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The ongoing electrification in light vehicle public fleets: Lessons learned from an experience at Brazilian public safety sector

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Abstract

This paper reports a pioneering experience in Brazil of implementing an electrified fleet for the Civil Municipal Guard of the city of São José dos Campos - SP. The main objective is to bring contributions to the expansion of light vehicle public fleet electrification through lessons learned and recommendations established from this case study linked to the public security sector. Semi-structured questionnaires were applied to fleet managers and users, in addition a survey of data on vehicles, fuel and electricity prices, to then present implementation barriers, financial savings estimations and lessons learned with recommendations. The bureaucracy present in public hiring processes and convincing users to change to an unknown technology were the main barriers raised. The implantation presented economic viability, considering the characteristics of the fleet, and demands some adjustments related to the technical specification of the vehicles and chargers to avoid influences on the core activities. Based on these results, the main recommendations are the early and detailed construction of the basic project for contracting, establishing a maintenance plan that includes preventive actions and stock of imported spare parts and a training plan that involves all users, prior experimentation and emphasis on vehicle efficiency and autonomy.

Keywords: electric vehicle; public safety; corporate fleet.

1. Introduction

Transport is an intensive fossil energy-consuming activity that generates a significant impact on the emission of greenhouse gases. Thus, the energy transition to zero-emission vehicles is one of the ways to achieve the emission reduction targets agreed-upon by the nations (Kester et al., 2018; LaMonaca and Ryan, 2022; Li et al., 2017; Roemer and Henseler, 2022; Sierzchula, 2014; Vuichard, 2021). In Brazil, where more than 80% of electricity is produced by renewable resources (Brasil, 2022), the Electric Vehicle (EV) is a promising solution. Despite that, Oliveira Filho et

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al (2023) presents that there is a lack of a National Plan for Electric Mobility, as well as structured policies that defines a future vision and encourage the consolidation of this segment in the country.

Public fleets, as well as other commercial electric fleets, present an intense usage, they can use centralized recharging stations and are managed by professionals with better comprehension of costs and actives lifetime (Sierzchula, 2014). Despite these advantages, they still encounter early adoption resistance and are still much below their potential (Iwan et al., 2019). This study focuses on light EV fleet adoption in Brazil with the objective of contribute to build a base of knowledge that reduce resistances and guide deployment of EV public fleets, through the study of a real case in the public security area.

In transitions toward a sustainability perspective, EV tends to replace a dominant technology regime, the internal combustion engine (ICE) dependent on fossil fuel. For this reason, several dimension barriers should be overcome, since not only does this transition imply technological change, but it also implies on users' practices, regulation, infrastructure, and also cultural and market aspects (Geels, 2002, 2005).

Some of the main barriers are related to the acquisition costs, the existence of charging and support infrastructure, as well as a set of uncertainties and lack of knowledge about the technology and misperception around the ease of usability of these vehicles (Kester et al., 2018; LaMonaca and Ryan, 2022; Sierzchula et al., 2014; Singh et al., 2021; Vuichard, 2021). Overcoming the last one, the so-called soft barrier, is revealed important to the adoption of corporate fleets (Iwan et al., 2019; Vuichard, 2021), which constitutes the main argument of this work.

From the perspective of the public fleets' electrification, in addition to the gains linked to the reduction of emissions and operational gains, the role of the government as a promoting agent is also highlighted, in a "demonstration effect" that contributes to popularize the technology (Barisa et al., 2016; Mazzucato, 2014). The public organizations may contribute by establishing a minimum percentage for its own fleet, 30% for example, as it was done in China (Zhang and Bai, 2017)

The electric transition of corporate fleets goes through two instances in organizations: the decision of managers and the perception of end users (Roemer and Henseler, 2022). The factors that influence the decision to adopt EV fleets can be classified into three categories: the technological factors, which deal with the reduction of emissions, costs, maintenance, charging infrastructure, system reliability, among others; the intrinsic ones, that deal with issues such as companies' environmental consciousness and sustainability plans, managers' attitude, and user acceptance. Finally, the external factors, such as the regulations, public policies, incentives for financing, electricity prices, among others (Bae et al., 2022).

The intrinsic values of organizations, linked to social responsibility and environmental consciousness, pioneering advantages, improvement in the public image of the company, and benefits granted by governments through public policies were identified as the main factors that motivate the adoption of EVs in corporate fleets, according to research in Europe and the USA (Bae et al., 2022; Sierzchula, 2014).

In order to understand the Brazilian situation related to the adoption of public fleets of electric vehicles, this paper sought, through exploratory and descriptive study of fleet electrifying at a Civil Municipal Guard (CMG), presents the main barrier to the early adoption, the motivations, the business model, operational costs calculations, and a set of recommendations that can be useful to promote other electrification processes at the public service, emphasizing some specificities of public safety activities fleet use.

2. Methodology

This is an exploratory study of a pioneering case among Brazilian cities of public safety electrified fleet implementation in the city of São José dos Campos (SJC), in the State of São Paulo (Brazil). It was conducted through in-locus research, with interviews from managers - from both public service and the private operator - and the drivers of the vehicle occurred in January of 2023, complemented by surveying the organization's documents, and public information about electricity and gasoline price used to conduct operational costs saving calculations. The questionnaire used as an instrument for conducting the semi-structured interviews with managers and drivers are shown in tables A1 and A2 respectively, at Appendix A.

The case study and the qualitative procedures are justified for two reasons: first, to the low level of EVs fleet adoption in Brazilian public organizations, and second, because this method allows an in-depth exploration of the process of electrifying fleet in this public organization.

In interviews with fleet managers (two from municipality and one from the private operator), the factors that influence EVs adoption decision were discussed, such as the environmental agenda and the operating costs, the main barriers to the early adoption, the users´ resistance, and the business model chosen. With the users of the fleet (eight drivers was interviewed), emphasis was given to the uncertainties and resistance in the beginning, the question of autonomy and way of recharging, ending with positive and negative outcomes, considering the activities carried out by public safety comparing to an ICE vehicle.

3. The description of the case – Fleet electrification of Municipal Guard of São José dos Campos City

São José dos Campos is a large city (approximately 737 thousand inhabitants in 2023) around 50 miles (80 km) from the city of São Paulo, the capital of the State which is a significant area of Brazil in terms of both population (22% of the entire country) and GDP (around 34% of the domestic product). It is an important technological hub for metallurgical, military and aerospace industries. To support these activities, the city has the most relevant public research centers in Brazil (such as ITA- Aerospace Technological Institute; INPE - National Space Research Institute) and the Technological Park (TechPark), a hub for technology companies and startups of all sizes, universities and research institutes, public policies and society. Furthermore, in 2022, São José dos Campos was certificated by Brazilian Association of Technical Standards (ABNT) as the 1st smartest city in Brazil (Prefeitura Municipal de São José dos Campos, 2022).

In relation to electric mobility, São José dos Campos has taken an essential step in decarbonizing transport by designing Law No. 9.684/2018, which establish the municipal policy to incentive and regulate the use of electric and hybrid cars; it was the first Brazilian law designed to promote electric vehicle in Brazil. Since then, the city implemented 30 electric vehicles in its Municipal Civil Guard (MCG) fleet in 2108, that is focus on the paper.

3.1. Fleet Characterization and Deployment

MGM is a civil institution, whose aim is to carry out preventive protection on municipal public goods, facilities that provide public services and the population that uses them. They operate with two teams that share thirty electric cars. The operational team carries out preventive patrolling and guarding public facilities, and the specialized team works to respond to incidents and is ready to provide support to other demands, when required. Patrolling takes place at lower speeds, while support or response to incidents requires higher speeds. Each team works 12 hours per day, covering up to 150km per shift, and there is no allocation of vehicles to a pre-determined agent. In this way, the vehicles operate 24 hours and can travel up to 300km a day.

In 2018, the municipality was planning to improve innovation and environmental sustainability in its actions, the market price analysis showed that there was no significant difference in rental costs between electric and internal combustion vehicles, and it could be included in the contract all maintenance costs. The monthly savings with operational costs were estimated at up to BRL R$2,000 (around U$ 400) per month, per vehicle.

The municipal management found two main barriers to the process of contracting and implementing the electrified fleet. The first is the bureaucratic barrier, since public contracting requires the instruction of a process with several documents and analysis by administrative, legal, and public account control bodies that demand time and hard work.

The second barrier was related to the process of convincing users, since it was an unknown technology for the security agents, who naturally carry doubts and uncertainties regarding the use of this new vehicle. The concerns expressed by users were related to the autonomy of the vehicle and the safety operation of the braking system. Some previous tests were done, and from the perspective of the police agents, among their perceptions, it was clear that the doubts and concerns about the use of the new technology were overcome with the beginning of the use.

3.2. Operation: usage and perceptions by fleet operators and users

MCG was then equipped with a fleet of thirty battery electric vehicles, Sedan type, imported from China, with a maximum power of 160kW engine, 47.5kWh battery and 300km range. Twelve 40kW three-phase AC chargers with a standard CCS2 connector were also installed at strategic points in the city. The recharge system does not contain

card usage control or telemetry. Fleet and chargers' maintenance is being managed by the contracted fleet operator, who maintains a specialized EV service in the city.

Recharging occurs between one and four times per shift through chargers located at selected points in the city, either in the support spaces of the municipal guard, or in some public facilities (hospitals, schools, and squares), trying to deliver the car with at least 70% of charge to the other shift. During recharging time, the presence of vehicles and agents in public spaces results in preventive action regarding crimes, that contributes to the city guard's mission. In addition, at these times, the teams have meals or fill in data at the occurrence monitoring system.

The agents of the specialized team pointed out difficulties regarding the autonomy of the vehicles and the relation to the fulfilment of public safety activities, notably when there is an urgent demand for displacement over long distances and high speeds, especially due to the unpredictable nature of these displacements. For the operational team, the energy consumption of the batteries is lower, therefore, the vehicles and the charging conditions are more adjusted to the conditions of use.

During police calls, the cars can operate closer to their limits, suffering faster wear of some systems, especially the suspension and tires. By this way, the fleet operator's main challenge is to maximize the availability of vehicles for use in its core activity, reducing the times required for preventive and corrective maintenance.

The agents were encouraged to point out the weaknesses and strengths of the electric vehicle in their opinion. The autonomy, which requires several recharges at each shift; the braking process, that differs from the usual combustion vehicles, in which police officers use the engine-brake more frequently; the low ride height or ground clearance, which requires agents to be more careful when traveling on irregular floors; and the weight of the vehicle, which associated with the way of driving raise doubts about the stability in curves, and greater wear of the tires are the highlights among the weak points. Performance, expressed by torque and speed; comfort since it is automatic and with a very low noise level; robustness, which does not require frequent maintenance and fuel economy are the positive highlights pointed out by the agents.

Uncertainties, strengths, and weaknesses pointed out by guards using EVs are summarized in table 1.

Table 1. Uncertainties, weaknesses, and strengths pointed out by guards

Uncertainties	Weaknesses	Strengths
autonomy	autonomy	torque and speed
braking system	braking system	low noise
	low ride height	comfort
	tire wear	robustness
	curve stability	economy

3.3. Estimated savings with replacement of traction energy

To carry out an analysis of the financial resources savings with the replacement from gasoline to electric vehicles, the costs of electric energy and common fuel in the city of São José dos Campos in the period from 2018 to 2023 were raised. Figure 1 shows the average price of car traction energy in the city of SJC between 2018 and 2022. The gasoline price (a) was obtained from the medium price practiced in the city disclosed by the Petroleum National Agency (ANP). The electric energy price (b) was obtained from Brazilian Electric Energy Agency (ANEEL), and considering a low voltage public sector consumption, that includes the tariff flags used to increase energy prices during dry periods, since Brazilian electric energy is strongly hydraulics dependent. The colors in this figure represent the tariff flags that go through green (no additional fee) to purple (hydric shortage, and greater increment).

Table 2 shows the efficiency and the day travelled distances that was considered to perform the calculations (there was no telemetry on board of the vehicle and neither at the charge stations). Figures 2 show the estimated results calculated month by month (a), and in an accumulated way (b). Fuel and electricity prices showed seasonal patterns with similar variation in the studied period, but the growth rate of gasoline cost in the period from 2020 to 2022 was higher than electricity. For this reason, the estimated savings presented exceeded the expectations of the preliminary studies, resulting in 5.5 million reais (around U$1.1milion) of estimated savings at the end of 5 years of operation.

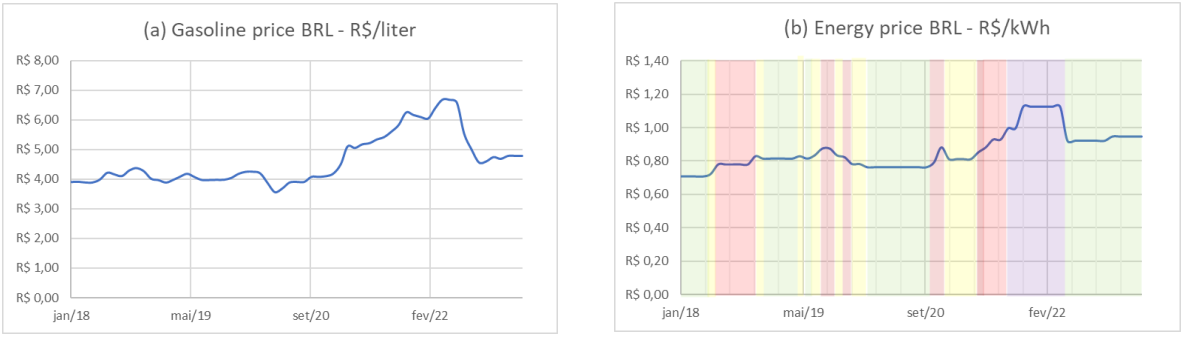

Figure 1. Average price of traction energy in the city of SJC between 2018 and 2022: a) gasoline, Source: ANP. b) electricity for low voltage consumers in the public sector, Source: ANEEL.

Table 2. Considered vehicle parameters for saving calculation

Vehicle	Efficiency	Distance/day/vehicle
EV (E5 BYD)	6,32 km/kWh	250 km
MCI (GM Vectra 2.0)	8,7 km/l	250 km

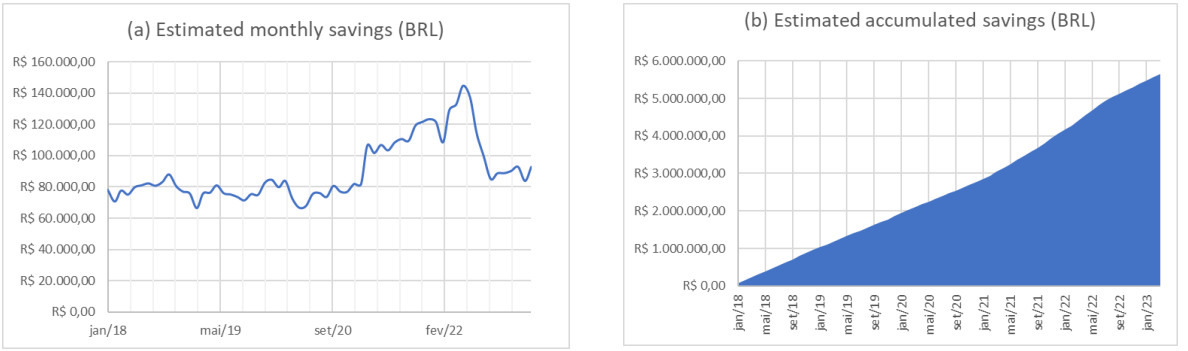

Figure 2. Estimated savings calculations: a) monthly; b) accumulated (BRL).

4. Lessons learned and recommendations

Based on this real case analysis, by listening to those involved in the process, it was possible to establish a set of recommendations based on the lessons learned. First, new contracting models need to be evaluated, seeking to contract the service instead of acquiring the goods, in such a way that the public service team is focused on carrying out the final activities. It can also increase the availability of resources, including vehicles and chargers.

To overcome bureaucratic barriers, it is recommended, in advance, the construction of a detailed preliminary technical study, that should compare technical-economic viability of some alternatives, as well as look for the environmental impact of the contract. This basic project (or reference term) must contain the necessary and sufficient elements, with an adequate level of precision, to characterize the object of the public bidding. It is important that these projects:

- Carry out technical studies regarding the dimensioning, quantity, and adequate positioning of chargers in the fleet's operation area, based on monitoring data from previous fleets, so that the vehicle's autonomy does not bring problems regarding the availability of the vehicle for carrying out its activities.

- Consider the demands for preventive and corrective maintenance of vehicles to define the number of cars in the fleet, including backup vehicles in order to guarantee full availability.
- Carry out telemetry of vehicles and chargers, in order to keep information updated in real time on vehicle location, state of charge of vehicle batteries and availability of chargers.

For the fleet operation with reduced vehicle downtime, the great challenge is in maintenance management, which must consider the deadlines for importing parts. The following points are recommended:

- Conduct a preventive maintenance plan.
- Organize a local stock of parts to guarantee a quick response in case of imported cars.
- Maintain frequent and transparent communication between the fleet operator, the public managers, the specialized EV workshop, and the users, to understand the corrective maintenance demands and reduce them through frequent guidance of those involved.

Finally, it is strongly recommended to establish a training plan with experimentation about the proper use of the technology before deployment. The following points are recommended:

- The plan must involve all users, making sure that new users go through this process as well.
- Emphasis should be given to the question of autonomy, in particular the relationship between energy consumption and the speed given to the vehicle.
- In terms of driving the vehicle, exploring the use of braking with energy regeneration, making a counterpoint to the use of engine braking; and, on the influence of the vehicle's weight on its performance, stability when cornering and wear on the parts that make up the suspension.

5. Discussion

Soft barriers (gaps in knowledge, reliability, or acceptance) demand much less resources to be overcome than the hard ones (linked to the investments in vehicles or charging infrastructure) (Biresselioglu et al., 2018; Vuichard, 2021). These soft barriers were presented in this case study. The guards resisted using an unknown technology, and previous experimentation with part of the group was not enough. From the perspective of public managers, they also identified the bureaucratic nature of the hiring process, especially for a new kind of service - leasing police vehicles - as another important barrier, that is still related to knowledge gaps.

The main motivation for implementing an electrified fleet, as found in this study, is linked to the pioneering advantages. This fact is presented for both public management, that sought smart and resilient city certification, and for solution providers, that sought to strengthen the technology and their brand. The pioneer and the environmental values were the factors found in other studies (Bae et al., 2022; Sierzchula, 2014).

The energy transition of the fleet of the Municipal Civil Guard of São José dos Campos proved to be financially viable based on the comparison of the costs of fossil fuel and electricity, especially due to the large daily distances covered. A McKinsey recent study in Brazil (2023) showed that the total cost of ownership (TCO) of a midlevel electric vehicle that is intensively used (more than 150km) is still lower than a combustion one (McKinsey & Company, 2023).

Entrepreneurial municipal management from São Jose dos Campos city, which sought innovation and sustainability, also played an important role in pioneering the fleet electrification process. The support of the management was converted into technical and administrative solutions to overcome the bureaucratic process. Mazzucato (2014) points out that major innovations require time and patience, and the state must take risks to create a market, especially in green technologies.

6. Conclusion

This study achieved its objectives since it investigated in depth a pioneering EV fleet implementation in the public service and established a set of recommendations that can be used in others electric fleet adoption. Among them are the construction of a basic project which considers technical requirements fitted to the characteristics the fleet, followed by a training plan that involves all users and emphasis the influence of vehicle weight and speed in the

autonomy, braking and wear of parts, and finally a maintenance plan that consider a preventive action, a local stock of imported parts and a communication management between users, managers, and mechanics.

The electrification of the corporate fleet used in public safety in the city of SJC presents positive and relevant operational results. In addition to reducing GHG emissions, it is possible to highlight the financial savings by changing the fuel, and the reduced unavailability of vehicle on maintenance stops obtained with the leasing contract when compared to the conventional business model of ownership. The silence and speed up displacement, and the presence of preventive policing in the city during the recharging also contributed to the security activities. Technical issues related to the distance of the vehicle's chassis from the ground and its autonomy need to be adjusted to minimize the influence of the type of vehicle and its recharger on the security core activities.

The construction of a guide that conducts the implementation process of corporate fleets of light vehicles in the public service is important and can collaborate to optimize and bring better results for the energy transition of vehicles. The experience of the GCM in the city of São José dos Campos brings together relevant contributions to be included in these guidelines that are under construction in Brazil. Furthermore, this experience allowed the municipality to accumulate enough knowledge to improve the requirements incorporated in the new public bidding that is currently being developed, which aims to increase the number of electric vehicles in the city's public fleet.

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Appendix A

Table A1. Semi-structured questionnaire applied to managers.

The Fleet	Motivations
How many cars compound the fleet actually? Are there combustion vehicles? How many? Describe how the vehicle is used (frequency, daily distances, recharge form…)?	Why did your organization decide to adopt VEs fleet? And about expanding plans? Can you describe a list of factors that drove the decision to adopt EV? Were there external factors that influenced the VE adopt decision?
Environmental agenda and costs	**Barriers**
What is the importance of the environmental agenda in the decision-making process for fleet electrification? Have there been or are ongoing discussions, comparative analyses, or calculations related to the operating costs of the fleet deployment process?	Can you describe the barriers encountered in the process of implementing the electrified fleet? Was there any specific action to reduce these barriers? If so, how was it done? Would you recommend some actions based on your experience?
Users' resistance	**Business model**
Was there any type of resistance from users or the organization's management in the process of EV adoption? Would you recommend any previous training or experimentation?	Was there a change in the way of acquiring, managing, and operating the fleet in this transition to low-emission vehicles? If so, is it possible to describe the business model used? Based on your experience, what information do you consider important to be included in an EV public corporate fleet implementation guide?

Table A2. Semi-structured questionnaire applied to EV users.

The vehicle, user´s experience and acceptance
Describe how you use the vehicle (average distance travelled, schedules, about recharging...?
Was there any uncertainty/doubt about the new technology that caused discomfort or resistance to acceptance?
In your user opinion, is there anything that can be highlighted as positive and negative points of the vehicle?
Did the vehicle autonomy associated with charging conditions cause any inconvenience at the beginning of vehicle use? and currently, is this something that bothers you?
Can you report operational difficulties in using vehicles or charging infrastructure?
Would you recommend any training or experimentation process prior to implementation?
Did knowing the electric vehicle in your organization create any motivation for you to have one? What motivates or demotivates you the most?

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