SSM1100Y

Analyzing the driving factors for Electric Vehicle (EV) adoption in Municipal Cities: lessons learned from the world, for application in City of Toronto's TransformTO EV target by 2030.

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Contents

Abstract

In 2021, the City of Toronto updated its climate action plan called TransformTO, in line with its 2040 net-zero goal, that prioritized emissions reductions from four sectors - buildings, energy, transportation and waste. Emission reduction targets were set for each of these. One of the interim targets for the transportation sector is that 30% of the registered vehicles in the city of Toronto should be electric by 2030. To achieve this target, the city has an Electric Vehicle (EV) strategy but the EV adoption rate in Toronto is not as high as other cities around the world with similar targets. Therefore, for this research paper, an evaluation framework was developed to assess Toronto's EV strategy based on the factors driving EV adoption among consumers as well the success factors observed in four cities with high EV adoption rate- Shanghai, San Francisco, London and Oslo. The evaluation framework was developed using EV driving factors that were determined from the reviewed literature and a relative level of importance was assigned to these factors in alignment with the interpretation of the literature. Based on the evaluation conducted, the areas for improvement were determined and corresponding recommendations were developed for the City of Toronto in alignment with what was seen as best practices in the Cities that were reviewed.

Introduction

The impact of urbanization has resulted in increased concerns for climate change, requiring cities to reduce their greenhouse gas emissions through climate mitigation strategies(Georgeson et al., 2016). Cities across the world account for ~80% of the global energy consumption and generate 60% of the greenhouse gas emissions (GHG), reflecting the critical need to adopt emissions reduction strategies (Harris et al., 2020). Cities play an integral role in Climate Change governance by supporting the adoption of government and other sub-national policies, implementing them at the local level and evoking the importance of climate change among the community members (Castán Broto, 2017).

In 2017, the City of Toronto like many other cities across the world adopted the ambitious target of net zero emissions by 2050 with respect to its emissions generated in the baseline year of 1990 (City of Toronto, 2018). In 2019, City Council declared a climate emergency and unanimously committed to reaching net zero emissions by 2040 or sooner in alignment with IPCC recommendations(City of Toronto, 2019). With the development of the TransformTO Net Zero Strategy in 2021, the city adopted a new target of net zero community wide GHG emissions by 2040 (City of Toronto, 2021). To further stimulate the target initiatives, the city adopted interim 2030 targets across all sectors in alignment with the overarching 2040 targets mainly pertaining to the emissions generated from buildings, transportation, waste and energy (City of Toronto, 2021). The sectoral contributions to community-wide greenhouse gas emissions for the City of Toronto as per the latest GHG inventory are:

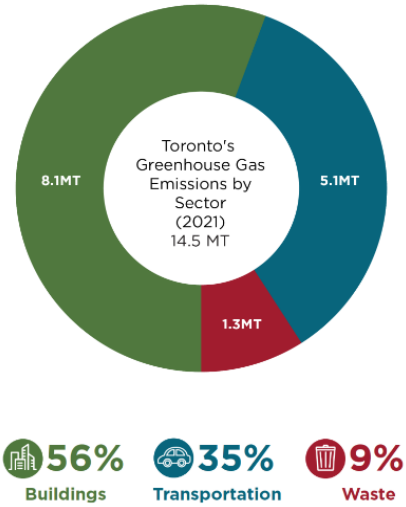


Figure 1: Toronto' GHG emissions sector wise distribution

buildings (56% of the total emissions), transportation (35%) and waste (9%) (City of Toronto, 2021) .

For the City, the decarbonization plan is therefore built on core focus areas of reduction targets relevant to how people move, how buildings operate, how energy is produced and how waste is generated and disposed of. With transportation being the fastest growing source of GHG emissions and number one source of air pollution, cities across the world including Toronto are committed to implementing restrictions on high polluting vehicles and promoting electric vehicle options through specific targets (Tan et al., 2023). In a study conducted to measure the impact of air pollution on human health in Toronto, it was found that passenger and heavy-duty vehicles with Internal Combustion Engines (ICE) have significant impact on human health (Shamsi et al., 2021). Hence it is important to focus on reduction of emissions pertaining to transportation sector from the aspects of improving both environmental and human health in Toronto.

For this research paper, the focus was on the analysis of the TransformTO target that 30% of registered vehicles in Toronto should be electric by 2030 (City of Toronto, 2021). Under this target there are several sub targets which focus on the different types of vehicles and their uses: personal vehicles, freight and commercial vehicles. The research objectives of this paper addressed only the target related to personal vehicles.

The next section further outlines the key research objectives which formed the overall research topic and the question for this paper.

Research Focus of Paper

The research objectives and their individual questions discussed in the sections below determine the overall research topic ***Analyzing the driving factors for EV adoption in Municipal cities: lessons learned from the world, for application in City of Toronto's TransformTO EV target by 2030*** and the more specific research question ***What more can Toronto do to achieve TransformTO goal that 30% of registered vehicles in Toronto are electric by 2030?***

Research Objective 1: Review the academic literature to assess theories for drivers and barriers in Electric Vehicle adoption.

Studies conducted to analyze consumer behaviour towards EV adoption outline different factors impacting the buying behaviour such as human behaviour, economic feasibility, psychological traits such as environment concern, affinity towards technology among others (Corradi et al., 2023). Some literatures have identified vehicle ownership costs, charging time, driving range as the major factors which impede the adoption rate among the consumers (Coffman et al., 2017). Therefore, it was critical to gain a better understanding from the academic literature perspective and determine which factors primarily impact EV adoption. This formed the basis for the Research Objective 1.

Research Objective 2: Review the Electric Vehicle strategy adopted by Cites with high EV adoption rate across the world.

The global transition rate to Electric Vehicles , which is considered a key emissions reduction lever has seen a tremendous growth in recent years, with the highest market share in China, followed by some parts of Europe (*Trends in Electric Light-Duty Vehicles – Global EV Outlook 2022 – Analysis*, 2022). However, the positive deployment rate of EVs in other countries across the world

is not at the similar level as China, parts of Europe and the United States. This could be attributed to regional variation in the EV prices, government incentives , automakers' presence among other factors (*Trends in Electric Light-Duty Vehicles – Global EV Outlook 2022 – Analysis*, 2022). Hence, it was important to analyze the EV Strategy and identify different factors which are driving the adoption rate of passenger (light duty vehicles- cars and vans) electric vehicles in Cities with a high adoption rate. This formed the core purpose of the Research Objective 2 which answered the following question:

Which factors have successfully contributed to driving EV adoption in Cities across the world?

The Cities that were selected for this research objective are: London, San Francisco, Shanghai and Oslo. The rationale to select them is discussed in the literature review section of this paper.

Research Objective 3: Develop an evaluation framework to measure Toronto's EV Strategy

With many cities adopting ambitious electric vehicle targets for decarbonizing transportation related emissions in alignment with the Paris Agreement, it is estimated that cities will need to increase their charging infrastructure by at least 20% (C40 Cities, 2020). This is one of the many challenges that stem from various parameters such as financial, technology, accessibility, socio-economic and consumer acceptance factors that impact the successful implementation of a city's EV strategy. It was therefore important to analyze Toronto's EV strategy through an evaluation framework. Based on the analysis conducted through the research objectives 1 and 2, an evaluation framework was built.

Research Objective 4: Evaluate Toronto's EV Strategy and identify lessons learned from the other Cities for application in TransformTO 2030 EV target.

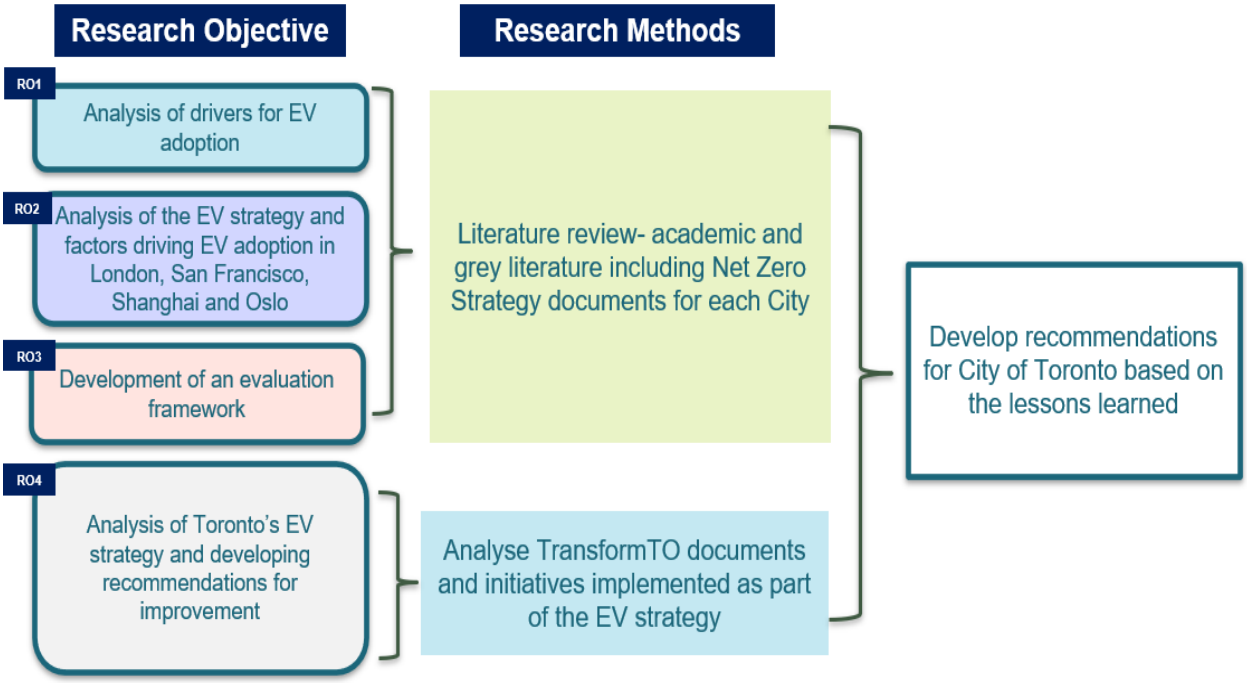
This objective answered the question- *What are the recommendations for TransformTO's 2030 EV target, based on the lessons learned from other cities in the world?*

To achieve the TransformTO Net Zero target of 100% zero emissions from transportation by 2040, it will be necessary to have 100% of the personal vehicles to be Zero-emission vehicles (City of Toronto, 2021). Therefore, it was considered important to evaluate Toronto's current strategy, policy incentives, resources and identify the gaps. With the aid of the evaluation framework developed in Research Objective 3, an evaluation of Toronto's EV Strategy was conducted. This helped in identifying the current gaps in Toronto as well as determining the best practices and recommendations from other Cities.

Methodology

An overview of the research methods for each research objective is highlighted through the figure 1 below.

Figure 1: Overview of my research methods for each research objective



Review of academic and grey literature to determine drivers in EV adoption

Research Objective 1: Review the academic literature to assess theories for drivers in Electric Vehicle adoption.

The following research method was used for this objective:

Literature review- A systematic literature review was conducted to identify the established theories for the factors driving the adoption of personal Electric Vehicles in Urban Cities. Both academic and grey literature were included in the review since grey literature is prominent in the electric mobility sector and it gives a technical perspective of the recent developments across the globe.

This step was precedent to the research methods for Research Objective 3, where the evaluation framework was developed to assess and compare the performance of Cities in terms of their EV Strategy.

Reviewing the factors driving EV adoption in four Cities: London, San Francisco, Oslo, Shanghai

Research Objective 2: Review the Electric Vehicle strategy adopted by Cites across the world.

The Research Objective 2 answered the following question:

Which factors have successfully contributed to driving EV adoption in Cities across the world?

Rationale for selection of the four Cities **-** The first step for this objective was determining the rationale for selecting the Cities based on the research objectives requirements.

The first rationale for shortlisting the Cities was the percentage of the EV sales share in comparison to the total sales of personal vehicles in 2022. The International Energy Agency (IEA) Global EV data explorer tool was used to analyse the EV sales share. The tool provides country-level data of the percentage of the number of EVs sold out of the total number of cars sold in 2022 (Global EV Data Explorer – Data Tools, 2023) . The tools also offered additional filter options for selecting the transport mode. To align with the research objective of the paper, cars were selected from the list which included other transportation modes such as Trucks, Vans and Buses. The EV sales share for each country was reviewed and it was identified that Norway, China, United Kingdom and United States were some of the countries with high rate of EV sales share in 2022 with Norway having the highest percent in the world. The below table outlines the EV car sales share in 2022 as reviewed in the IEA Global EV data explorer (Global EV Data Explorer – Data Tools, 2023).

Table 1: EV car sales share % in 2022 for selected countries

Country	EV car sales share % in 2022
Norway	88%
China	29%
United Kingdom	23%
United States	7.7%

The second rational for shortlisting the Cities was through a review of publications which discussed the EV capitals of the world. A publication on EV capitals of the world with the emphasis on Cities with highest number of EV sales share of new passenger vehicles registered was reviewed and analysed (Electric Vehicle Capitals: Cities Aim for All-Electric Mobility, 2020) The publication highlighted 25 cities with highest EV sales share as shown in the figure 2 below.

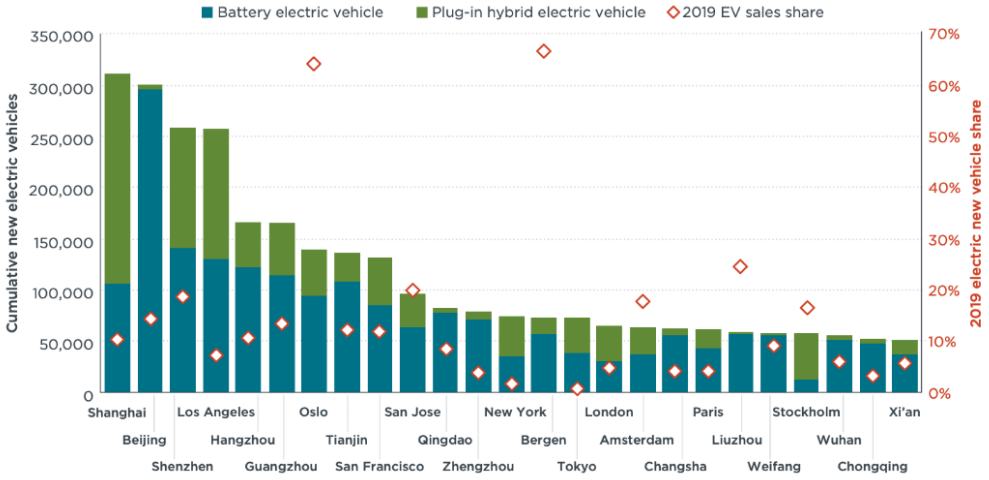


Figure 2: Cumulative electric passenger vehicles through 2019, and 2019 electric vehicle share of new passenger vehicles in the 25 metropolitan areas with the most electric vehicles.

Based on the list of countries identified from the IEA Global EV data explorer and the cities that were discussed as EV capitals in figure 2, four Cities were shortlisted for reviewing their EV strategy in further detail: Oslo, Shanghai, San Francisco and London.

Following the selection of cities, a systematic review of academic and grey literature for analyzing the Cities' EV strategy and factors contributing to the EV adoption was conducted. The literature review included an assessment of the Cities EV strategy which encompasses the targets, policies, incentives, and other relevant implementation plans. Through this research objective, a comprehensive analysis of the successful EV strategies adopted by Cities across the world was conducted which in turn helped with the development of the evaluation framework and the comparative analysis for measuring Toronto's performance.

Developing Evaluation Framework

Research Objective 3: Develop an evaluation framework to measure and compare the EV Strategy in Cities.

As highlighted earlier, measuring the performance of Toronto's EV strategy is integral to determine the effectiveness of its current initiatives. Therefore, an evaluation framework was developed for a comparative analysis.

The following steps were implemented to develop the evaluation framework:

a) Identification of the parameters for evaluation framework: Based on the research objectives 1 and 2, the key parameters which act as drivers for EV adoption in Cities were analysed and aggregated. The aggregated parameters were then classified into social, economic, technological, environmental, and policy-related factors for the analysis.
b) Development of the framework: Based on the parameters identified, an evaluation framework was built to evaluate the EV strategy of Toronto.

Evaluating City of Toronto's EV strategy

Research Objective 4: Evaluate Toronto's EV Strategy and identify lessons learned from the other Cities for application in TransformTO 2030 EV target.

An evaluation was conducted based on the analysis of TransformTO documents and other relevant literature in alignment with the evaluation criteria built in Research Objective 3. Post the evaluation, gaps from Torontos' current strategy were identified and lessons learned from other Cities were documented to determine the recommendations.

Literature Review

Review of factors driving EV adoption among consumers

As part of the Research Objectives 1, a systematic literature review was completed to identify the parameters which drive EV adoption among consumers. Both academic and grey literatures were analysed, as grey literature is a prominent in the ever-evolving field of Electric Vehicles and provides more technical and real-time aspects of the different factors impacting its adoption.

29 academic journal articles and 19 grey literature reports were shortlisted and reviewed to analyze the factors which drive EV adoption among the consumers.

A large number of academic and grey literature studies indicated that the primary driving factor for EV adoption among the consumers were regulations and targets introduced by the government such as- greenhouse gas reduction targets (Brescia et al., 2023; Cecere et al., 2018; Du et al., 2018) ; government policies and targets to achieve certain percentage of car sales to be EV by a target year(Habich-Sobiegalla et al., 2019; Lin & Wu, 2018; Tan et al., 2023); climate -related targets

and action plans issued at the different levels of the government (Austmann, 2021; Chandra, 2022; Jansson & Rezvani, 2019; Rietmann & Lieven, 2019). In addition to the policies and targets for EVs, another factor which was discussed as a driving factor in the document was the government incentive in the form of preferential or free parking offered for EVs in public areas (Bjerkan et al., 2016; Chandra, 2022; Ghasri et al., 2019; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; Ling et al., 2021; Rietmann & Lieven, 2019; Sovacool et al., 2019). Some literature also suggested that toll waivers offered for EVs successfully motivated the consumers to make the purchasing decision in some cities (Bjerkan et al., 2016; Chandra, 2022; Habich-Sobiegalla et al., 2019; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; Rietmann & Lieven, 2019; Xue et al., 2021). It was observed that the factors discussed above were stemming from the common focus area of government policy, targets and regulation related initiatives.

Several documents that were reviewed indicated that financial incentives offered to purchase EVs in the form of subsidies or financial discounts or income tax credits and discounts were highly instrumental in promoting the EV uptake among the consumers across the world (Austmann, 2021; Bjerkan et al., 2016; Cecere et al., 2018; Junquera et al., 2016; E. Kim & Heo, 2019; Salari, 2022; Tan et al., 2023). In addition to purchase incentives, another factor which was frequently interpreted as a motivation factor for EV adoption was the availability of funding for EV charging infrastructure for both private and public parking spaces as discussed in different literatures (Austmann, 2021; Chandra, 2022; Habich-Sobiegalla et al., 2019; Junquera et al., 2016; Rietmann & Lieven, 2019; Tan et al., 2023). Another economic factor that was interpreted by the literature as a motivating factor for adoption of EVs was the vehicle related tax exemptions or discounts from Value Added Tax (VAT) or purchase tax or vehicle registration tax (Bjerkan et al., 2016; Brescia et al., 2023; Chandra, 2022; Ghasri et al., 2019; Ingeborgrud & Ryghaug, 2019; Ling et al., 2021; Sovacool et al., 2019; Tan et al., 2023; Ye et al., 2021). The reduced operational costs associated with the transition from fossil fuel to electric powered vehicles was interpreted as a driving factor among the consumers, especially in the regions where the cost of electricity was cheaper than gasoline as discussed by a number of documents (Brescia et al., 2023; Cecere et al., 2018; Chandra, 2022; Ingeborgrud & Ryghaug, 2019; Salari, 2022; Tan et al., 2023; Westin et al., 2018; Xue et al., 2021).

There were several social factors that were identified to be influencing the decision- making process for consumers while transitioning to the EVs. Community awareness and engagement with respect to the EV related incentives offered by the government and accessible services in the form of public EV charging infrastructure was interpreted by a number of literatures as a motivating factor (Kothari & Sclar, 2020), (C40 EV Charging infrastructure and business case models : Cities, 2023). The neighbourhood planning and zoning for equitable accessibility of the EV infrastructure across all levels of income groups was also discussed as a social factor which promoted EVs among different communities (C40 EV Charging infrastructure and business case models : Cities, 2023), (Werthmann & Kothari, 2021a), (Kothari & Sclar, 2020). The literatures highlighted that prioritizing equal accessibility to public EV charging infrastructure enabled community engagement as well as developed a positive outlook towards EVs among the community members. There were some additional socio-demographic factors that were discussed as determinants for EV adoption: gender (Berliner et al., 2019; Bjerkan et al., 2016; Chandra, 2022; Ghasri et al., 2019) and family size (Berliner et al., 2019; Bjerkan et al., 2016; Ghasri et al., 2019; Sovacool et al., 2018; P. Wang et al., 2022). However, some literature indicated that there was no clear corelation between these factors- gender, household size and the purchasing decision for EVs among the

consumers (Habich-Sobiegalla et al., 2019; Jansson & Rezvani, 2019; Ye et al., 2021). Therefore, these socio-demographic characteristics such as gender and household size were not considered further for the development of the evaluation framework.

Availability of the EV charging infrastructure in public and residential areas was highlighted as one of the most significant drivers of EV adoption in several documents (Austmann, 2021; Ingeborgrud & Ryghaug, 2019; Junquera et al., 2016; E. Kim & Heo, 2019; Ling et al., 2021; Rietmann & Lieven, 2019; Tan et al., 2023; P. Wang et al., 2022; White & Sintov, 2017; Xue et al., 2021). The literature highlighted the corelation between the availability of charging infrastructure with driving range anxiety and further explained how availability of an extensive charging network in public spaces helped alleviate the anxiety associated with low battery of the EVs while driving long distances. Another factor which was frequently discussed in the literature as a motivating factor for the transition to EVs was the availability of the technology to convert the existing public infrastructure into charging stations as seen for the pole-mounted chargers in areas with limited personal parking spaces (C40 EV Charging infrastructure and business case models: Cities, 2023). The feasibility to convert the existing lamp poles into charging points specifically for residential areas with no personal parking spaces was analyzed to be instrumental in greatly influencing the EV purchasing decisions among residents with no personal parking spaces in some cities such as London, San Francisco (Saha et al., 2022; Werthmann & Kothari, 2021a).

Some literature identified that environmental benefits such as the reduction of greenhouse gas emissions and the reduction of air pollution motivated consumers to make the transition from ICE vehicles to the EVs. The literature suggested that the consumer's concern for climate change and environment consciousness was directly corelated with their intention to purchase an EV and make a positive impact on the environment (Berliner et al., 2019; Bjerkan et al., 2016; Brescia et al., 2023; Cecere et al., 2018; Du et al., 2018; Habich-Sobiegalla et al., 2019; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; Tan et al., 2023).

Legal factors such as the emission control mandates in the form of emissions inspection fee levied on ICE car owners was discussed in some literature as one of the factors which motivated the consumers to make the transition to EVs (Austmann, 2021; Ghasri et al., 2019; Ling et al., 2021). The literature suggested that the introduction of fees for emissions generated by the ICE vehicles enabled the transition to EVs in some countries. A similar emissions standard introduced for the car manufacturers by mandating them to sell EVs as certain percentage of their total car sales motivated the sale of EVs as it helped alleviate the issues associated with the low supply in the market in comparison with the demand.

The above factors which were identified through literature review conducted as part of the objective 1 were further analysed from the perspective of their relative level of importance to develop the evaluation framework as part of the objective 3. The analysis of these factors and their level of importance is discussed in the analysis section of the paper.

Review of the factors driving EV adoption in four Cities: London, San Francisco, Oslo, Shanghai

As part of the research objective 2, four cities: London, San Francisco, Oslo and Shanghai were analyzed from the perspective of what factors contribute towards the high adoption rate of personal EVs among the residents of the Cities. Both academic and grey literature were analyzed for each

of the City. The grey literature was more specifically referred since it provided a better overview of the City's initiatives, policies and other relevant contributions towards EV adoption.

San Francisco

a) **EV related policies and targets at different levels of government** has played a major role in achieving high adoption rate in San Francisco (Saha et al., 2022). At the federal level, there is a National Ambition that 50% of all new vehicles which are light duty vehicles (LDV) sold in the United States will be zero emissions vehicles by 2030 (IEA Global EV Policy Explorer – Data Tools, 2023). Furthermore, California Air Resources Board (CARB) has the regulation- Advanced Clean Cars II Rule (California Air Resources Board, 2022). As part of this regulation, the State laid down a year-by-year roadmap to ensure that the sale of all new passenger vehicles in the state will be zero-emission by 2035 (California Air Resources Board, 2022). At the City level, San Francisco's 2021 Climate Action Plan outlined that by 2030 vehicle electrification will increase to at least 25% of all registered private vehicles, and to 100% by 2040 (San Francisco Climate Action Plan, 2021).
b) **Policies relevant to commercial and residential charging infrastructure in parking lots for EVs** were interpreted to be one of the major factors promoting EV adoption among the consumers in San Francisco (Saha et al., 2022). In 2021, Bill 970 was implemented which fast tracked the permit application review process (within 20 days) for charging stations (Bill Text - AB-970 Planning and Zoning Electric Vehicle Charging Stations Permit Application Approval., 2021). Additionally, the City of San Francisco has a Green Building Code with an EV readiness requirements which are applicable for residential and commercial buildings that will be constructed newly as well as the existing buildings which are undergoing major alterations.
c) **Funding and incentives** offered by the government for purchasing EVs was one of the factors that were considered to be of relatively higher importance in San Francisco as discussed in (Fisher et al., 2020) and (Debnath et al., 2021). The Federal government offers Clean Vehicle tax credit which provides funding up to $7,500 for new EVs purchased with certain criteria needed to be fulfilled for qualifying (San Francisco Environment Department (SFE), 2022). Additionally, there is also a $4,000 tax credit offered for used EVs. The State of California has a California Clean Vehicle Rebate Project (CVRP) which offers rebate of $1000 to $4500 for purchasing or leasing qualified EVs. The accessibility to different funding options from the national, state and the city level government enables the effective implementation of San Francisco's EV target as well as supports higher EV adoption among the consumers from varying income groups (Fisher et al., 2020).
d) **Community engagement and equitable accessibility-** Low-income households receive additional $2,500 rebate under required qualifying criteria. This supports the equitable accessibility of EVs to the underserved community members (San Francisco Environment Department (SFE), 2022). The Pacific Gas and Electric (PG&E) offers an Empower EV program which provides incentives upto $2,500 for eligible low-income households supporting them to cover some of the cost associated with purchasing an EV and/or installing the charging infrastructure. The Clean Cars for All program offered by the Bay Area Air Quality Management District provides incentives of up to $9,500 for low-income Bay Area residents which includes the City of San Francisco, to retire their older car and replace it with a hybrid, plug-in hybrid, battery, or hydrogen fuel cell electric vehicle (Bay Area Air Quality Management District- Clean Cars for All, 2024).
e) **Preferential access to HOV lanes-** The California Department of Motor Vehicles provides special decals/stickers for electric vehicles if they meet the qualifying criteria of specific

emissions standards. These decals/stickers enable the electric vehicles to access the High Occupancy Vehicle (HOV) lanes (California Air Resources Board, 2024). The preferential access to HOV lanes provided to the EVs is perceived to be one of the motivating factors for EV adoption among consumers (Chandra, 2022); (Ghasri et al., 2019); (Rietmann & Lieven, 2019).

f) **EV charging infrastructure subsidy –**Based on the literature reviewed for San Francisco, it was suggested that making charging infrastructure affordable was an essential part of achieving the ambitious target related of 100% EVs by 2040 (Werthmann & Kothari, 2021a). At the Federal level there is a National Electric Vehicle Infrastructure Formula Program (NEVI formula) which provides funding to states for the deployment of the electric vehicle charging infrastructure (Bipartisan Infrastructure Law - National Electric Vehicle Infrastructure (NEVI) Formula Program Fact Sheet | Federal Highway Administration, 2021). There are several incentives provided by the San Francisco City Utility providers for EV charging infrastructure installation including the EV Charge SF. The EV Charge SF provides funding of up to $120,000 for installation of EV chargers and related infrastructure for both commercial and residential projects that meet the minimum requirements (EV Charge SF, 2023).

g) **Emission Standards for cars-** Different publications argued that the introduction of stringent standards for gasoline cars enabled the implementation of San Francisco's EV target. The literatures mainly referred to Advanced Clean Cars II regulation (California Air Resources Board, 2022). Under the Advanced Clean Cars II, the State of California has set stronger standards compared to the US EPA which sets the requirement of gradual increase in the number of ZEVs to 100% by 2035. Setting of the stringent emissions standards can therefore be considered as a motivating factor for car owners to replace their gasoline cars with electric vehicles.

h) **Accessibility to public charging infrastructure-**Equitable distribution of the charging infrastructure accessible to the consumers from different types of residential areas, and income levels, especially in the areas where the residents use on-street parking was considered to be relatively higher important driving factor for EV adoption (Werthmann & Kothari, 2021a). San Francisco's Climate Action Plan outlines its plan of expanding the public charging infrastructure by completing an evaluation framework to develop curbside charging pilots by 2022, as well as expand charging to 10% of the spaces owned by commercial and municipality owned parking lots (San Franciso Climate Action Plan, 2021).

i) **Lower operating cost-** Fuel cost savings associated with switching the fossil-fuel run cars with electric vehicles is considered as one of the driving factors for EV adoption among the consumers, specifically in the Cities like San Fracisco where the utility providers offer discount rates for home charging (San Francisco Environment Department (SFE), 2022). Additionally, the City provides the consumers an opportunity to compare the cost of driving an alternative fuel vehicle through the Alternative Fuels Data Center's Vehicle Cost Calculator- an United States Department of Energy's initiative (Alternative Fuels Data Center: Vehicle Cost Calculator- US Department of Energy, 2023).

Oslo

a) **EV-related targets and policies implemented by the government-** Several academic and grey literatures that were reviewed inferred that Oslo's success story for EV adoption could be significantly attributed to the ambitious carbon neutrality targets set by the City(Here's How Oslo Became the Capital of EV Cars- Infrajournal, 2022). The City has set aggressive targets for carbon-neutrality in transportation with the aim of having all the newly registered car sales to be electric by 2025 (C40 EV Charging infrastructure and business case models : Cities, 2023). The

Norwegian EV Scheme which dates back to the 1990's is often cited as one of the most important factor for making Norway a pioneer in the EV revolution (Aasness & Odeck, 2015).

b) **Tax exemptions-** The City offered exemption of 25% Value Added Tax (VAT) on purchase of an EV from 2001 to 2022. Additionally, no annual road tax had to be paid by the EV owners from 1996 until 2021. These exemptions were removed in 2022 due to achievement of the relevant EV-related target when the government reviewed the incentives for EV in 2021. Based on the analysis of driving factors discussed in different literatures, it was observed that tax exemptions were one of the major motivating factors for EV purchasing decisions (Bjerkan et al., 2016).
c) **Toll waivers-** During the period of 1997-2017, the City of Oslo offered 100% toll waivers for the EV owners. This incentive helped motivate the purchase of EVs among the consumers (Ingeborgrud & Ryghaug, 2019) . Based on the success observed in the EV adoption rate, the government reduced the incentive rate to 50% toll since 2018.
d) **Incentives for charging infrastructure-** The City of Oslo introduced a few incentives for charging infrastructure: installation of 400 charging points at public locations through the Climate and Energy funds, subsidies for home charger installations using the Housing Cooperative Fund (C40 EV Charging infrastructure and business case models : Cities, 2023). The incentives offered for chargers for both public and residential locations supported the accessibility to charging infrastructure which in turn motivated the adoption among consumers in Oslo (Bjerkan et al., 2016).
e) **Preferential parking-** As part of its early incentives offered to EV owners, the City of Oslo offered free public parking and charging in municipal areas from 1997 to 2017 (Aasness & Odeck, 2023). This incentive was discussed in the academic literatures as one of the successful factors that supported the adoption of EV among consumers. Since 2017, the parking fee is 50% of the amount charged for the conventional vehicles powered by fossil fuel.
f) **Access to High Occupancy Vehicle (HOV) lanes-** The EV owners in the city are allowed to access the bus lanes. This incentive helped the EV owners reduce their travel time during peak hours, however with the increase in the number of EVs in the City, the lanes were observed to get congested resulting in some amendments where only the EVs with more than one passenger can take the lane now(Aasness & Odeck, 2023).

Shanghai

a) **EV-related target and policy issued by the government-** The City of Shanghai had a target of annual sales of new EVs to be 60,000 by 2020 which was achieved with more than twice the targeted sales numbers (ICCT- Accelerating New Energy Vehicle Uptake in Chinese Cities, 2023). Furthermore, there is a national level EV target- New Electric Vehicle Sales in key air pollution control regions to account for about 50% of new vehicle sales by 2030. Several documents argued that EV related mandates in the form of target issued at the city and the national level supported the high adoption rate of EVs among the consumers in Shanghai and China overall (Zhao et al., 2022).
b) **Tax exemptions-** Most of the literature discussed the National level tax exemption offered on the purchase of EVs for both annual vehicle tax and purchase tax. Based on the interpretation of the literatures, it was inferred that tax exemptions motivated the consumers to prefer buying EVs in comparison to the conventional vehicles (Peng & Bai, 2023).
c) **Financial assistance for charging infrastructure-** The City of Shanghai offers subsidy to every EV owner for their home charging infrastructure in a manner that the subsidy is directly linked to the individuals home account with the municipal power company. Additionally, the City has implemented a building-code for EV charging infrastructure to ensure the residents have access

to the relevant charging needs (ICCT- Accelerating New Energy Vehicle Uptake in Chinese Cities, 2023) . It was suggested by the literature that the accessibility to charging and incentives offered for the installation of charging infrastructure was one of the most important driving factor for EV among the consumers (Yang & Chen, 2021; Zhang & Bai, 2017; Zhao et al., 2022).

d) **Preferential parking for EV owners-** The presence of dedicated parking spot for EV owners in the municipal parking locations promoted the adoption of EVs (N. Wang et al., 2017). Shanghai reserves 10% of the spots in the municipal parking lots for electric vehicles (ICCT- Accelerating New Energy Vehicle Uptake in Chinese Cities, 2023). This has been considered as one of the incentives that have positively impacted the EV purchasing decisions among the consumers (Peng & Bai, 2023).

London

a) **Government target related to EV-** Based on the interpretation of a grey literature , it was inferred that the transportation commitments under the Net Zero Strategy at the city and national level was responsible for promoting the uptake of EVs among consumers (C40 EV Charging infrastructure and business case models : Cities, 2023). The Government of UK announced that by 2030, the sale of new diesel and petrol fuelled cars will be phased out (City of London-Transportation Strategy , 2021). By 2035, all new cars and vans must have zero emissions at the tailpipe. This ambitious target enabled the EV adoption among the consumers.

b) **Tax exemption-** As part of the EV strategy, the government offers 100% exemption from vehicle tax for EV owners (Transport for London, 2021). Furthermore, there is no vehicle excise duty required to be paid, which promotes the purchase of EVs among the consumers as it supports monetary savings every year in comparison to the purchase of ICE vehicles (ICCT-Can London be a model for Zero Emission Mobility, 2018). This incentive was observed to be one of the factors which supported the consumers to uptake EVs.

c) **Subsidies for charging infrastructure-** As part of the EV infrastructure strategy, the City of London provides funding to support the charging infrastructure - extend support for charge point installation at homes, workplaces, and on street locations and expand the accessibility to charging stations- support the roll out of larger on-street charging schemes and rapid hubs. Furthermore, the City offers on-street residential charge point scheme (ORCS) which funds up to 50% of the capital cost of installing a device (C40 EV Charging infrastructure and business case models : Cities, 2023). The charging infrastructure funding incentives were interpreted from the literatures as one of the primary factors which promoted the adoption of EVs among the consumers.

d) **Accessibility to public charging infrastructure-** The City of London has acknowledged the importance of a network of high-speed charging infrastructure across public locations to successfully implement its 2030 target. Therefore, the city has allocated more than 4,800 on-street predominantly lamp post column charging points with a plan of further increasing them. The city has more than 8,600 charging points, including 700 rapid charging points which supports in increasing the consumer confidence and provides reassurance to the EV drivers to take long distance routes with ample coverage of charging points across the City (City of London-Transportation Strategy, 2021).

e) **Emissions inspection fee-** London has an Ultra Low Emissions Zone (ULEZ) which charges cars a toxicity fee every day to enter if they are fossil-fuel powered. The EVs are given a 100% discount to enter the ULEZ with no fee charged to them (C40 EV Charging infrastructure and business case models : Cities, 2023). This incentive promoted the consumers to consider switching to an EV and save on the emissions inspection fee they otherwise have to pay for their conventional fuel-powered cars.

The literature review for both the research objectives 1 and 2 as discussed above, suggested that the factors driving EV adoption among the consumers in Cities were attributable under different focus areas: social characteristics such as community engagement; economic characteristics such as income level, and operational savings on EVs; political factors such as government led EV targets and incentives, technological characteristics; environmental benefits such as GHG reductions and legal attributes associated with inspection fees. Therefore, based on the preliminary analysis of the factors as well as drawing inspiration from the analysis used in academic literature (Chen et al., 2020), (Debnath et al., 2021), it was decided to categorize the EV driving factors under either one of the political, economic, social, technological, environmental or legal (PESTEL) categories. Furthermore, the factors were analyzed and assigned a relative importance level based on the qualitative interpretation of the literature to support the development of the evaluation framework. This is discussed in the analysis section of the paper.

Analysis

Analysis of the factors and development of an evaluation framework

Based on the literature review of the factors driving EV adoption among the consumers (objective 1) as well as in the cities (objective 2) as discussed in the above section, the factors were categorized into PESTEL categories, and a relative level of importance was assigned to them based on interpretation of the literature to develop an evaluation framework:

Political

- **EV-related commitment/ targets** taken by the government was considered to be of high importance criteria among the different factors that were analysed. This was interpreted based on the analysis that for all four of the Cities had outlined this factor as one of the primary driving factors for EV adoption. Additionally, several academic studies highlighted the relatively high importance of this factor in terms of its power to influence consumer's purchasing decisions (Austmann, 2021; Brescia et al., 2023; Cecere et al., 2018; Chandra, 2022; Du et al., 2018; Habich-Sobiegalla et al., 2019; Ingeborgrud & Ryghaug, 2019; Jansson & Rezvani, 2019; Rietmann & Lieven, 2019; Tan et al., 2023)
- **Incentives introduced by the government in the form of toll waivers, driving lanes and license plates** were assigned a medium level of importance. Two of the four cities that analyzed offered some of these incentives- for instance only Oslo and San Francisco offered special access to lanes for EVs. License plates for EVs were offered only by Shanghai when compared to other cities. The academic literatures interpreted them as secondary incentives which supported the EV adoption among the consumers in combination with other relatively more important factors such as financial incentives (Bjerkan et al., 2016; Chandra, 2022; Habich-Sobiegalla et al., 2019; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; Lin & Wu, 2018; Ling et al., 2021; Rietmann & Lieven, 2019; Sovacool et al., 2019; Xu et al., 2021).
- **Incentives for EV manufacturers**- The subsidies offered by government to the EV manufacturers was discussed as a positive influence on consumer's perception on EV (ICCT- Accelerating New Energy Vehicle Uptake in Chinese Cities, 2018; Habich-Sobiegalla et al., 2019; Tan et al., 2023; Zhang & Bai, 2017). However, this incentive was considered as a secondary factor by the literatures in terms of it influencing power on consumers since it is for the manufacturers and acts as a supportive factor to other direct

factors impacting the consumers. Based on the analysis of the literatures, a medium level of importance was attributed to this factor.

- **Policies for preferential parking and charging for EVs in public**- This factor was given a medium level of importance in comparison to other factors. Several literatures interpreted this factor to positively influence the consumers and act as a supportive parameter to factors which were relatively of higher importance- purchase incentives, government targets for EVs among others (Austmann, 2021; Bjerkan et al., 2016; Chandra, 2022; Ghasri et al., 2019; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; Li et al., 2020; Rietmann & Lieven, 2019; Sovacool et al., 2019; Xue et al., 2021). Shanghai, Oslo and London offer discounted/free or preferential parking to EV owners, and it was interpreted to be one of the driving factors for the uptake of EVs among the consumers.

Economical

- **Financial Incentives to purchase EV-** Provision of financial incentive to purchase an EV was interpreted by several literatures to be one of the most important driving factors for EV adoption (Austmann, 2021; Bjerkan et al., 2016; Brescia et al., 2023; Cecere et al., 2018; Chandra, 2022; Ghasri et al., 2019; Habich-Sobiegalla et al., 2019; Junquera et al., 2016; E. Kim & Heo, 2019; M.-K. Kim et al., 2018; Li et al., 2020; Ling et al., 2021; Rietmann & Lieven, 2019; Salari, 2022; Tan et al., 2023; P. Wang et al., 2022). Additionally, funding incentives offered by the City of San Francisco was considered very critical in promoting equitable uptake of EVs among different income groups (Fisher et al., 2020). Therefore, this factor was given a high importance compared to other factors.
- **Exemption from various vehicle related taxes-** Exemption or discounts from taxes such as one-time purchase tax, value-added tax, road tax and annual vehicle tax were considered to be one of the economic benefits that enabled the uptake of EVs among consumers in London, Shanghai and Oslo. The literatures interpreted this factor as a supportive influence on other economic factors like purchase incentives since tax exemption would act as an added benefit on the overall economical savings for the customers (Austmann, 2021; Brescia et al., 2023; Ghasri et al., 2019; Ingeborgrud & Ryghaug, 2019; Ling et al., 2021; Rietmann & Lieven, 2019; Tan et al., 2023; Ye et al., 2021). Therefore, a medium level of importance was attributed to this factor.
- **Incentives for EV charging infrastructure-** Several studies attributed a significantly high level of importance to the charging infrastructure incentives for a successful implementation of EV strategy in Cities (Austmann, 2021; Chandra, 2022; Habich-Sobiegalla et al., 2019; Rietmann & Lieven, 2019; Tan et al., 2023; Werthmann & Kothari, 2021b). Additionally, all the four cities- Oslo, London, Shanghai and San Francisco attributed incentives for charging infrastructure as a primary driving factor for EV adoption. Therefore, this factor was given a high level of importance.
- **Reduced operating cost for EVs compared to ICEVs-** Reduced operating cost for EVs was interpreted by several literatures as a supporting factor for purchase incentives and other economic factors which enabled a positive influence on the consumers (Brescia et al., 2023; Chandra, 2022; Ingeborgrud & Ryghaug, 2019; E. Kim & Heo, 2019; Tan et al., 2023; Xue et al., 2021). In comparison to other factors such as financial incentives and charging infrastructure subsidy, reduced operating cost was considered to be of lower importance by the literatures and therefore assigned a low level of importance.

Social

- **Community awareness on EV benefits-** Understanding the needs of the community through community engagement with different groups of stakeholders including the representatives of local community members is considered a vital requirement for planning the implementation EV strategy (C40:How to Build an Electric Vehicle City: Deploying Charging Infrastructure, 2021). Different literature suggested that while community engagement was considered to be a supportive factor in influencing consumer's buying decisions, it was mostly complementing other factors such as government targets for EVs, subsidies and incentives which were more significant in influencing consumers and therefore its importance was assigned a low level (C40:How to Build an Electric Vehicle City: Deploying Charging Infrastructure, 2021), (Kothari & Sclar, 2020),(Salari, 2022).
- **Equitable accessibility of EV infrastructure-** Equitable accessibility of charging infrastructure as well as funding for EVs for different income level groups was considered to be one of the most critical factors influencing the success of EV targets in Cities (C40 EV Charging infrastructure and business case models : Cities, 2023). London and San Francisco offer funding opportunities to ensure equitable distribution of the charging infrastructure across varying income levels. The literature interpreted this factor to have a high level of importance from the perspective of effective implementation of policies and targets relevant to EV targets at the city-level (Austmann, 2021; (C40 EV Charging infrastructure and business case models : Cities, 2023; Chandra, 2022; Sovacool et al., 2018; Tan et al., 2023).

Technological

- **Availability of public charging infrastructure-** Accessibility to charging infrastructure greatly influences consumer's perception of driving an EV, the driving-range anxiety linked with charging the EVs is eliminated with an extensive range of public charging infrastructure (C40 EV Charging infrastructure and business case models : Cities, 2023). All the four cities that were reviewed have initiatives and policies to enable the implementation of an extensive charging infrastructure network in residential areas through pole-mounted charging points, building ready-codes, and policies for commercial parking areas. Literatures attributed a very high level of importance in effective implementation of the EV targets in cities (Austmann, 2021; Ingeborgrud & Ryghaug, 2019; M.-K. Kim et al., 2018; P. Wang et al., 2022; White & Sintov, 2017; Xue et al., 2021) .Therefore this factor was attributed a high level of importance.
- **Technological advancements to convert existing infrastructure into charging point—** The Cities are often confronted with the high cost of installation charges and lack of space for installing chargers. Therefore, many Cities like London have adopted the technology to convert existing curb-side streetlamps into an extensive charging infrastructure network of pole-mounted chargers in London (City of London- Transportation Strategy, 2021). Different studies that were reviewed for this factor interpreted that the availability of technological advancements for on-street charging infrastructure supplemented other factors which were more vital such as charging infrastructure subsidy and incentives from the government (Saha et al., 2022; Salari, 2022; Werthmann & Kothari, 2021a). Therefore, it was given a medium level of importance.

Environmental

- **EVs contributing to reduction in air pollution and emissions-** Some of the academic literature outlined that consumer's concern for climate change prompted them to switch to EVs considering the benefits associated with it in the form reduction of GHG emissions and air pollution(Berliner et al., 2019; Bjerkan et al., 2016; Brescia et al., 2023; Habich-Sobiegalla et al., 2019; Ingeborgrud & Ryghaug, 2019). These literatures outlined that consumer's environment consciousness and the environmental benefits associated with EVs did not directly influence the EV buying decision but supplemented other factors such as government policies and targets for EVs in influencing the consumer's buying decisions. Therefore, a low level of importance was given to this factor.

Legal

- **Emissions Standards for vehicles-** The introduction of emissions standards specifically for vehicles such as the vehicle sales standard enacted by the State of California under its Advanced Clean Cars Rule (IEA- Data Policy Explorer, 2023) influences consumers to purchase EVs. Vehicles standards not only influence the consumer's decisions to switch to EVs but also the car manufacturers who need to follow the strict guidelines while manufacturing the cars to ensure zero emissions from the cars. Although it is responsible impacting the EV sales, some literature argued that it was more relevant in influencing the manufacturers directly rather than the consumers (Austmann, 2021; Chandra, 2022; Ling et al., 2021). Therefore, this factor was given a medium level of importance.
- **Emission inspection fee for vehicles-** The emissions inspection fee levied in Cities with Zero Emissions Zones is interpreted to be influencing the uptake of EVs among the consumers living or working in those zones (C40: *Zero Emission Area Programme*, 2022). London has seen an increase in the EV sales which is directly corelated to Ultra Low Emission Zone (C40 EV Charging infrastructure and business case models : Cities, 2023). Several literatures interpreted that this factor successfully complements the implementation of government policies and targets for EVs in Cities by influencing consumers' buying choices (Austmann, 2021; Ghasri et al., 2019; Ling et al., 2021). Therefore, a medium level of importance was assigned to this factor.

Based on the above PESTEL factors and the level of importance assigned to them, the evaluation framework was developed as shown below. For each factor, evaluation guidance was developed as well. This framework was used for evaluating the City of Toronto's EV strategy which is discussed in the next section.

Table 2: Evaluation framework for evaluating City of Toronto's EV strategy

Category	Evaluation metric	Relative importance of the metric	Guidance for evaluation
Political	EV related commitments/targets taken by government	High	Whether the city has any EV related target/ commitments in the City?
	Incentives introduced by the government in the form of toll waivers, preferential access for license plates and driving lanes for EVs	Medium	Whether the City offers incentives for EVs such as: 1. Toll waivers 2. Preferential access of license plates 3. Driving lanes

	Incentives for EV manufacturers	Medium	Whether the government offers any subsidies to the EV manufacturers thereby promoting local manufacturing and high supply of EVs
	Policies for preferential parking and charging for EVs in public and residential zones	Medium	If there are any preferential parking and charging infrastructure-related policies in public places and residential zones.
Economical	Financial Incentives to purchase EV	High	Whether the city offers any financial incentives for purchasing personal EVs
	Exemption from various vehicle related taxes	Medium	Exemption of vehicle registration taxes, one-time purchase tax, sales tax among others
	Incentives for EV charging infrastructure	High	Availability of incentives for installation of EV charging infrastructure at home, residential buildings
	Reduced operating cost for EVs compared to ICEVs	Low	Whether the electricity cost to charge an EV is lower than the cost of using fossil-fuel powered vehicles?
Social	Community awareness on EV benefits	Low	Does the City create community-engagement initiatives for building awareness on EV target taken by the city and incentives, benefits?
	Equitable accessibility of EV infrastructure	High	Whether the EV infrastructure planning is done in a manner which ensures equitable accessibility for all income groups?
Technological	Availability of public charging infrastructure	High	Presence of EV charging points across the city, in comparison with the number of EVs
	Technological advancements to convert existing infrastructure into charging point- eg pole mounted charging points	Medium	If the existing public infrastructure can be used to be transformed into an EV charging facility such as on-street parking.
Environmental	EVs contributing to reduction in air pollution and emissions	Low	The progress made in reduction of the City's emissions through EV adoption
Legal	Emissions Standards for vehicles	Medium	Whether the city has any mandates for car manufacturers in terms of emissions standards?
	Emission inspection fee for vehicles	Medium	Whether the City has any inspection fee mandated for vehicles powered by fossil fuel?

Evaluation of City of Toronto's EV strategy using the evaluation framework

Based on the evaluation framework developed using the factors that were reviewed as part of the literature review, the evaluation of the City of Toronto's EV strategy was conducted with respect to each evaluation metric. A colour coding-based evaluation was done for each metric depending on the performance: green colour was assigned if the City performed well, yellow colour was assigned if there was opportunity to further improve and red colour was assigned if the City did not perform well at all and needs to work on that metric. The evaluation is further discussed in the table below.

Table 3: Evaluation of City of Toronto's EV strategy done using the evaluation framework

Category	Evaluation metric	Relative importance of the metric	Evaluation
Political	EV related commitments/targets taken by government	High	The City of Toronto has a TransformTO Net Zero Strategy with sector-specific interim targets for 2030 (City of Toronto, 2021). As part of the interim targets, the TransformTO strategy outlines an EV related target that 30% of the registered vehicles in Toronto will be electric by 2030 (City of Toronto, 2021). It is therefore interpreted that the city performed well in this metric with a strong EV related target, which is expected to influence the consumers to adopt EVs based on the success rate in certain cities.
	Incentives introduced by the government in the form of toll waivers, preferential access for license plates and driving lanes for EVs	Medium	The Ontario government has a Green License Plate Program which offers green license plates to eligible low carbon vehicles (Green license plate Ontario, 2024). The car owners with the green license plates can drive in High-Occupancy Vehicle (HOV) lanes. As seen in the case of Oslo, incentives like access to HOV lanes and toll waivers helped drive EV adoption among the consumers. The accessibility to HOV lanes offered by Ontario can therefore support the EV uptake among consumers in the City of Toronto who can benefit from the green license plate on highways. The City of Toronto performs well in this evaluation criteria, but there is room for improvement to supplement this with additional incentives.
	Incentives for EV manufacturers	Medium	The Ontario government has a 10-year strategy 'Driving Prosperity Plan' to encourage EV adoption among consumers by supporting the EV manufacturers and create a domestic corridor EV infrastructure within North America (Driving Prosperity, 2024). Furthermore, as part of the 2023 Ontario Budget, the government provides 10% refundable Corporate Income Tax Credit to lower the costs for manufacturers based in Ontario (Ontario Made Manufacturing Investment Tax Credit | Ontario.Ca, 2023). It is expected that this incentive will further attract EV manufacturers in Ontario to support the consumer demand and alleviate the supply chain issues. However, the initiative is at a very nascent stage since its implementation very recently. The implications of the initiative are not yet visible on the EV adoption rate and therefore cannot be included as part of the evaluation fully. It is therefore concluded that the City of Toronto is has not performed well in term of incentivizing EV manufacturers, but it is expected to improve with the provincial level initiatives implementation.
	Policies for preferential parking and charging for EVs in public and residential zones	Medium	Since 2023, the Toronto Parking Authority (TPA) has been operating and maintaining the EV chargers for both on-street and off-street parking points. TPA is the largest municipally owned commercial parking operator in North America, it is leveraging its parking portfolio to promote EV adoption among the consumers by offering EV charging points at its on-street as well as off-

			street parking areas (EV Charging – Green P Parking, 2023). Therefore, this initiative is expected to support City of Toronto to align its EV parking and charging strategy with the targeted growth in EV numbers by 2030. For residential areas, the Toronto Green Standard (TGS) outlines the requirements of EV charging outlets for the residential facilities. As per TGS, each new constructed dwelling unit with a residential parking space must be provided with an EV charging outlet capable of providing Level 2 Charging. Furthermore, the mid to high rise and commercial units with parking spaces must have 25 percent of the residential and non-residential parking spaces to have a Level 2 charging or higher (Toronto Green Standard, 2022). In 2018 the provincial regulations were changed to make it more convenient for the condominium corporations and owners to obtain approval for installation of charging infrastructure in Multi-Unit Residential Buildings (MURBs) (City of Toronto, 2019). Therefore, it is interpreted that this standard for residential areas is helping City of Toronto in aligning with the expected growth in EV numbers in the future. Although the City of Toronto does not offer any free or preferential parking space for EV owners, it has initiated EV charging facilities within the existing parking spaces in public and residential areas which will support the EV uptake among the consumers. However, there is still some room for improvement in terms of policies for preferential parking and charging for EVs.
Economical	Financial Incentives to purchase EV	High	The Government of Canada offers an Incentive for Zero Emission Vehicle (iZEV) under which rebates of upto $5,000 is offered to the buyers to reduce the high purchase price of the vehicles (Government of Canada, 2024). At the provincial level, the Ontario government does not offer any purchase incentive unlike British Columbia, Quebec and other provinces (Plug'n Drive Electric Vehicle Incentives, 2024). The City of Toronto currently does not offer any financial incentives to purchase EVs, therefore the consumers are dependent only on one incentive offered at the Federal level. Therefore, it is interpreted that the City of Toronto performs poorly in this evaluation metric.
	Exemption from various vehicle related taxes	Medium	There are no tax related incentives or exemptions offered in Canada. The City of Toronto currently does not offer any exemptions on vehicle related taxes for EVs, which can be recommended for improving the rate of EV adoption among the consumers. Therefore, it is deduced that the City does not perform well in this metric in comparison with other Cities with high EV adoption rate.
	Incentives for EV charging infrastructure	High	The City of Toronto offers a range of financial incentives for EV charging infrastructure. The EV Station Fund offers rebate of up to 50% of the installation cost for up to 20 EV charging stations to a maximum of $5,000 per Level 2 Charger, $15,000 per DC fast charger and $50,000 per DC fast+ charger to the residents of Greater Toronto and Hamilton Area (The Atmospheric Fund, 2022). At the federal level, the Zero Emissions Vehicle Infrastructure Program (ZEVIP) provides incentives up to 50% of the project costs, to a maximum of $5,000 per level 2 charger and $15,000- $75,000 per fast charger (City of Toronto- Electric Vehicles, 2021). Additionally, the City offers low interest loans – Home Energy Loan Program to support the cost associated with improving the infrastructure for installation of EV charging points in single-family properties such as detached, semi-detached or a row-house (City of Toronto, 2017b). Similarly, Energy Retrofit Loan program is offered to homeowners for financing the cost for retrofitting their homes to install EV chargers (City of Toronto, 2017a). It is interpreted that the City of

			Toronto performs well in this metric, and these incentives will help accelerate the EV adoption in the city.
	Reduced operating cost for EVs compared to ICEVs	Low	As per Toronto Hydro, the cost to charge a battery EV is $530 per year with the assumption that the charging will be done at a reduced electricity rate during the night at $1.45 per day. The plug-in hybrid EV will cost $925 per year with the assumption of $2.50 per day for both gasoline and electricity (Electric Vehicles- Toronto Hydro, 2024). Meanwhile, the cost associated with a gas vehicle is nearly five times with the cost of $1000 to $2800 per year. Furthermore, the electricity rate for charging can be further reduced if the EV owners use nighttime charging by availing the Toronto Hydro - Ultra Low Overnight (ULO) rates from 11pm to 7am (Toronto Hydro Residential Electricity rates, 2024). Therefore, it is interpreted that the City is performing well in terms of offering reduced operating cost for EV vehicles through a low cost electricity rate compared to gasoline.
Social	Community awareness on EV benefits	Low	The City of Toronto conducted Public Workshops to seek feedback on the EV Strategy from the aspects of the charging facility infrastructure, partnerships and education awareness programs for the residents (City of Toronto, 2021). Public surveys are conducted periodically, with the most recent one being concluded in September 2023. However, based on the publicly available information regarding community awareness initiatives linked with the TransformTO EV target, it is interpreted that the city has room for improvement when compared to other cities with high EV adoption rate.
	Equitable accessibility of EV infrastructure	High	The City of Toronto is developing a Public EV Charging Network Study to gather inputs from the current and future EV owners to identify the areas of need and make EV charging fit into equitable low carbon transportation system (City of Toronto, 2021). Moreover, The Atmospheric Fund (TAF) is providing $5 million of charging infrastructure funding (sponsored by the Natural Resources Canada) specifically aimed at the communities where charging stations are not accessible such as homes with on-street parking, multi-residential buildings, community properties etc (TAF's EV Station Fund Supports Priority EV Charging in the Greater Toronto and Hamilton Area, 2023). According to the Zoning Bylaw 569-2013 amended in December 2021 and the revised version of the Toronto Green Standard for EV infrastructure launched in May 2022, all the residential parking spaces for multiple dwelling unit buildings must be provided with Level 2 or higher charging outlets (Electric Autonomy- EV-Ready Condo Bylaw Tracker, 2022). Based on the above points it is interpreted that the City is performing well in the metric.
Technological	Availability of public charging infrastructure	High	The Toronto Parking Authority (TPA) is responsible for installation and maintenance of the public EV charging infrastructure for both on-street parking spaces as well as the Green P parking facilities (City of Toronto, 2023). This will help leverage the TPA maintained 300+ public charging facilities and the 20,000 on-street parking spots to be utilized as EV charging spots. As per the latest EV network information provided on the TPA EV charging website, there are 287 Level 2 chargers installed at 27 off-street locations, 23 DC fast chargers installed at 10 locations and 47 on-street stations across 23 locations (EV Charging – Green P Parking, 2024). Although, the City of Toronto is implementing tremendous efforts to increase the accessibility of public charging infrastructure, there are still concerns among the residents in terms of accessibility of charging points with respect to the targeted number of EVs by 2030. As per a survey conducted among Toronto residents in May 2022, 81% of the respondents wanted to purchase electric cars as their next car, however

			the main hindering factor was the limited availability of the on-street charging facilities (Toronto EV Charging Survey- The Atmospheric Fund, 2022). With many respondents highlighting the issue of lack of availability of a home garage to install their personal EV chargers, the issue of 'garage orphan' was further highlighted, with about 67% of the respondents mentioning that they will be more likely to buy an EV if on-street charging was available nearby. It can therefore be inferred that there are still areas for improvement for the City to make public charging accessible.
	Technological advancements to convert existing infrastructure into charging point- eg pole mounted charging points	Medium	The lack of availability of a dedicated parking space for the car owners in Cities is inextricably linked with the technology of converting on-street or curb side parking spots into charging areas since (Werthmann & Kothari, 2021c). In Toronto, the pilot program conducted in 2020 for on-street parking led to the installation of 47 charging points (City of Toronto, 2022). The TPA plans to have more than 150 stations of on-street charging points by end of 2024. However, the installation should be accelerated further to meet the anticipated growth in number of EV owners with respect to the TransformTO 2030 target. There is a greater reliance on the on-street EV charging points due to high number of current and prospective EV owners not owning a garage to install a private charging station for their EVs. Based on the current numbers, the city needs to improve its strategy for this metric.
Environmental	EVs contributing to reduction in air pollution and emissions	Low	The latest carbon emissions inventory for Toronto showed an 8 percent increase in emissions in 2022 compared to 2021 (2022 GTHA Carbon Emissions Inventory- The Atmospheric Fund, 2023). However, the number of EVs purchased increased by 70% in 2022 (2022 GTHA Carbon Emissions Inventory- The Atmospheric Fund, 2023). Therefore, the correlation between the increase in EVs and decrease in emissions did not align for 2022 as per the desired criteria for this metric. The evaluation criteria for this metric focuses on the corelation of decrease in GHG emissions with the increase in the number of EVs, it is therefore interpreted that the city did not perform well in this metric.
Legal	Emissions Standards for vehicles	Medium	The Government of Canada committed to achieving 100% zero-emission vehicle sales by 2035 for light duty vehicles (Government of Canada, 2024). As part of this target, the Government implemented the Canada's Electric Vehicle Availability Standard which was finalized in December 2023. Under this Standard, the auto manufacturers and importers must ensure that they meet their annual sales targets of zero emission vehicles (ZEV) with a requirement starting in 2026 (at least 20% of the sales in that year should be ZEV and increase to 100% by 2035 (Government of Canada- Electric Vehicle Availability Standard, 2023). It is anticipated that this standard will reduce the supply chain related issues and cater to the growing domestic demand for EV among the consumers while simultaneously supporting the progress for EV related targets. Since this standard is recently launched at the national level, its impact will be observed on the EV adoption rate in the future and therefore was not used to evaluate the current performance. Moreover, neither Toronto nor Ontario has any pre-existing standard requirement for auto manufacturers in terms of EV sales. Therefore, it is interpreted that the city did not perform well in this metric.
	Emission inspection fee for vehicles	Medium	Although there is no direct emissions related inspection fee levied on the Internal Combustion Engine (ICE) vehicles, there are federal and provincial carbon levies, and fuel taxes for gasoline, diesel and propane in Ontario (Government of Canada, 2016). This is not levied on electricity consumption; therefore, it can act as a motivating factor for the Toronto residents to consider switching from ICE vehicles to EVs. Hence, the performance of Toronto was considered to be medium with room for improvement in terms of emission inspection fee levied by other Cities with high EV adoption rate.

Conclusion

Based on the evaluation conducted for the City of Toronto it was observed that the city is performing well in the metrics related to presence of an ambitious EV related target, incentives offered for charging infrastructure, preferential access to HOV lanes through green license plates, reduced operating costs for EVs, and equitable accessibility for EVs in the city through different initiatives. The city is performing at an intermediate level with improvement expected in the upcoming years for the following metrics: incentives for manufacturers, policies for preferential parking and charging of EVs in public and residential areas, community engagement and awareness on EV initiatives and services, availability of public charging infrastructure, technological advancement to convert existing infrastructure into EV charging points and inspection fee for emissions from personal ICE vehicles. Lastly, the city is not performing well for the following metrics: financial incentives offered to purchase EVs at the City as well as the Provincial level, exemption from various vehicle related taxes as an incentive, reduction of GHG emissions in alignment with increase in number of EVs, presence of an emissions standards for vehicle manufacturers to comply with the EV targets at the city level. Based on the evaluation conducted, the metrics which were identified to be either not performing well or performing at an intermediate level were reviewed further and recommendations were developed. The recommendations were derived from the best practices as observed in the four cities that were reviewed.

Recommendations

What more can City of Toronto do to achieve its EV-related TransformTO target for personal vehicles?

Based on the evaluation with respect to different evaluation criteria and the best practices that were reviewed from other Cities, the following recommendations are developed:

1. **A flexible funding approach for EV charging infrastructure-** The residents of Toronto have a number of EV charging infrastructure incentives available for them through the federal incentive program and the EV station fund managed by The Atmospheric Fund. However, the city can consider offering a three-pronged incentive approach similar to what is offered by the CleanBC Go Electric charger rebate program (B.C.'s EV Charger Rebate Program- BC Hydro, 2023). The three pronged approach provides flexible funding opportunities to EV owners requiring different EV related infrastructure updates in their buildings or homes: **EV ready plan** rebate which covers 75% of the cost for a maximum of $3,000 for creation of an EV ready strategy; **EV ready infrastructure** rebate which covers 50% of the cost to install electric infrastructure required as a step to implement the EV ready strategy and lastly the **EV charger rebate** which offers 50% of the cost to purchase and install Level 2 networked EV chargers. A similar incentive is recommended for Toronto as it can help the EV owners with varying level of infrastructure readiness to install chargers and accordingly receive the relevant funding required.
2. **Community engagement and involvement through EV taskforce-** The City of Toronto has done public consultations through engagement workshops and surveys, however given the need of more public EV charging infrastructure, it is recommended that citizens should be included in working groups to represent the community needs with respect to the infrastructure and enable a smooth implementation of the EV strategy for the city.

3. **Introduce a low emissions zone in certain parts of the city-** In order to reduce GHG emissions from the transportation sector and motivate the residents to consider switching to EVs, it is recommended that the City of Toronto should introduce low emissions zone in certain areas which observes large traffic during the weekdays. It is recommended that by converting this area into a low emissions zone, ICE vehicles will not be allowed to enter and penalized through an emissions entrance fee similar to what is being done in the City of London (C40 How C40 Cities Are Implementing Zero Emission Areas,2020). This will help the city reduce its GHG emissions from the transportation sector as well as develop a motivating factor for the people using this zone to consider switching to EVs. s

It is recommended for the City of Toronto to lobby for additional funding and support from provincial government as well as the federal government for implementing the following recommendations:

1. **Availability of public charging infrastructure –** 30% of the respondents in a survey conducted among the residents of Toronto highlighted that they do not have a home garage while 23% parked their cars in open driveways (Toronto EV Charging Survey- The Atmospheric Fund, 2022). This highlights the high dependency on public charging infrastructure in the city due to lack of options to install EV chargers at home. This problem termed as 'garage-orphan' is being considered as one of the barriers for EV adoption in Toronto(Global News, 2023). Currently, the Toronto Parking Authority is responsible for installing and maintaining the public charging infrastructure for both on-street and off-street parking. However, the number of on-street charging points is not sufficient to meet the growing demand for the EVs especially with 75% jump in 2022 figures compared to 2021 (2022 GTHA Carbon Emissions Inventory- The Atmospheric Fund, 2023). The City of London has implemented an On-Street Residential Chargepoint Scheme (ORCS) which supports the local authorities by funding 50% of the eligible capital cost related to the installation of charging points for residents with no access to personal parking spaces (On-Street Residential Chargepoint Scheme Guidance for Local Authorities, 2023). This funding is an added incentive to the London Electric Vehicle Infrastructure Funding that is offered to support the EV charging infrastructure. The ORCS is aimed specifically at making street charging points more accessible to the residents with no personal parking options, similar to the issue faced in Toronto. The ORCS funding has been successful in installing EV charging points on existing lampposts which has enabled the increase in number of public charging points. As of January 31, 2024 the City of London has 18,628 public charging points which is mainly contributed by the on-street charging locations (EV Charging Statistics 2024 - Zapmap, 2024). It is recommended that City of Toronto should consider lobbying for financial funding from the government for establishing a similar on-street charging fund which can be requested in co-ordination with the community feedback and the Toronto Parking Authority's analysis. This will help remove the fear associated with the lack of charging infrastructure that arise with garage orphan issue and can further help promote the equitable accessibility of EV charging facilities among the residents from varying areas as seen from the success of ORCS in London.
2. **Policy for incentives in the form of preferential parking and charging in public places-** Currently, the City of Toronto does not offer any preferential parking facilities in public parking places for the EV owners. A free or discounted parking and charging option at the Green-P parking locations for a few months as pilot study will help the city officials analyze

and evaluate the benefits of this incentive for the long-term. Since the TPA already manages the parking space and the EV charging program for public spaces, it will probably be more convenient for them do the analysis of the pilot study. The City of Oslo offered free parking and charging options to EV owners in municipally owned parking places until 2017. After the City witnessed a positive trend in EV adoption, the incentives were altered to charge 50% of the parking fee that is being paid by ICEVs. This incentive was one of the factors which prompted car owners to make the switch in Norway (Aasness & Odeck, 2015). Similarly, the City of London allocates free or discounted parking and charging for EV owners as part of its EV strategy (Transport for London, 2021).

3. **Financial incentives to purchase EV-** The high purchasing price for EVs is one of the major barriers for EV adoption among the consumers (Chandra, 2022). The residents of Ontario are eligible for only one incentive that is offered by the Government of Canada- Incentive for Zero Emissions Vehicle program which provides up to $5,000 to offset the purchase prices. However, other provinces such as Quebec and British Columbia offer additional provincial level incentive to further support the offsetting of the purchase prices (Electric Car Incentives And Rebates In Canada- ChargeHub, 2024). The additional province level incentives have enabled higher EV adoption rate in Montreal and Vancouver in comparison to the City of Toronto (Jarratt, 2023). To support the residents of Toronto to offset the high purchase prices for EV, it is recommended that the city must submit a recommendation requesting Ontario Government to offer additional rebates similar to some of the other provinces or bring back the rebate offered until 2018. .
4. **Incentives for exemption from vehicle related taxes -**Based on the evaluation conducted for the City of Toronto, it was observed that there are no financial incentives offered in Canada in the form of exemption from vehicle related taxes. A 25% exemption from Value Added Tax and100% exemption from road tax was successful in driving EV adoption among consumers in Oslo, Norway (Bjerkan et al., 2016). This was discontinued by Norway in 2022 in alignment with the incremental growth in EV purchase numbers. Furthermore, London currently offers 100% exemption from Vehicle tax for EVs and no vehicle excise duty is charged (Transport for London, 2021). China has a national policy for exemption from vehicle registration tax as part of its National Electric Vehicle Policy. This has greatly helped in accelerating the adoption of EV in Shanghai as discussed in different literatures that were reviewed (Peng & Bai, 2023). Toronto should consider lobbying for additional funding from the Provincial and Federal government to be able to support with similar incentives and promote EV adoption among the consumers.

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