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Using electric vehicles for freight transport purposes and challenges to do an implementation in Brazil

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Abstract: The aim of the current is to address the main successful international public policies aimed at expanding the fleet of electric vehicles used for road freight transport purposes and how these policies could be adapted to the Brazilian market. Analysis applied to the main public policies that resulted in tax incentives, helped expanding the existing infrastructure and promoted new businesses in the transition from the fleet of conventional to electric vehicles in foreign markets, as well as studies focused on investigating likely adaptations allowed by the Brazilian legislation to these policies to meet the national market are the main challenges to this sector. However, although electrification appears as the main alternative to improve energy efficiency, several countries have not yet implemented public policies to boost their fleet transition process. Results in the current research may contribute to future studies focused on investigating the adequacy of successful public policies and their likely adaptations to the Brazilian business model.

Keywords: Electric vehicles, Freight transport, Public policies, Sustainable mobility, Energy efficiency.

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Introduction

According to Vaz et al. (2015), increasing urbanization processes tend to lead to the natural expansion of road freight transport demand values. This factor raises concerns about the energy sources used by vehicles that, in their turn, have contributed to environmental pollution and to worsened greenhouse effect over the years.

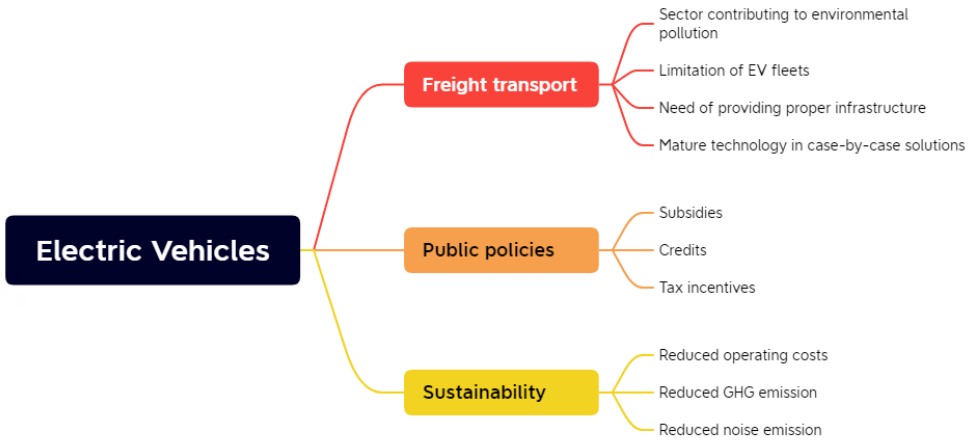
Talebian et al. (2018) advocate that electrification has emerged as the main alternative to help improving energy efficiency, as well as reducing atmospheric pollutant and GHG (Greenhouse Gases) emissions, and noise pollution. Based on this scenario, the aforementioned authors also point out that the investigation of urban freight electrification remained in the background of comparative analyses conducted with electric vehicles built for passenger transportation purposes, mainly in comparison to private vehicles, which, in their turn, already have relatively significant impact on both urban transport planning and public policy formulation processes.

Thus, electric vehicles emerge as sustainable urban freight alternative, mainly for freight transport in cities. However, despite their numerous benefits, they still face several economic, technological, social, cultural and infrastructure-related barriers capable of hindering their expansion process. According to Vaz et al. (2015), nowadays, markets showing successful transition from combustion-powered vehicle fleets to electric vehicles account for approximately 35% of electric trucks used for road freight transport purposes, mainly in countries such as Sweden, Norway, Germany, Switzerland, France and the Netherlands.

Therefore, the aforementioned topic is quite relevant in the transport sector sustainability field, since it represents real opportunities for the successful implementation of electric vehicles in the Brazilian market model. Such an implementation process can be based on examples of successful international markets within the scope of public policies, which played fundamental role in the transition from combustion-powered vehicle fleets to electric vehicles in these markets. This is the main factor motivating the current study, given the significant relevance of this topic for sustainability and environmental preservation issues.

Figure 1 presents the main variables of the problem observed within the context of the investigated scenario. It also highlights the links between them, as well as the way some secondary factors connect to the main variables of this problem.

Figure 1 – Conceptual diagram



Source: The author, 2021.

The increased or decreased acquisition of new electric vehicles to be used for freight transport purposes in Brazil is the main variable of the herein investigated problem. By extension, it is an independent variable, since it is not directly influenced by changes in the guidelines set for new freight transport vehicles purchased by companies interested in transitioning from conventional to electric vehicle fleets, or by new public incentive policies issued by the Brazilian government that do not go hand in hand with the expansion in the sales of new electric vehicles.

However, different factors place obstacles for a more effective transition from conventional to electric vehicles in the Brazilian case. Among them, one finds economic factors associated with initial costs with investments in, and ownership of, vehicles for freight transport-related companies; social factors associated with occupational diseases, such as the case of individuals working in garbage collection companies, as well as risks of accidents due to the silent nature of electric vehicles that, in some cases, can even prevent pedestrians from hearing them.

In addition, there are also environmental factors directly linked to the production and assembly line of electric vehicles, which still accounts for significant GHG gas emission in Brazil. It mainly happens in the process to manufacture batteries, since their recycling market in the country remains inefficient; oftentimes, it is necessary starting a new production line, although some vehicles, and their components, could be reused.

However, freight transport is a dependent variable, since increasing the fleet of electric vehicles used for freight transport purposes can substantially affect the quality of its vehicles, as well as help improving sustainability (dependent variable) through services focused on environmental preservation, which are highly beneficial to the Brazilian society, from the economic, social and environmental perspective.

According to Vaz et al. (2015), the freight transport sector accounts for significant pollution in Brazil from the perspective of the context of public policies, which represent an intervening variable in the herein investigated topic. It only ranks second to the industrial sector in terms of polluting gas emissions into the atmosphere. Thus, it is clear that transitioning from the current fleet type to electric vehicles is of paramount importance, as well as necessary to enable a more sustainable future. However, this fleet is quite limited, mainly in terms of trucks and vans, whereas electric vehicles built for private use are at a more mature technological stage.

Therefore, it is necessary developing the charging and infrastructure industry, based on public policies focused on providing tax incentives and investments to encourage companies to transition from their freight transport vehicle fleets to electric vehicles. Moreover, this technology is at significantly different maturation stages in several sectors; in some cases, it represents point solutions for consumers. Therefore, the public power must provide infrastructure capable of motivating companies to make large investments in these vehicles, as well as the necessary conditions to enable them to improve their activity and to become more sustainable, on a daily basis.

General and specific aims

The general aim of the present study is to investigate the potential of electric vehicles in order to establish the conditions capable of making their use in the road freight transport sector viable in the Brazilian market.

However, it is necessary adopting a systemic approach different from that observed in other studies carried out in this field in order to meet this aim. Therefore, the current study is an innovation in the freight transport fleet electrification scope, since studies previously carried out in this field focused on investigating specific topics and electric vehicle components, rather than on emphasizing propositions capable of contributing to the gradual transition of this fleet in Brazil. This approach, which is specific to the present study, comprises several factors associated with the electric vehicle system, such as energy sources, EV types (Electric Vehicles), batteries, vehicle size, freight transport operations, charging methods, among others. By extension, it is essential investigating successful guidelines adopted in other international markets, such as financial incentives previously tested in some countries in the form of subsidies, credits, tax incentives and exemptions from fees and taxes; as well as in the infrastructure field, such as charging projects and testing sites.

On the other hand, the specific aims of the current study are to propose solutions for the main challenges to the gradual transition from conventional to electric vehicle fleets, such as users' lack of knowledge, high acquisition costs, low autonomy of electric vehicles, long recharge time, self-discharge or internal battery resistance at extreme temperatures and deficient second-hand market for batteries.

Research methodology

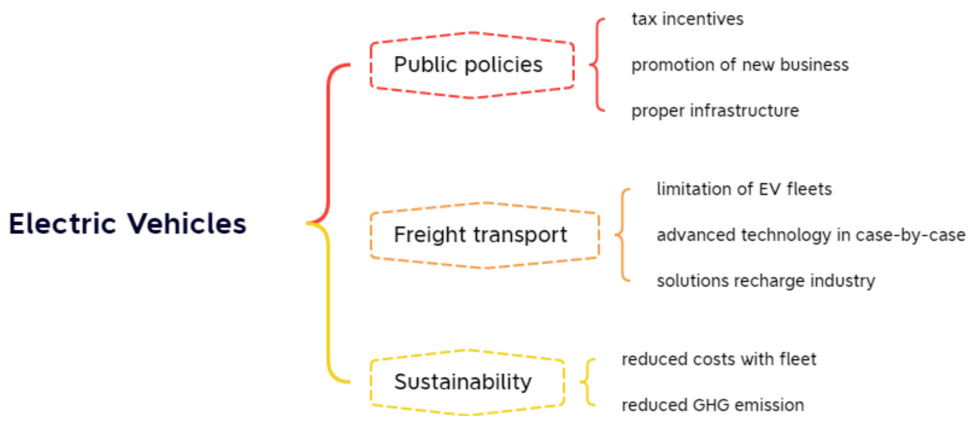
The following methodological procedures were performed to help answering the main question of the current research: articles, theses and dissertations associated with the herein investigated topic were initially selected based on their title and abstract. Then, the initially selected articles were read and the ones presenting a wide range of information about the investigated topic were selected through qualitative analysis.

Search for articles was carried out in databases such as Web of Science, Science Direct and Scopus; they were carefully assessed to ensure the quality of those selected as basis to the development of the current study. Four meshes were initially used in the article-search process, namely: electric vehicles, freight transport, public policies and sustainable mobility. Since "electric vehicles" was the mesh leading to most results when Boolean operator "or" was used together with all other meshes, and since it is the most important mesh for the current study, it was used in combination to all other meshes, based on using Boolean operator "and". Articles published from 2010 to 2020 were selected, since they presented the most recent investigations focused on the proposed topic, without spatial delimitation.

In addition, documentary research about original public policies successfully implemented in other international markets was also carried out to help explaining - in further detail - their association in terms of tax incentives, infrastructure measures and the promotion of new business through the expansion of electric vehicle fleets used for road freight transport purposes.

Figure 2 shows the main variables involved in the aforementioned scenario, with emphasis on the research plan developed to help answering the main question of the current study.

Figure 2 – Research plan



Source: The author, 2021.

Electric vehicles and public policies on the world stage

According to Lebkowski (2017), electric vehicles emerged in 1832, when Scottish businessman Robert Anderson invented the first electric car. However, electric vehicles were only subjected to continuous development in late 19th century, when lead-acid batteries were invented. This battery type was used in the 1880s to power electric cars in the US, UK and France. Back then, studies were carried out to investigate the regenerative braking technology, which is capable of transforming the kinetic energy of moving cars into electrical power to be stored in the battery to be used in the future. Moreover, studies were also carried out to investigate hybrid systems comprising both electricity and gasoline.

According to Porchera et al. (2016), a hybrid model similar to the current ones was produced in early 20th century: its internal combustion engine was used to provide traction and to charge the battery, whereas its electric motor provided extra power to the combustion engine and the electrical part of it worked alone in slow traffic. These models were created to counterbalance the low efficiency of batteries used in purely electric vehicles and the precarious electric power distribution structure available at that time. Vaz et al. (2015) advocated that rural areas did not have access to electric power, whereas urban areas experienced significant limitations in this service. Public roads had poor lighting, whereas only the richest families had access to electric power at home. At that time (early 20th century), there were more electric than internal combustion-based vehicles circulating in the streets.

Vaz et al. (2015) reported that the prevalence of internal combustion-based vehicles was only threatened by the oil crisis in the 1970s. The embargo of OPEC (Organization of Petroleum Exporting Countries) countries resulted in oil supply shortage and in considerable increase in oil-barrel prices. Such an increase, in its turn, had direct impact on gasoline prices and triggered a global crisis that forced several countries to rethink their policies focused on fossil fuels, which were less expensive and more abundant in the past. There was evident need of more independence in the process to supply these inputs, as well as of developing alternative propulsion technologies, including the electric one.

The aforementioned authors have advocated that the introduction of electric vehicles in the freight transport sector is a matter of sustainability that will bring several benefits to the Brazilian economy. However, economic, political and environmental factors pose obstacles to the transition from traditional to electric vehicles. Kampker et al. (2018) reported that light-to-medium vehicles have been the main focus of research and development projects for two different reasons, namely: global regulatory pressure to reduce heavy traffic and emissions in urban areas; as well as because light-to-medium vehicles are similar to electric private and passenger vehicles, which, in their turn, are much more advanced, in technological terms.

Unfortunately, public incentive policies in Brazil do not go hand in hand with companies' desire to expand their electric vehicle fleets. Therefore, this transition gets increasingly slower, since companies do not find the necessary governmental support to invest in fleet modernization processes and, consequently, to help increasing sustainability in their daily tasks. Thus, exemptions from tax rates, tax credits and incentives, and the development of organized infrastructure for companies to invest in modernizing their fleets should be increasingly addressed by the Brazilian government.

However, a series of embargoes have contributed to the fact that these vehicles remain underused in Brazil. Vaz et al. (2015) have stated that, in addition to incentives in the financial and infrastructure fields, other practices can help reducing traffic jams and comply with the global regulatory pressure to reduce the number of heavy vehicles in road freight transport. Among them, one finds free public parking, using exclusive lanes, restricting the access of internal combustion-based vehicles to certain locations in the so-called Low Emission Zones (LEZ) at certain times, and implementing traffic jam pricing policies to reduce the incidence of these vehicles, mainly of heavy vehicles, in the streets.

According to Chaud et al. (2012), traffic jam charging in London is managed by a private company under government supervision; the resulting revenues are invested to improve the transportation system. This practice enabled reducing traffic volume and, consequently, reducing traffic jams and travel time. The aforementioned authors have also indicated that medium- and large-sized trucks cannot circulate on some of the main roads in São Paulo City, from 05:00 am to 09:00 pm on weekdays, and from 10:00 am to 02:00 pm on Saturdays, except for holidays. It is done to help reducing emissions, traffic jams and accidents, mainly during peak hours, in the so-called Maximum Traffic Restriction Zone.

Since the road prevalence in the freight transport sector will not change quickly, and the context experienced by most countries is similar to the American context, introducing electric vehicles in this sector is a way to help mitigating the pollution caused by conventional vehicles. Despite the numerous advantages associated with such an introduction, it also faces barriers to its development. Among them, one finds lack of information available to both the population and companies about this propelling force type and its environmental benefits, a fact that triggers distrust among many individuals and hinders the full exploitation of these vehicles' potential; high acquisition costs, which are mainly boosted by costs with the research, development and manufacture of batteries; low battery autonomy, which may require frequent recharges, even among customers of the same distribution or collection, since reducing the number of deliveries is not a profitable option; and, finally, the need of increasing battery capacity, which, in its turn, is quite heavy and can reach 450 kg.

According to Wang and Thoben (2017), researchers' goal lies on developing a lightweight, small, high-capacity battery to increase the battery range-to-size ratio, as well as to reduce electric vehicles' weight and dimensions. However, overall costs still limit both the development and the use of these innovations. Another obstacle lies on the fact that both the industry and the charging infrastructure necessary for electric vehicles remain at significantly early development stage, a fact that makes several users skeptical about their respective effectiveness. Thus, it is necessary overcoming these obstacles to make the use of electric vehicles for freight transport purposes fully feasible.

Brazil ranks a privileged position in the energy sector worldwide given its high renewable energy production and consumption rates; however, the national transport sector has low efficiency due to its prevalent road transport mode, which accounts for 90% of polluting gas and CO2 emissions, based on Pessanha et al. (2011). According to aforementioned authors, high prices and the well-developed market for sugarcane-derived fuels are the factors hindering the expansion of the electric vehicle market in Brazil.

Renewable sources are continuously introduced in electric power generation processes in Brazil; 37.2% of the electric power produced in Northeastern Brazil is generated by wind farms, whereas its generation by solar source increased by 300% in 2016 and 2017, despite the crisis faced by the country (GOMES et al., 2018). Such a high electric power production rules out the existing risk of imbalance in electrical grids, since they are intermittent energy sources that can be quite useful for regions facing extreme temperatures countrywide. Among them, one finds the intense heat observed in Northeastern states and the intense cold recorded in the Southern region. It happens because places subjected to these conditions have higher clean energy supply to recharge electric vehicles that, in their turn, show extra energy demand due to higher losses taking place during the charging process, which requires longer time to be completed. Regional and state variations in GHG emissions deriving from electric power generation processes are in compliance with the mix of sources generating this energy. The mix comprising different renewable energy sources is even more necessary to maintain zero emission rates at night, when it is not possible using solar energy, unless a generator combined with a battery bank is connected to the photovoltaic system to store this energy in order to use it at night (BLUESOL ENERGIA SOLAR, 2017). Table 1 shows the Brazilian states presenting the highest installed capacity of wind and solar energy sources.

Table 1 - Brazilian states presenting the highest installed capacity of wind and solar energy (2019)

	Wind Source		Solar Source
State	Installed Capacity (MW)		
RN	4,159.5	MG	426.5
BA	4,074.4	RS	299.6
CE	2,045.5	SP	268.0
RS	1,831.9	PR	210.1
PI	1,638.1	MT	143.5

Source: Adapted from ABEEólica (2019) and Absolar (2020).

Northeastern Brazil accounts for approximately 86.4% of the 15.4 GW of wind energy capacity in the country; only Alagoas State does not have wind farms among this region's nine states. The Southern region ranks second place, with 95 installed wind parks - most of them (n=80) are installed in Rio Grande do Sul State. The only wind park located out of these two regions is installed in Southeastern Brazil, most specifically, in Rio de Janeiro State (ABEEÓLICA, 2019).

Another factor helping the country lies on its electric power production, which is mostly based on hydroelectric plants that account for 61.1% of the total energy produced countrywide (ABSOLAR, 2020). These trends are also observed in other Latin American countries that avoid CO2 emission based on the WTW (Well-to-wheel) approach, according to which, emissions are measured from the electric power production to its final consumption.

The transport sector in this region accounts for 19% of CO2 emissions.

However, it is worth mentioning that Brazil is currently facing crisis in the electric power sector. Although this phenomenon tends to be temporary, in the short term, it can naturally inhibit companies interested in starting their transition from conventional to electric vehicle fleets, as well as municipal, state and, mainly, federal government's will to provide tax incentives and to invest in the research, development and construction of proper infrastructures to enable the operation of electric vehicle fleets, and the application of beneficial public policies to companies in the road freight transport sector that have started operating with new electric vehicles.

It is essential using these energy production sources because, in addition to being clean, they will supply the extra energy demand and consumption to be observed due to the expansion of electric vehicles in the market. Such a process will have technical, economic and operational impact on the electrical system; moreover, it will require investing in projects focused on the modernization and expansion of electric power distributors to ensure energy security in several countries, worldwide. Furthermore, if the region manages to simultaneously exploit its growing renewable energy matrix and its electric power distribution system - which is highly reliable and has costs lower than those of liquid fuels -, electric vehicles can penetrate all segments in most countries within approximately two decades, based on estimates in the present study.

EVs' application based on service type

Different service types have different logics concerning the use of electric vehicles due to their charging capacity and infrastructure. The focus of the present manuscript lies on road freight transport; thus, it is necessary describing urban and home deliveries, as well as auxiliary services discreetly adopted in some Brazilian regions, such as garbage collection service and mail delivery, in details. There is also the long distance freight transport service available in some European markets such as Sweden, the Netherlands and Denmark. However, given Brazil's geography and early fleet transition process, and because it lacks proper infrastructure for long distance transport services, changes in the country should first start in urban delivery services with shorter routes, home deliveries and auxiliary services. Naturally, this process would help both educating and adapting the Brazilian population to this new system.

Urban deliveries are carried out within the limits of a given city, where goods are transported in semi-light or light trucks from urban consolidation centers to individual stores or from urban distribution centers, such as supermarkets, to urban convenience stores. Urban Consolidation Centers are logistics platforms where the overflow of different shipments takes place; then, they are gathered in a single shipment to be transported by a single truck. This procedure enables to better occupy vehicles, reduce costs, energy consumption and raw materials' extraction, mitigate traffic jams, reduce the number of travels, shorten traveled distances, reduce atmospheric pollutant, greenhouse gas and noise emissions, as well as to deliver products from different suppliers in the same area (this process is known as demand consolidation). Urban distribution centers are seen as solution to optimize logistics sustainability in the locations they are based in, by adopting the best solutions for the chain comprising carriers, drivers, suppliers, authorities and customers; they also support the collection and distribution of different goods in the last mile of the urban zone served by them, as well as the cooperation between medium- and long-distance logistics operators and other service agents.

This service type mostly have short journeys that mainly take place on the main urban roads; electric vehicles used in their operations have their batteries recharged at wireless recharge points, while goods are loaded or unloaded in establishments that have recharge equipment, or at intervals between shifts; this procedure increases practicality and enables using lower capacity batteries. The installation of recharging equipment in the goods' unloading area can help reducing the price paid by customers to receive the product, due to the recharging service provided to carriers. Vehicles can also be recharged throughout their route, a fact that can speed up the operation and reduce recharge time at goods' loading and unloading time or at intervals between shifts, since carriers can take advantage of the fact that their vehicles travel through pre-determined routes equipped with the CoM (Charge-on-the-move) system.

Some vehicles feed directly from the electrical network through the catenary system, which enables moving vehicles to remain connected to it. These vehicles do not require significant energy stock in internal accumulators, such as batteries; they are called RPEV (Road Powered Electric Vehicles). Trains and old trams are the best known examples of these vehicle types. Trolley trucks are the best known example of them in the road environment; they were introduced in freight transport in Sweden, in 2016 (Plötz et al., 2019). Given their load capacity, these vehicles are medium-sized, semi-heavy and heavy trucks that were first used for mining activities and close to ports. Minimum vehicle height is required for this system to be used, and it makes these vehicles unsuitable to be used as cars; therefore, operational and infrastructural costs would have to be borne by the freight sector, alone. Other challenges inherent to these vehicles comprise the high voltage wires above the roadway, which can pose significant threat to safety. In addition, in the event of collision between vehicles and support poles on the road, repairing them would require great effort. Since they feature an inflexible load, they have significant impact on the energy system. Figure 3 shows an example of trolley truck.

Figure 3 – Example of trolley truck

Source: Plötz et al., 2019.

Home deliveries consist in transporting goods from local distribution centers and supermarkets to consumers by using light commercial vehicles. Since most home delivery trips cover short distances with frequent stops, and given the possibility of replacing all conventional vehicles with capacity up to 3.5t by electric ones, home delivery is the most suitable service for EV use, mainly for vehicles with battery power range available for the requested route.

The number of home deliveries is increasing; consequently, the number of light commercial vehicles in different cities is also increasing, a fact that puts increasing pressure on cities' habitability. Compact utility vehicles equipped with drive or electric assistance mechanism and mopeds can provide a solution, since they require lesser space both in traffic and at goods' unloading time; they are easily driven and maneuvered; their batteries, mainly the ones with smaller capacity, perform better; they are often designed for specific purposes; and they are an alternative to drivers' shortage in big cities.

Bicycles are another example in the investigated scenario. In addition to provide human propulsion, which helps recharging batteries, they have been improved to be used for goods' transport purposes. Among the aforementioned improvements, one finds lighter manufacturing materials, the development of goods' loading and unloading areas and the implementation of electric motors to help cyclists, mainly in uphill trips, to mitigate their fatigue by providing them with a more comfortable driving – thus, these bicycles feature a hybrid system. However, Brazilian tropical climate does not favor the use of bicycles as means of transport to perform these tasks as it happens in other markets, mainly in Europe. Nevertheless, they could be tested in several delivery services provided in the national territory, preferably within city limits.

These vehicles are called light electric freight vehicles (LEFVs), which feature a subcategory of light commercial vehicles that have been increasingly used by logistics service providers in European cities, mainly in downtown areas. Such an increase is directly linked to the increased number of self-employed workers; to the likelihood of having low-income individuals entering the labor market; to the new and growing trends towards delivery services provided by supermarkets, restaurants, grocery stores, fast food restaurants, pharmacies, bookstores and clothing stores, among others, to meet orders placed by customers in mobile applications; as well as to the delivery of construction materials and to garbage collection services.

Garbage collection vehicles feature a case different from the others because, besides the energy necessary for their journeys, they also need energy for bin-lifters, garbage compaction and security lighting, among other systems. Their driving cycle comprises many acceleration and deceleration events, which take place in short time intervals and benefit from regenerative braking. One of the issues faced by these vehicles lies on the fact that charging stations can be affected by hostile environments associated with garbage collections; thus, CoS (Charge-on-the-stop) technology could be used in key locations along their route, while these vehicles remain stationary for a certain amount of time during garbage lifting and compacting processes. The compaction process plays fundamental role in increasing garbage transport capacity by decreasing its volume; however, it produces remarkably loud noises that can harm garbage collection workers' hearing and is the service consuming most of trucks' energy.

The mail delivery activity goes through the receiving, sorting and posting stages, before it is properly carried out. After leaving the distribution center, postmen cover their planned delivery routes on foot, when the final mail destinations are close to the DC, or they can board a bus to the delivery location, with their bags of mail to be delivered still empty.

BEV-type LEFVs have been tested by companies to provide better sustainability at economic, social and environmental level. Among them, one finds the electric tricycles used by postmen to deliver the whole mail set per route in a single trip, without the need of refilling their mailing bags; therefore, this strategy dismisses the use of vehicles required in the previous way, as well as of DM. Postmen leave the distribution center in the tricycles and only disembark from them to deliver the mail to recipients. Figure 4 depicts what tricycles look like.

Figure 4 – Post office electric tricycles

Source: Correios, 2014.

Based on tests already carried out, it was possible noticing decrease in atmospheric pollutant and GHG emissions between mail departure from DCs to the delivery routes, if one takes into consideration both the end use and the life cycle of these emissions. However, some disadvantages were also perceived, such as higher cost per delivery, due to higher LEFV acquisition value in the first case. This disadvantage was not observed for tricycles, which recorded lower cost per delivery and higher productivity than that of combustion vehicles. Quak et al. (2016) mentioned employees' health improvements, such as decreased heart rate in individuals who previously presented high HR, as social benefit deriving from tricycles. However, the aforementioned authors also pointed out that, so far, Brazil lacks progressive implementation of these electrical system types, as one can see, for example, on line n. 562 of the French system, where SEDEX delivery based on electric vehicles has been operating since 2014.

Proposals to enable introducing "EVs" in the Brazilian road freight transport system

Solutions suggested to overcome each challenge faced by the electric vehicles described throughout the current study are highlighted below. The herein proposed solutions are the ones that, nowadays, provide technical and/or financial benefits to help solving the investigated issue:

- Users' lack of knowledge:

a) Transition through hybrid vehicles: The technical benefit is represented by the combination of the internal combustion engine to one, or more, electric Motors; it makes hybrid vehicles more technologically mature than electric vehicles. The economic benefit, in its turn, is represented by acquisition cost lower than that of purely electric vehicles. According to Juan et al. (2016), the change of fleets increased by approximately 30% in countries where this transition took place;

b) Drivers' training: The technical benefit is represented by drivers' training-based acquired ability to adapt to the technical and operational peculiarities of electric vehicles. The economic benefit, in its turn, is represented by the financial condition many companies currently have to invest in training for their drivers. According to Juan et al. (2016), fleet transition in companies with trained drivers increased by more than 60% in countries where this training took place.

- **High acquisition costs**:

a) Surveys focused on producing cheaper batteries: These surveys will provide significant economic benefit, since batteries are the most expensive component in electric vehicles; consequently, reducing their respective prices can help reducing the total price of electric vehicles. According to Nicolaides et al. (2018b), these surveys promoted significant increase (by approximately 60%) in companies' investments in fleet transition in the main European countries, since they optimized the prospects of greater autonomy for the sustainable road freight transport system.

- Low autonomy:

a) Tests and Demos: The technical benefit is represented by the discovery of load segments and logistics operations best suited to electric vehicles. According to Nicolaides et al. (2018b), tests and demos account for approximately 20% of investments in the road transport sector in European countries, such as England and Sweden. Moreover, because it is not such a big investment, companies' return reaches approximately 45 % in new benefits and in privileged contracts with the government, when new research projects are developed to make the fleet transition in the involved companies easier;

b) Route-planning: The technical benefit is represented by intelligent route planning systems capable of performing this activity, since most distances are previously known by companies accounting for operating in this sector. According to Nicolaides et al. (2018b), route optimization through increasingly sophisticated intelligence and logistics services can provide significant return of approximately 70% to companies operating in the road freight transport sector, as well as increase their autonomy and the number of sustainable activities performed by them, on a daily basis.

- **Long recharge time**:

a) Fast charging stations: The technical benefit is represented by the likelihood of supplying 80% recharge and of traveling approximately 100 to 160 kilometers after approximately 20-minute recharge. The economic benefit, in its turn, lies on the fact that costs with the implementation of fast charging stations are relatively equal to those of other urban infrastructure projects. According to Nicolaides et al. (2018a), countries that implemented this venture type sped up the fleet transition process by approximately 55%;

a) Implementation of the underground recharge system: The technical benefit lies on maintaining the charge at high levels, and it reduces the idle time for recharge purposes. The economic benefits, in their turn, are represented by reduction in charging costs, which would be a free service under this condition, as well as by increase in vehicles' payload and, consequently, in delivery capacity and profits;

a) Implementation of battery replacement stations: The technical benefit lies on these stations ability to replace batteries in less than 10 minutes or in approximately 5 minutes when this service is performed by automated stations. The economic benefit lies on the fact that these stations' costs are lower than those of fast charging stations. According to Nicolaides et al. (2018a), although battery replacement stations are not the main solution in the investigated scenario, they support the circular economy of the countries they were implemented in, and contribute to increase fleet transition by approximately 15%, when these countries already have satisfactory infrastructure for fast charging stations.

- **Self-discharge or internal battery resistance at extreme temperatures**:

a) Previous thermal conditioning of the vehicle cabin: The technical benefit is represented by increased battery autonomy range in comparison to battery efficiency losses. According to Steward et al. (2019), automakers that adopted this conditioning procedure as priority item to develop their new electric trucks in some European countries recorded approximately 45% battery autonomy gains, a fact that increased their vehicles' reliability in the market;

b) Vehicle information panel: The technical benefit is represented by the indication of the remaining range, real-time energy consumption and charge status.

- **Low levels of second-hand market for batteries**:

a) Battery remanufacturing: The technical benefit is represented by reduced energy consumption and life cycle emissions. The economic benefit is represented by maximized battery value and by savings corresponding to more than 70% of the cost associated with battery replacement;

b) Reusing batteries: The technical benefit is represented by the extension of batteries' useful life, beyond their first use. The economic benefit is represented by higher value extraction from the use of batteries. According to Steward et al. (2019), some European countries that adopted the reuse procedure to favor the circular economy of this sector recorded increase in fleet transition by approximately 30%;

c) Recycling batteries: The technical benefit is represented by the ability to accommodate the most different battery models, with different nominal capacities, that become part of the sector's circular economy.

Other suggested proposals, such as exemption from tollways and traffic taxes in urban centers, captive parking spaces, vehicle insurance discounts and inspection waivers, have been implemented worldwide to meet the goal of introducing electric vehicles, such as electric bicycles, in the market. Rizet et al. (2016) have suggested the following aspects as policies: priority or obligation to use electric vehicles to make deliveries in certain areas; authorization for EVs to deliver throughout the day, whereas other vehicle types have time restrictions; and the rental of battery-powered vehicles. Quak et al. (2016) have suggested priority access initiatives, such as access to high-occupancy vehicle lanes, extended customer service time window, and exemption from maximum weight limit.

According to Ehrler et al. (2020), another partnership aimed at identifying the freight transport segments mostly suitable to the fast change to EVs, and at promoting their development, happens between original equipment manufacturers (OEM) and the government, which, in its turn, funds research institutions; together, they find the desired answers through pilot projects and assess the development of the topic through learning curves. Thus, costs, risks and profits associated with opening the market to EVs will be shared among several actors acting in this business; they will all benefit from its expansion, since their image will be associated with sustainability and they will stand at the forefront of this innovation.

Iwan et al. (2019) have stated that public authorities are the main agent influencing the acceptance of electric urban-freight-transport vehicles through both monetary and non-monetary support. Naumanen et al. (2019) have stated that significant transition into electric mobility is unlikely to happen without stringent emission regulations for automakers and private fleets. According to Mirhedayatian and Yan (2018), there are two main types of taxes for vehicles, namely: registration and circulation; circulation taxes are paid to enable vehicles to be used on roads. The aforementioned authors have suggested two possibilities, namely: EVs are exempt from at least one of these taxes, or these two taxes work in the same way through the application of a proper discount rate.

Although the so-called Feed in Tariff (FIT) public policy - which aims at encouraging the adoption of renewable energy sources - is at advanced development stage in countries such as Germany and Japan, it remains quite incipient in Brazil. It consists in paying tariffs to companies that produce energy by alternative means, such as photovoltaic panels on the roofs of houses, and commercial and industrial buildings, to supply both isolated systems and electric power supply networks. The main aim of this policy is to enable the implementation of production plants, whose expenses to generate energy are relatively high (SOLARVOLT, 2015).

According to Quak et al. (2016), different public policies (mentioned in the current study) played fundamental role in encouraging research development and in intensifying the production of new vehicles to carry out road freight transport tasks in markets where the vehicle fleet transition is gradually and successfully taking place. By extension, the governments of these countries played extremely important role in defining municipal, state and national policies to optimize fleet transition, as well as provided the incentives necessary to build the proper infrastructure for transport tasks, in compliance with public policies established in each region.

Limitations of the current study

One of the limitations of the current study lied on the impossibility to collect data about the total number of public electric stations already installed in the country and about the number of freight transport-intended EVs purchased in the most recent years, since EVs used for freight transport purposes remain at a quite early stage in Brazil. These data would help better explaining the current status of the conventional-to-electric-vehicle transition process in Brazil, in the herein investigated scenario.

Another limitation referred to the analysis of EVs currently used for freight transport purposes, since some of them did not have all the desired technical information available.

Finally, it was not possible performing a comparative economic study between conventional and electric trucks to mathematically prove the higher financial viability of EVs, based on their lower energy and maintenance costs, despite their higher acquisition cost.

Conclusions and implications of public policies

The introduction of electric vehicles in the road freight transport sector has already started in some markets, although in a slow and gradual manner. Thus, it is essential understanding the freight and logistics operation sectors mostly suitable to enable the transition from traditional combustion-powered vehicles to new electric ones.

However, since this technology remains at maturation stage, electric vehicles face challenges to their introduction in the freight transport sector. Among them, one finds, the need of a specific infrastructure to enable their operation, high acquisition costs, low autonomy, long recharge time, as well as the yet incipient second-hand market for batteries, among other components. These challenges can also be a considerable factor hindering investments in electric vehicles by both individuals and companies, despite their countless environmental and sustainability-related benefits.

It was possible seeing the excellent environmental and economic potential of electric vehicles based on results observed through the herein proposed methodology. Consequently, one can emphasize the relevance of this topic and the herein presented justifications to encourage the transition from traditional to new electric vehicle fleets in the road freight transport sector.

Tax reduction policies, such as IPI (Brazilian Tax on industrialized products) and ICMS (Brazilian Tax on the circulation of goods and services), as well as the bill aimed at ruling out taxes on the imports and sales of electric cars, are the first steps towards effectively boosting the fleet transition process. Similarly to other countries and economic blocs, Brazil must also set a target to reduce the amount of GHGs and atmospheric pollutant emissions by a pre-determined year by continuously introducing electric vehicles in the national road freight transport system.

It is recommended performing further specific studies aimed at investigating the numerical benefits EVs have brought to countries where this technology is already at more advanced stages in terms of reducing atmospheric pollutant and GHG emissions. By extension, it is also recommended performing studies about the Brazilian legislation and, consequently, suggesting methodologies to enable importing and, subsequently, adapting successful international public policies to the Brazilian business model in order to expand tax incentives and investments in infrastructure to help the gradual vehicle fleet transition process in the country.

In addition, studies in the recycling field associated with electric vehicle batteries, among other components, should also be conducted to help improving and even developing new methodologies focused on the yet incipient second-hand market of this sector.

Thus, companies undergoing fleet transition will be able to negotiate subsidies directly with the government, by basing their requests on the road freight transport service they intend to provide, including auxiliary services. By extension, these subsidies will be also allocated to the assembly of proper infrastructure to serve these activities in the most diverse transport services that can be performed in the national territory. Fleet transition-pioneer companies had great support from their respective governments in markets where this change was successfully done. They received the main incentives needed in all fields associated with the research, development, assembly and infrastructure necessary to enable electrifying their fleet.

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SciELO

Utilização de veículos elétricos no transporte de cargas e os desafios para implementação no Brasil

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Resumo: Esta pesquisa discute as principais políticas públicas internacionais bem sucedidas voltadas para a expansão da frota de veículos elétricos para o transporte rodoviário de carga, e como tais políticas poderiam ser adaptadas ao mercado brasileiro. Análises sobre as principais políticas públicas em mercados estrangeiros que resultaram em incentivos fiscais, expansão da infraestrutura existente e fomento de novos negócios na transição da frota de veículos convencionais para veículos elétricos, além de estudo sobre as possíveis adaptações que a legislação brasileira permite para que essas políticas possam ser adaptadas ao mercado nacional são os principais desafios para o setor. Entretanto, embora a eletrificação surja como a principal alternativa para melhorar a eficiência energética, muitos países ainda não implementaram políticas públicas para dinamizar a transição de suas frotas. Os resultados da pesquisa podem contribuir com futuros estudos sobre adequação de políticas públicas bem sucedidas e possíveis adaptações ao modelo de negócio brasileiro.

***Palavras-chave*:** Veículos elétricos, Transporte de carga, Políticas públicas, Mobilidade sustentável, Eficiência energética.

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Uso de vehículos eléctricos en el transporte de carga y los retos de implementación en Brasil

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Resumen: Esta investigación analiza las principales políticas públicas internacionales exitosas destinadas a ampliar la flota de vehículos eléctricos para el transporte de carga por carretera y cómo estas políticas podrían adaptarse al mercado brasileño. Análisis de las principales políticas públicas en los mercados exteriores que resultaron en incentivos fiscales, ampliación de la infraestructura existente y promoción de nuevos negocios en la transición de la flota de vehículos convencionales a vehículos eléctricos, además de un estudio sobre las posibles adaptaciones que el brasileño La legislación permite que estas políticas puedan adaptarse al mercado nacional son los principales retos del sector. Sin embargo, aunque la electrificación aparece como la principal alternativa para mejorar la eficiencia energética, muchos países aún no han implementado políticas públicas para agilizar la transición de sus flotas. Los resultados de la investigación pueden contribuir a futuros estudios sobre la adecuación de políticas públicas exitosas y posibles adaptaciones al modelo empresarial brasileño.

***Palabras-clave*:** Vehículos eléctricos, Transporte de carga por carretera, Políticas públicas, Movilidad sostenible, Eficiencia energetica.

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