
[6] Salvage value is based on a 5% resale value of the acquisition cost.
[7] Total Cost of Ownership (TCO) = Acquisition Cost + Lifetime Fuel + Lifetime Maintenance - Salvage

Table 3. City of Seattle Total Cost of Ownership (TCO) Analysis

City of Seattle - Fleet Management Division

Total Cost of Ownership (TCO) Analysis of PEO Scooters: Gas vs. EV							
Type	**Life Cycle**	**Acquisition[1]**	**Life Fuel[2]**	**Life Maint**	**Salvage[3]**	**TCO[4]**	**Fleet Cost (78 scooters)**
Gas	7	$ 32,660	$ 7,870	$19,220.25	$ 6,532.0	$53,218.52	$ 4,151,044.78
EV	7	$ 40,230	$ 1,274	$ 4,152.82	$8,045.92	$37,610.51	$ 2,933,620.08

[1] Upfitting not included. Models prior to 2014 corrected for (3% annual) inflation

$ 1,217,424.71 City Savings by converting to EVs

[2] Fuel assumptions: 5200 miles/yr; $4/gal; EVs kWh cost = $0.035/mi; Gas PEO MPG = 18.5

[3] 20% resale value assumed for PEO Scooters (not available on Kelley Blue Book).

[4] TCO = (acq cost + fuel + PM) - salvage value

Prepared by Andrea Pratt as of 6/18/14

Table 4. VPD EV Survey Questions

1. What is the exact email address at which you received the link to this survey? Note: you will not receive follow-up information after completing this survey.
2. On what days of the week do you most frequently use a VPD pool car (i.e. Ford Fusion)?
3. In the past, at approximately what time did you sign-out a VPD pool car?
4. During what time(s) have you driven, or most frequently drive a VPD pool car? (Select multiple times if necessary)
5. In the past, at approximately what time did you return the VPD pool car?
6. In the past, approximately how many times per week did you sign out a VPD pool car?
7. Think back to the last time you used a VPD pool car. Approximately what neighbourhood did you drive to and how many kilometres did you drive in total? Approximately what neighbourhood did you drive to? Approximately how many kilometres did you drive in total?
8. A total range of 80 kilometres would be adequate to serve _____ of my daily VPD pool car needs?
9. If either car were available, which would you choose for a trip within 80 kilometres?
10. When choosing between a gas or electric vehicle, what is the most important factor to consider?