POLICY TOOLS FOR ELECTRIC VEHICLE ADOPTION IN CURITIBA CITY

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Abstract

The role of electric vehicles (EVs) in more sustainable cities is widely recognized, with their adoption increasing rapidly. Most governments have targets for continued EV adoption rate growth, and some plan to ban fossil-fuelled vehicles altogether. Yet, in most countries, including Brazil, the proportion of EVs among new vehicles sold remains low. EV adoption poses multiple technological, economic and social challenges that require targeted policy mechanisms. This study assesses policy measures to expedite EV adoption for road transport decarbonisation and sheds light on the critical role of EVs in sustainable urban development. We explore electric mobility challenges in urban areas, focusing on the case of Curitiba City in Brazil. We investigate existing challenges and barriers to policy implementation in Curitiba and successful interventions in cities worldwide to identify suitable policies for Curitiba. The study uses in-depth interviews with relevant stakeholders to examine policy tools, including financial, legal, knowledge-based, and societal instruments. The study recommends complementary instruments and measures to accelerate their adoption in Curitiba. Overall, the study's results, which identify criteria for policy design and implementation towards complete transport decarbonisation, should be valuable for decision-making in transport and mobility planning.

Keywords: electric vehicles, sustainable transport, urban policy, Curitiba

1 Introduction

Decarbonization of the transport sector is a challenging task. The transport sector is difficult to decarbonize due to the complexity of techno-economic factors, spatial context, and interests of various stakeholders engaged in the transformation. Zero-emissions transport fleets are recognized as one of the solutions. The adoption of electric vehicles (EVs) poses technological, economic, and social challenges. Cities play an essential role in the transition to a climate-neutral transport sector. With the

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growing urban population, the demand arises for new policy instruments and shifts in behavior to effectively address mounting challenges and facilitate the integration of smarter and more efficient technical solutions.

There are several factors that could influence the adoption of EVs. Firstly, technology-related factors such as limited driving range (Lieven *et al.*, 2011), long charging times (Hidrue *et al.*, 2011), battery life concerns (Yong and Park, 2017) as well as high purchase prices (Brownstone, Bunch and Train, 2018) are among the main barriers in the decision to purchase an EV. Second, policy support, such as subsidies, preferential tax treatment, or free parking, can also have a positive impact on EV adoption (Li, Long and Chen, 2016). Moreover, consumer characteristics, such as income and education levels, play a role in determining the uptake of EVs (Hidrue *et al.*, 2011). Finally, external factors, such as fuel and electricity prices, as well as the availability, accessibility, and location of charging stations (Egbue and Long, 2012), also influence the adoption of EVs.

The city of Curitiba in Brazil is considered a pioneer in sustainable urban planning. Still, the transport sector accounts for a 67% share of GHG emissions in Curitiba City (Municipal de Curitiba, 2020). To tackle the transport challenges, Curitiba Climate Change Adaptation and Mitigation Plan was approved in 2020, covering five strategic sectors including urban mobility (Municipal de Curitiba, 2020). Curitiba aims to reach a carbon-neutral city by 2050. This implies that at least 33% of transport vehicles need to be zero-emissions by 2030 and 100% of vehicles must be zero emissions by 2050.

The present paper explores policy mechanisms aimed at expanding the presence of private electric vehicles (EVs) within Curitiba City. It seeks to address urban mobility challenges, investigating a multi-level infrastructure transformation and technological innovation through a transdisciplinary collaborative approach. It is based on an ongoing study, focused on road transport for passenger (car and motor) vehicles, which represent 91% of passenger transport activity in 2019 (Gonçalves *et al.*, 2022). Semi-structured interviews and a literature review are combined to analyze the barriers to private EV deployment and investigate the role of policy to overcome the challenges.

2 Current policies and initiatives promoting electro mobility in Brazil

The share of diesel in total transport energy demand in Brazil has fluctuated between 34-53% since 1980, even though the country is considered one of the world's largest biofuel producers (Gonçalves *et al.*, 2022). The biofuel market should not be seen as the only alternative for a low-carbon development pathway in the Brazilian transport sector. The adoption of EVs varies substantially, largely in parallel with the level of government action and support policies at the national, provincial, and local levels. Brazil has not yet adopted the comprehensive EV promotion policies that are being implemented in the leading electric markets (e.g., China, EU, US). As for Brazil, the country aims to ban the sale of ICEVs by 2060 (Mota, 2019). There has been a notable surge in the electric car market in Brazil, with sales figures indicating a growth of 41% in 2022 compared to the preceding year, which itself was a remarkable 77% higher than the figures for 2020 (Wieder, 2023).

Several policy tools are to a certain extent in favor of EVs, including vehicle emission limits, tax exemption for hybrid vehicles, import tax reduction for EVs, and R&D for technology development including charging (Velho *et al.*, 2019). The latest scheme adopted by the Brazilian government in 2015 was "Rota 2030" (IHS Markit, 2018). The program seeks to stimulate investments and enhance the robustness of automotive enterprises by fostering the creation and implementation of novel technologies. The government's objective is to provide incentives that promote domestic vehicle manufacturing until the year 2030. Hybrid and pure EVs are for the first time included in the regulation with IPI (tax for industrialized products) reduction (Wieder, 2023). The new IPI rate for HEVs and EVs, which is up to 25%, will decrease to the 7%–20% range based on the vehicle's energy efficiency and curb weight. The new IPI rates started in November 2018, according to Decree 9.442/2018. Hybrid vehicles with flex-fuel technology will have an additional 2% IPI tax reduction. According to Gonçalves *et al.* (2022), current policy aimed at electric mobility in Brazil is scarce but will have greater potential for implementation by 2025. In some states in Brazil, including Paraná where Curitiba is located, the Tax on Property of Motor Vehicles (IPVA) of EVs is exempted to encourage the sale of electric cars (Wieder, 2023).

3 Methodology

Semi structured interviews and literature reviews are applied to analyze the barriers to private EV deployment and investigate the role of policy to overcome the challenges. The literature review and expert interviews suggest the important factors/criteria for designing policy to increase the uptake of EV in the Curitiba City. The synthesis of literature findings and insights gathered from expert interviews converge to outline essential factors and criteria integral to the formulation of policies geared towards fostering increased EV adoption within Curitiba City.

3.1 Literature review

The review focusses on barriers and the role of policy to accelerate the private EV uptake in the major cities in the world. The review provides lesson-learned and successful stories of other cities or countries dealing with challenges for EV adoption. Relevant sources were identified through open-access search engines, i.e., IEA policy database, ScienceDirect, and Scopus. The stemmed words "transport policy", "electric vehicles", "sustainable transport", "barriers deployment of electric vehicle", "strategies for increasing the uptake of electric vehicles" were used.

3.2 Expert interviews

This research draws on insights from in-depth semi-structured, open-ended interviews. Out of eight contacted, four interviewees responded. The project team has conducted the interviews since June 2023. The interviewees are selected to represent a wide range of perspectives on electro-mobility and sustainable city. The interviewees are leading experts in their field who are selected based on their long-standing experience, expertise and knowledge, as well as their roles in the organizations.

TABLE I. List of interviewees

No	Organisation	Interviewees	Data and duration of interview	Organisation code
1	UTFPR Federal University of Technology, Parana	Scientist	2023-06-27, 60 minutes	O1
2	Urbanização de Curitiba (URBS)	Regulator, Innovation manager	2023-07-04, 60 minutes	O2
3	Instituto de Pesquisa e Planejamento Urbano de Curitiba (IPPUC)	Urban planner, Advisor for public financing	2023-07-07, 60 minutes	O3
4	World Resource Institute	Senior electromobility analyst	2023-07-26. 45 minutes	O4

3.3 Classifying barriers to EV adoption

Previous research had been conducted to investigate the potential barriers to EV adoption. According to the relevant literature, barriers can be classified into several categories. In this research, the barriers are categorized into *infrastructure*, *technology*, and *market/demand*, following the classification proposed by Aungkulanon (2023). Infrastructure barriers include the availability and number of charging stations and networks, inadequate electric power supply, and the environmental impact of battery disposal. Technological or vehicle performance barriers are related to a range of the car travelling on a single charge, battery lifespan/efficiency, EV charging time, safety requirement, and driving performance. The market or demand barriers encompass high capital cost, vehicle servicing, and poor consumer perceptions and knowledge.

3.4 Classifying policy tools for increasing EV uptake

The policy process cycle consists of problem identification, analysis and selection of alternatives, policy formulation, implementation, monitoring, evaluation and feedback (Hill, 2005). This study analyses policy options to resolve problems (i.e., decarbonizing the road transport sector). Transport policy instruments are tools for influencing people, undertakings and other organizations and their behavior in the transport sector (Stelling, 2014). Generally, policy instruments are required to be cost efficient (the aim is reached at lowest possible cost) and viable (easy to administrate and supervise), to have a high acceptability, to raise incentives for technical development and changed consume patterns, and in the case of environmental instruments, to assure that the target is reached as quickly as possible. There are different ways of categorizing policy instruments. This study follows categorization used by Stelling, (2014):

1. *Economic instruments* aim at internalizing external costs. By internalization, the “polluter pays” principle is achieved. Economic instruments for reducing CO_2-emissions in the transport sector include carbon tax on fuels, congestion taxes/charges, vehicle tax and road fee/infrastructure fee, tax exemption, emission trading system, and kilometer tax.
2. *Legal instruments* are laws, regulations and norms. Legal instruments in the transport sector include fuel standards, vehicle standards, environmental zone, carbon-free area, restrictions of vehicle circulation and idle, obligation schemes.
3. *Knowledge-based instruments* consist of information and knowledge dissemination regarding logistic efficiency, vehicle efficiency, driver efficiency, and route efficiency.
4. *Societal instruments* include infrastructure, both investments and physical planning, modal shift, and intelligent transport systems (ITS).

4 Results and discussions

The conducted interviews reveal that experts perceive that the high upfront cost of EV is the main barrier for EV adoption. According to one interviewee “EV car is at least two to three times more expensive than the conventional car” (O2). This is aligned with the study conducted by Oliveira (Buranelli de Oliveira *et al.*, 2022), who find that the negative perception of the cost of EVs in Brazil is because EVs are still relatively new and expensive. The current government provides subsidies for reducing the price of ICE cars (the cheapest ICE cars is around $15,000-20,000), which makes it even harder for EV cars to compete (O1). Despite Brazil boasting a robust automobile industry, it's worth noting that all EVs in the country continue to be imported. This situation is compounded by the fact that Brazil imposes a considerable vehicle import tax of approximately 40%. Experts suggested a reduction of EV import tax for EV can help to increase EV sales (O1-4). Fostering the EV’s automotive sector within Brazil stands as a viable avenue to cultivate a domestic market. While the automobile industry is technologically inclined, its progression into the EV market necessitates targeted assistance to cultivate a commercially viable arena (O1). Currently, the domestic industry is actively engaged in cultivating local supply chains, a process expected to reach a mature production phase in approximately three to five years (O3). Yet, the establishment of an EV industry within Brazil is contingent upon substantial backing from the national government.

A mix of economic instruments is perceived to be important to remove barriers (market, demand, and infrastructure) for EV uptake. Experts suggested some criteria for effective policy design. "Brazilians don't like to be overcharged or prohibited of something for which they are indirectly responsible for" (O1). Tax exemption of low carbon vehicles is preferable and more acceptable for adopting the new technology, but it must be specific to EVs. Special electricity tariffs, discounted prices and energy subsidies can incentivize the EV car (O1-3). Such a tariff can be designed based on the level of electricity consumption or included in special parking arrangements (special parking fee, special electricity tariff and dedicated parking space in urban areas). However, although free battery charging may effectively promote EVs for a short period, it may not be a sustainable long-term strategy, as technologies are still developing (Noel *et al.*, 2020).

Gleaning inspiration from othermodels, notably the Chinese model with a more local scope, holds significance. particular, China's proactive approach in providing substantial purchase incentives to incentivize consumer adoption of EVs stands out. National subsidies are making way for local municipalities to take charge, handing out purchase incentive for new EVs and allocating budgets to meet charging demand for the influx of EVs. China has provided generous purchase incentives for EVs to encourage consumer adoption. These incentives include subsidies, tax exemptions, and license plate privileges. Initially planned to be phased out in 2020, the purchase incentives were extended until the end of 2023. These incentives have made EVs more affordable and attractive to consumers, stimulating demand. The new package extends the current one which expires at the end of 2023. EVs are exempt from purchase tax, which is around $4,000 per vehicle. The exemption will be halved and capped for purchase in 2026 and 2027 (Li and Lee, 2023).

The availability of public charging infrastructure and the supply of electricity are major concerns for EV development in Curitiba (O1,2). If there are not enough charging stations available, it can be difficult to make long journeys in an EV. Compatibility of charging technologies need to be established to serve a wide range of EV technologies (O4). Faster charging, more robust batteries, and a higher storage density are required to overcome adoption barriers (Adhikari *et al.*, 2020). Looking at Chinese experiences, a pronounced focus has been placed on establishing a resilient charging infrastructure network (Govt of China, 2022). The government has implemented policies to accelerate the deployment of charging stations and build charging facilities in urban areas, residential complexes, and public spaces. The rapid roll-out of charging infrastructure has alleviated concerns about range anxiety and provided convenient charging options for EV owners. China has the ambition to provide charging infrastructure to serve 20 million EVs by 2025, through subsidized public stations, and encourages regional governments to establish standards and subsidies that promote quality of service.

Inadequate electric power supply is a challenge for urban areas. Finding a compromise between good points recharging and good points for delivering energy (O1). Modernizing the electric power system entails significant planning and investment as well as reforming the energy industry sector. The city of Palo Alto in the USA has been able to overcome these challenges by engaging in comprehensive planning, workforce development, collaborative partnerships, innovative solutions, and sound financial planning to overcome these challenges (Robert Charette, 2022). The city can optimize its grid production capabilities, incorporate smart grid technologies, and implement demand response programs to effectively manage peak loads. Furthermore, seeking collaborations with technology companies and industry experts can expedite the upgrade process and leverage their expertise. A robust financial plan should be devised, considering various funding sources to support the necessary investments. Through a multi-faceted approach, Palo Alto can enhance its grid infrastructure and meet the escalating demands of an electrified future. Other strategies that have been implemented in other cities and countries could be applied to overcome the supply of electricity is vehicle to building, vehicle to grid systems coupled with energy generation and battery system. System benefits and limitations need to be considered for the implementation (IEA, 2022). For grid resilience, cities in Netherlands, UK and Canada have imposed smart charging and fast charging initiatives at home or at workplaces (Rajon Bernard *et al.*, 2022)

Legal instruments hold significant potential in fostering the adoption of EVs. In the case of Curitiba City, efforts are being directed towards establishing a low-carbon zone within the city center and providing complimentary parking for EVs (O3). Enhancing public awareness about these legal mechanisms and ensuring vigilant policy oversight are pivotal for the effective execution of policies. Notably, the existing prohibition of the congestion tax implementation in Curitiba with its potential revision slated for 2025 (O3), is a noteworthy aspect.

Clear national and local governmental commitment is key to drive the shift towards a low carbon transport system. The current governments of Brazil and Curitiba demonstrate strong political commitments in developing strategies and solutions for a low-carbon society (O1,3,4). The climate policy goals stated in the Curitiba Climate Change Adaptation and Mitigation Plan, aims to guide policies and actions to mitigate and adapt to climate change, has provide clear roadmap for transport policies that can contribute to the city's 2030 climate and Sustainable Development Goals (SDGs) (Municipal de Curitiba, 2020). Still, uncertainties remain for the continuity of the future policy implementation.

5 Conclusions

Well-designed economic instruments are needed for adopting low carbon vehicles. The study shows that tax exemptions (i.e., import tax, ownership tax), special electricity tariffs, dedicated parking space, carbon emissions zones, and non-incentivising fossil cars are crucial to accelerate EV adoption in Curitiba city. The establishment of national EV manufacturing industry and the entire supply chain is needed to further promote the technology for market expansion. Experts agree that private EV needs to be integrated in the matrix of transportation for complete road transport decarbonization, and highlight the critical role of EVs in sustainable urban development. While the government of Curitiba is working on a number of initiatives to connect the public and private mobility services, there is a need to articulate synergies between stakeholders and different infrastructure sectors in urban planning. Collaboration among stakeholders is crucial to take the most advantage of innovative technologies to improve mobility services and management of urban space and prepare for increased demand of EVs. Future work will include the perspectives of industry and technology providers as well as extend the literature review to a global context.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

All authors contributed to the study conception and design. Material preparation and analysis were performed by [FH]. Data collection was performed by [FH] and [HM]. The first draft of the manuscript was written by [FH] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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