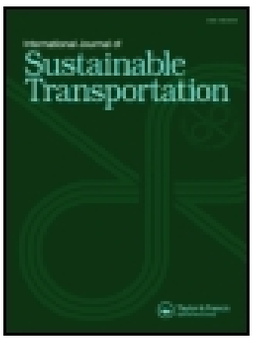

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Diffusion of electric vehicles in Brazil from the stakeholders' perspective

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ABSTRACT

A major challenge for humankind is to reduce global carbon dioxide (CO_2) emissions to avoid the most harmful impacts of climate change. The transport sector is responsible for almost 1/4 of the world's energy-related emissions, with road transportation representing around 1/5 of the fuel consumption. Electric vehicles (EVs) may help to reduce CO_2 emissions, but their diffusion is uncertain due to market barriers. This paper investigates the electric vehicle (EV), which has a smaller ecological footprint, as an alternative capable of meeting the needs of personal transport in Brazil. To carry out this evaluation, the study considers socio-techno-economic and political-environmental-innovation aspects to assess the challenges and opportunities facing the adoption of electric vehicles. The analysis was carried out based on a survey administered to a wide range of stakeholders. A SWOT analysis was performed to understand the most critical factors affecting the future of EVs in Brazil, which is a top-ten automotive manufacturer worldwide and a leader in sugar cane ethanol production. The results suggest light-duty electric vehicles (LDEV) as a first option for low-carbon passengers' mobility and that EVs expansion will require market regulation, incentive policies and adequate charging infrastructure. Both consumers and society in general will benefit most from the expansion of EVs due to low emissions and total cost of ownership (TCO). The results show where decision-makers should focus their attention.

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Climate change; CO_2 emissions; electric vehicle; greenhouse gas (GHG) emissions; SWOT analysis

1. Introduction

One of the major challenges for humankind is to tackle the effects of climate change, which can be achieved by cutting global carbon dioxide (CO_2) emissions in order to maintain the global average temperature between 1.5 °C and 2 °C above pre-industrial levels (Pachauri et al., 2014). In 2014, the transport sector was responsible for almost 1/4 of worldwide energy-related emissions and road transportation was responsible for around 1/5 of the fuel consumption (IEA, 2017). The search for low-emission transport should be a priority for governments worldwide, as they attempt to achieve the goal of reducing emissions set in the Paris Agreement (UNFCCC, 2018).

Brazil's automotive industry is in the top ten worldwide (OICA, 2019), and the fast growth of the automobile market in Brazil, due to increasing urbanization and consumers' access to cars, has contributed to worsening the levels of CO_2 emissions (Costa et al., 2018; Costa & Seixas, 2014). In 2014, the transport sector represented more than 32% of energy consumption in Brazil with road transportation accounting for more than 92% of that amount (EPE, 2015). Brazil has invested in ethanol as a clean fuel, becoming the world leader in the production of sugarcane ethanol. From 1990 to 2011, the cultivated area increased 45% and ethanol production increased by an average of 1.5 billion tonnes per year (Filoso et al., 2015). Ethanol has contributed to decreasing the growth of transport emissions in Brazil. However, increased ethanol production has led to other problems, such as deforestation, soil contamination, water and air pollution (from biomass burning), and the possibility of competing with food production (Filoso et al., 2015; Gauder et al., 2011; Martinelli et al., 2011).

The electric vehicle[1] (EV), has a smaller ecological footprint when compared with other road transportation options (Hooftman et al., 2016; Messagie, 2014; Seixas et al., 2015) and it is the most accessible low emission road transport technology (IEA, 2016). Life-cycle assessment (LCA) indicators reveal that EV generate around three times less CO_2 emissions than light-duty vehicles (LDV) powered by ethanol[2], around thirteen times less emissions than LDV powered by gasoline "C"[3] (Appendix B, Table B1) or about eleven times less than LDV flexible fuel[4] (flex), which

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[1]In this paper electric vehicle (EV) is synonymous of battery electric vehicle (BEV).

[2]Sales of vehicles powered by ethanol alone are negligible. Currently, flex fuel models represent around 99% of total LDV sales (ANFAVEA, 2020).

[3]Mixture of gasoline "A" with 27% Anhydrous Ethanol giving rise to Hydrated ethanol which supplies the flexible-fuel or flex vehicles.

[4]Flex fuel is an alternative fuel vehicle that can work with gasoline and ethanol at the same time. Vehicle equipped with internal combustion engine (Otto cycle).

Table 1. Participation of the sectors surveyed.

Sectors	Number of stakeholders contacted	% of valid responses
Government	127	13
Industry	161	32
Non-governmental organizations	96	4
Specialized media	23	44
Retail and service providers	78	56
Consultants, experts and enthusiasts	34	13
Total	629	23

represents around 94% of LDV sales in the country (ANFAVEA, 2020; Costa, 2019; Leite, 2016). EV emissions are very favorable to EV due to around 4/5 of the country's electricity production from renewable sources (EPE, 2019).

However, EV market penetration has been slow and limited to a few countries with market share of around 2%. China, the US, and Europe own 90% of the world's sales (IEA, 2020) of electric cars (EV and plug-in vehicles). For the most part, this is due to barriers such as: a) high sale price (without incentives) comparable with the internal combustion engine (ICE) models (Lin & Greene, 2011; Santos, 2017); b) small range to levels close to fossil fuel models (Catenacci et al., 2013; Lieven et al., 2011); and c) socio-technical barriers such as lack of infrastructure and long charging time comparable with ICE models (Sierzchula et al., 2014; Thiel et al., 2012).

As argued by Sovacool (Sovacool & Hirsh, 2009), even though transport studies tend to focus on the technical barriers and solutions to the adoption of EVs, it is necessary to draw on insights from a socio-technical perspective. As highlighted by Rogers (Rogers, 1995) in his renowned diffusion of innovations theory, "the diffusion of innovations is essentially a social process", and the meanings attributed to an innovation are socially constructed.

The social challenges in the transition to a carbon-neutral transport system include social and cultural values, as well as political interests, as they may be as important as technological challenges (Sovacool & Hirsh, 2009; Steinhilber et al., 2013). Moreover, other critical factors for the expansion of electrified mobility include the need for investments to improve technological resources, increase the renewable energy share, and improve transport innovation.

The ways that individuals subjectively perceive technological innovation and how these can be integrated into their everyday lives shape the diffusion processes. Individuals are influenced by (and learn from) others in their social networks, either to express distinction (when an innovation is adopted by individuals with higher social status and subsequently emulated by others) or because personal connections reduce the uncertainty associated with innovations (Bartiaux et al., 2016; McMichael & Shipworth, 2013). In fact, interpersonal relations have been considered one of the most powerful influences on behavior (Buttle, 1998; Watts & Dodds, 2007), and their influence has been observed regarding consumers' perceptions of plug-in hybrid electric vehicles (Axsen & Kurani, 2012).

Adopting incentive policies is one way of overcoming EV penetration barriers. Policies deployed in different countries result in different purchase incentives. There is the trend that the greater the incentive, the greater the penetration of the EV. Norway's case reveals that policies capable of delivering an incentive package on total cost of ownership (TCO) must be aligned with the attractiveness of the EV to the consumer, such as benefits of having free toll access on highways, free parking, and exemption or reduction in licensing fees among others (IEA, 2017). It is therefore necessary to know which incentive policies are most important for the Brazilian driver, i.e. discount or exemption from license fee and, in some cases, no circulation restrictions (PMSP., 2015).

The lack of broad incentive policies may be one of the causes of EV non-diffusion in Brazil: only around 23 thousand of light-duty electric vehicles (LDEV) were registered in the country from 2011 to 2019 (most of them acquired for study purposes). In this same period, more than 26 million light-duty vehicles (LDV) were sold, including models like ethanol, gasoline and flex fuel (ANFAVEA, 2020). The EV diffusion has been a topic of discussion in Brazil within a few small movements, almost all of them independent of the automotive industry and without government support (De Mello et al., 2013).

An option to encourage users to adopt EV could be to offer benefits, e.g. tax incentives. Currently, the government grants exemption from import tax (35%), but taxes on EV are still high (EV tax is from 43.6% to 49.6%, as shown Appendix B, Table B2), burdening the cost and making the commercialization of LDEV an option for a few buyers (Marx & De Mello, 2014): For example, in February 2020, a Nissan Leaf (battery 40 kWh) can be bought in Europe for less than 32,000 euros (Nissan, 2020a), whereas in Brazil it's sold for the equivalent value of 44,000 euros (Nissan, 2020b). The absence of adequate policies to promote EV can be attributed to some barriers such as the ethanol and the oil industry, as well as competing interests from other political and economic groups (Costa, 2019). Perhaps the government thinks investing in EV could mean splitting investments with ethanol and decreasing its economic activities. After all, ethanol is a successful Brazilian project that generates national pride. However, investing in EV means not moving away from technological advances and the opportunities that electric mobility (EM) offers as the smallest ecological footprint (Costa et al., 2017). The dominance of renewable energy mix in Brazil may be a good reason for broader adoption of EV incentive policies. In 2019, around 83% of electricity was produced by renewable resources (EPE, 2019).

Research is the natural way to identify critical factors and opportunities to guide policy makers and other stakeholders toward the EV mass-market, especially in developing countries (Tsang et al., 2012) where there is little information

Table 2. Topics of the survey questionnaire.

Groups of questions	Topics
Views on EV (1)	Diffusion (market penetration) Performance of the vehicle Environment Convenience of use Acceptability
Factors for the SWOT analysis (2)	Internal factors: Strengths and weaknesses External factors: Opportunities and threats (Socio-Technical, Political-Economic and Innovation-Environmental)
Social characterization (3)	Gender, age, education, work sector, business segment and job (occupation)

about EM. Our study aims at identifying the strengths, weaknesses, opportunities and threats for the expansion of the LDEV in Brazil, regarding socio-techno-economic, and political-environmental-innovation aspects. The study is based on SWOT matrix principles (Barrella et al., 2013; Gil et al., 2011; Markovska et al., 2009) applied to a survey which has been conducted among different sectors and important stakeholders with an interest in EVs.

The SWOT analysis considered aspects such as market variables, as well as policies capable of making mobility more efficient and ecological (Beise & Rennings, 2005; Dijk & Yarime, 2010; Geels, 2012; Porter & Van der Linde, 1995; Shepherd et al., 2012; Stern, 2006). SWOT analysis is a resource capable of assessing the challenges and opportunities of EM, taking into account both the tangible and intangible aspects of the EV and its charging infrastructure. It is capable of assessing strengths (revealing advantages over another type of mobility) and weaknesses (emphasizing the characteristics that put EVs at a disadvantage in relation to another technology) of EM (Dyson, 2004).

SWOT analysis is also capable of revealing opportunities (external factors capable of benefiting EVs evolution) and threats to EM (external factors that may threaten the success of EVs versus other technologies), providing strong insight and consistency of the study, making it possible to evaluate not only the acceptance of EM, but also the possibility of growth, consolidation and maintenance of EVs (Dyson, 2004). Aspects like EV technology, support infrastructure, energy efficiency and emissions reduction (Sperling, 2014), and subsidies, incentives and guidelines to provide the sustainable expansion of EVs (Sperling, 2014; Stern, 2006), are also elements considered by SWOT analysis.

The results of this research contribute to a better understanding of the critical factors that are affecting the potential of diffusion of EVs in Brazil, which may guide the public and private sectors on making decisions toward its expansion. The next section of the study will present the methodology, while section three will present the results and discussion of the main findings. The fourth section will conclude, highlighting the limitations and making suggestions for future studies.

2. Methods

Challenges and opportunities for the expansion of EVs in Brazil were assessed through a methodology based on a survey to a wide range of stakeholders in the country, whose responses were organized through a SWOT analysis.

We sought to evaluate how different stakeholders approach the EV in Brazil, and what their views were on critical factors to its massive adoption. The research was developed in four steps: the first and second steps were designed to plan and prepare the questionnaire. The third and fourth steps were evaluated to test, apply the survey, analyze the data and ascertain the results, as shown in Figure 1.

2.1. Research planning

This step was developed in two phases. First, to identify the stakeholders, we contacted the main representative organizations from all selected sectors listed in Table 1. Some agents, such as consultants, experts and enthusiasts, have been identified through news published in magazines, the internet and social media as well. Regarding the government we contacted some legislative members and three levels of executive power (central government, states and municipalities).

Second, to approach the stockholders (Table 1), at least six contacts were made. The first approach consisted of a letter of invitation explaining the basic information such as research purposes, institutions involved, methods, research ethics and how the results would be explored. About two weeks later, a second correspondence was sent to those who agreed to participate in the survey, providing additional information and emphasizing the importance of participating by completing the survey questionnaire. For those who decided not to participate in the survey or did not send feedback, additional information was provided in an attempt to persuade them in favor of the inquiry. A third contact was conducted to send the survey questionnaire. After that, three additional contacts were made: the first two (with an interval of about one week each between them) to follow up the survey and the last (about one month after the return of the last questionnaire) to thank them for the return of the questionnaire.

2.2. Preparation of the questionnaire

The questionnaire was carefully prepared to cover a comprehensive picture of EM in Brazil and to evaluate the diffusion potential of EVs considering the international experience (IEA, 2016). We identified which questions would be most appropriate to include in the survey according to the purpose of the study, as well as the best ways to classify the questions (Table 2) by reviewing literature (Accenture, 2011;

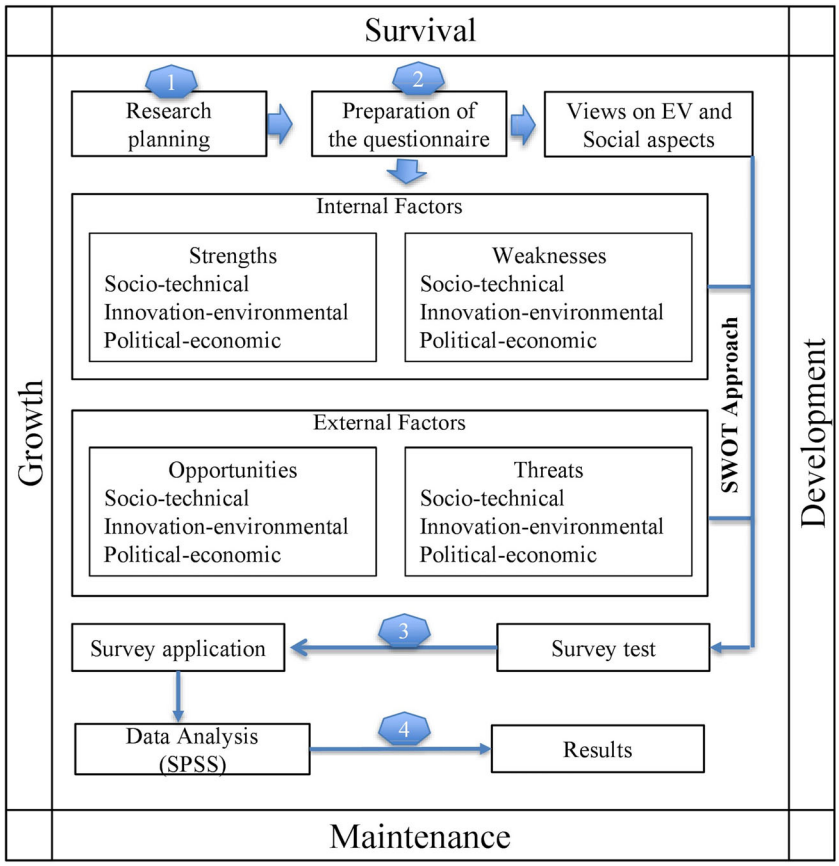

Figure 1. Step-by-step methodology scheme.

IEA, 2016; Jabeen et al., 2013; Krupa et al., 2014; Melton et al., 2017). This step was developed in three phases.

Phase 1 (see Table 2: group 1) aimed to identify the stakeholders' view of the future of EV in Brazil (Table 2). The EV categorization limits, mentioned in this phase, were established according to the research topic and literature data (Accenture, 2011; IEA, 2016; Krupa et al., 2014). For example, EV market penetration was considered current EV market and the EV potential penetration in Brazil and abroad (Costa et al., 2017; EPE, 2015; IEA, 2016). Regarding the EV performance, such as battery range, charging time, and other related issues the performance and use data of the electric models available in the market as well as the ICE models were taken into account (IEA, 2016).

Concerning environmental aspects, such as CO_2 emissions, historical data of EVs and ICE were taken into account (IEA, 2016; MMA, 2011). As to the issues related to EM policies, such as barriers, benefits and incentives, international experience data was taken into account (Costa et al., 2017; IEA, 2020).

Phase 2 (see Table 2: group 2) referred to aspects relevant to make a SWOT analysis. This analysis originated in the field of business management, and has been disseminated from the 1960s into academic business policy studies at Harvard Business School and other business schools (Hill & Westbrook, 1997; Markovska et al., 2009). Currently, SWOT analysis is used widely, including the transport sector (Barrella et al., 2013; Gil et al., 2011). SWOT analysis aims to identify the key internal and external elements that are essential to achieve a given objective and its application focuses on two factors: i) internal factors: are the internal strengths and weaknesses of the organization; ii) external factors: are the opportunities and threats that exist in the environment outside the organization (Dyson, 2004; Valentin, 2001). In SWOT analysis the strengths are tangible and intangible positive attributes that can support organizational success. Weaknesses are negative factors that can hinder the achievement of desired goals. Opportunities are external factors that can be beneficial to project development and threats are externalities that can compromise desired outcomes (Dyson, 2004).

Some factors act as anchors in the application of SWOT analysis. These include: i) maintenance is often perceived as a condition of supporting the key processes performed in an organization in order to maintain its competitiveness. The role of maintenance is to achieve a sustainable and competitive environment by nurturing knowledge from within the organization. The goal is to build capabilities to avoid or minimize the risks of the organization (Jasiulewicz-Kaczmarek, 2013); ii) growth reflects the organization's ambition to thrive solidly and stand out in its segment. To ensure growth the organization must constantly evaluate its core business (its products) and focus on strategic management. It is necessary to be vigilant to the external and internal aspects (Gradinaru & Gradinaru, 2018); iii) development reveals the potential of the organization to thrive based on its business trajectory from the analysis of its products and services. Applying SWOT analysis from these

Table 3. Topics of the survey questionnaire.

Sex	Segment of action
Male	*Industry*
Female	*Service provider*
	Education and dissemination
	Electrical energy sector
	Government
Age	Profession
Up to 18	*Top manager and presidents*
18 – 30	*Intermediary manager*
31 – 45	*Communication and information*
46 – 60	
Over 60	
Education	Sector of activity
No higher education	*Public*
Bachelor	*Private*
Master's and PhD	*Mixed economy*
	Third sector

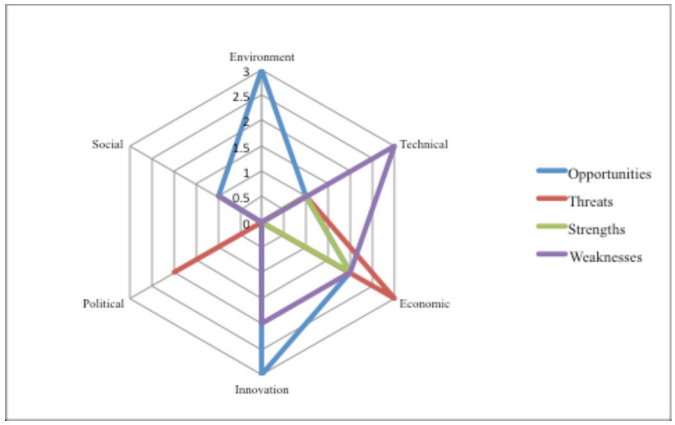

Figure 2. Main results of the SWOT analysis.

elements will develop the strategic profile to draw the organization's direction toward the expansion of its domains (Gradinaru & Gradinaru, 2018); iv) Survival is the effort that any organization must make to survive in its various environments, fulfilling the mission. Focusing on the factors of internal interaction and the external environment must be a constant exercise for the survival of the organization (Schein, 1999). Based on these concepts, the survey can help to understand how the future of EV in Brazil might be.

The SWOT analysis intended to address the development of the EV in Brazil, from the point of view of the automotive industry and not considering any particular organizational context. The analysis covered three dimensions: a) socio-technical factors, in order to evaluate the critical factors and opportunities for the expansion of a new low emission transport technology (Faber & Frenken, 2009; Sovacool & Hirsh, 2009); b) innovation-environmental factors, to evaluate the transition to a more efficient and sustainable transport system, including aspects like the transition to a low-carbon energy system with adequate charging infrastructure (Bruckner et al., 1996); and c) political-economic (Sovacool & Hirsh, 2009) factors, to identify the potential competition of EVs with ICE models.

Based in SWOT analysis principles and previous studies (Bruckner et al., 1996; Faber & Frenken, 2009; Niu et al., 2017; Raslavičius et al., 2015; Sovacool & Hirsh, 2009) we prepared two sections of thirteen questions each (meaning a total of 26 questions). In the first section, stakeholders were invited to evaluate the strengths and weaknesses (internal factors) affecting the diffusion of EV in Brazil. For this they had to choose one of three options: strong point, weak point or neutral. In the second section, stakeholders were asked to evaluate opportunities and threats (external factors) by choosing one of three options: opportunity, threat or neutral.

The questions were designed in order to correspond to the main variables involving socio-technical, political-economic and innovation-environmental factors (Bruckner et al., 1996; Faber & Frenken, 2009; Sovacool & Hirsh, 2009) and were classified (see Table 2). The way how these variables were classified indicates Brazil's automotive industry potential (strengths and weaknesses) as well as the externalities outside its domain (opportunities and threats) for the diffusion of EM in the country.

This analysis has the potential to reveal whether the diffusion of EV in Brazil is a matter of survival, of maintenance of the status quo or offers opportunities for growth and development (Figure 1) of electric technology in the country, according to stakeholders' perspectives.

Phase 3 (see Table 2: group 3), the last one, collected data on the social characteristics of the respondents, as shown in Table 3. This information allows the researches to deepen the analysis of stakeholders' social perceptions. In fact, we intended to learn if there are significant differences between the interviewees' profile and the research questions. In addition, understanding what the different social groups think may more clearly indicate the future of EV in the country, i.e. a clear and favorable indication of EV by the younger stakeholders group may be a more valuable indicator of the future of mobility in the country, since young leadership will probably have more possibilities to influence the future of EV. Similarly, feedback from members of government may point a clearer direction for the future of EV in the country.

2.3. Test and survey application

After preparing the questionnaires, a pilot study with a group of 38 people composed of researchers, professors and people connected to EM was conducted to test the comprehensiveness, clarity and suitability of the questionnaire. The test phase followed the same parameters and tools indicated for conducting the stakeholder survey. After adjustments to the testing phase, we sent the questionnaire survey to selected stockholders. A total of 629 questionnaires were sent and 23% of the returned forms were validated (Table 1). Data collection took place between May and July 2017. The administration of the questionnaire was implemented through a computer software program '*Encuestafacil*'.

2.4. Data analysis and results

For the analysis phase (see Figure 1: phases 3 to 4), we have adopted quantitative analysis for social characterization

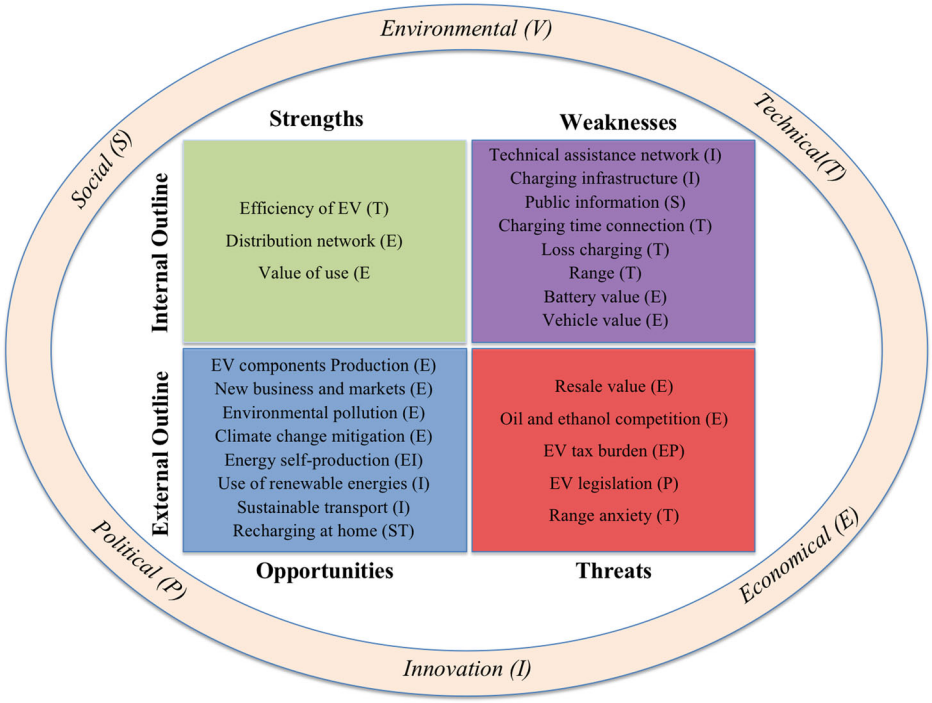

Figure 3. Detailed SWOT analysis result.

issues as well as for stakeholders' overview of the future of EV in the Brazilian market (Table 2 and Appendix A, Table A1). To evaluate risks and opportunities of EV mass-market diffusion in the country, we adopted the SWOT analysis. In an attempt to enrich the analysis in search of new results, we crossed the information between the different categories of the research questionnaire, allowing us to understand the behavior of a given group of stakeholders in relation to a given event. For example, by combining the answers about the EV penetration with the stakeholder sector, it will be possible to know if any sector perceives the future of EV differently. For realization of this type of analysis we adopted the statistical analysis software (SPSS).

3. Results and discussion

The results show that stakeholders consider the EV more appropriate to use than the ethanol-powered vehicle and fossil fuel due to its low ecological footprint (the hybrid ethanol-electric vehicle is the second option), although they highlighted the limited charging infrastructure for EV (Figure 3) as a weakness. The main findings of the survey are included below.

3.1. Views from stakeholders on EVs in Brazil

This section presents the results of the stakeholders' views on the diffusion of the technology, performance of the vehicle, environment, convenience of use, and acceptability (Table 2) of the LDEV. The results, based on the inputs from the respondents, are shown in the next topics.

3.1.1. Diffusion of LDEVs

According to the respondents, the diffusion of the EV (Appendix A, Table A2) takes place mostly in Southeastern Brazil (71%). This is consistent with economic aspects, since Southeastern region is responsible for around 70% of the industry's production and for more than 50% of the country's vehicle fleet. More than 1/3 of the respondents expect that by 2030, electric vehicles will have a penetration from 2% to 10% and say that the country should prioritize investment in the EV, reflecting the view of most studies on EV expansion, including the Brazil energy research company (EPE). Furthermore, respondents (55%) consider the incentives for EVs will have the greatest impact on the increasing in the penetration of EM. For 35% of the interviewees, the government should prioritize the creation of legislation to regulate the EV in Brazil. The stakeholders view is in line with several studies that show a correlation between benefit granting policies and EV penetration.

From a cross-analysis perspective, younger respondents (from 18 to 45 years old), with "higher literacy" and belonging to the "electric energy sector" believe EV's market penetration will be between 2% and 10%. On the other hand, the most optimistic are those over 60 years old, "without higher education" and working in the "industry sector". They believe that the EV's penetration will be between 11% to 20%. Thus, the results of the research reveal expressive differences related to respondents' social characterization: stakeholders up to 45 years old consider the diffusion of EV in Brazil will be slow, with a small market share (up to 10%), will occur more actively in the Southeast of the country and will be dependent on incentives. It is older stakeholders (60 years old or over) who are the most optimistic, admitting that EV expansion could reach 20% in the

country. More details concerning cross-analysis topics about EV diffusion are presented below (see Appendix A, Table A3).

a. Hybrid plug-in cars – respondents with higher literacy (master and PhD degrees) are the ones who most (32%) believe the penetration of plug-in vehicles will be from 2% to 10%. People "without higher education" (25%) and "bachelor's degrees" (25%) believe the penetration will be from 21% to 30%. The difference in vision between the groups can be explained by the low level of reports and work papers for the Brazilian market. As the largest amount of information about the EV is usually conveyed in English naturally, access to broader EV information will be restricted to groups that can access English publishing channels.
b. EV by age – respondents between 18 and 45 years old (90%) believe the LDEV penetration will be from 2% to 10%, while those over 60 years old (37%) believe penetration of EV will be from 11% to 20%. This result reveals that the younger group of stakeholders is in tune with the EV penetration trends disclosed by the specialized information channels. On the other hand, the senior group seems to be more influenced by sources of information that convey techno-optimistic views regarding the future, in accordance with the belief in technological progress as a solution for environmental problems, e.g. Electric Vehicles Initiative (EVI) has set a target of 30% market share for electric vehicles by 2030 (EV30@30), compared to around 2% in 2019 (IEA, 2020). Differences in knowledge from work experience should also be taken into account. It is also possible that older respondents, having witnessed the successful expansion of ethanol in Brazil, might feel more optimistic about this new development.
c. EV by sector – stakeholders from the "electric energy sector" (54%) believe it will be from 2% to 10% while those of "industry sector" (26%) believe the penetration will be from 11% to 20%. A possible explanation for the highlight of the choice of the electric energy sector group can be seen from the fact that electricity companies, especially utilities, are intrinsically involved in the diffusion of EM. They participate in most EV projects in Brazil and account for most EV specialists. In many cases, they are a source of information for studies on EM. Therefore, their assessment reflects fine-tuning with what is expected for the future of EV. The optimism of the industry group, on the other hand, may reflect an expectation of development of a new technology and the possibilities of promising new horizons for the automotive sector.
d. Overall, most stakeholders agree that "regulation" and "incentives" are the most important features that should be prioritized to promote the penetration of EVs in greater volume and less time. This perception was highlighted by the automotive industry which indicated "acquisition incentive" as more important (61%) than the "production incentive" (36%). This fact may reveal that the industry is more interested in gains in sales volume than in incentive gains. Additionally, the indication of the attributes "regulation" and "incentives" is coherent, as they are intrinsic situations.

3.1.2. Performance of the electric vehicle

Results regarding of the performance of EVs (Appendix A, Table A4) revealed that most of those surveyed believed that the LDEV in Brazil should have a top speed of 120 km/h, and a range of 300 km; in addition, it should be able to recharge in less than an hour in public chargers and at home take up to 6 hours. These results show consistency with similar studies in countries that encourage EV expansion (discussed in topic 3.4).

3.1.3. Environment

The majority of respondents identified EVs as the best solution for major urban centers due to its low CO_2 emissions (Appendix A, Table A5). Moreover, a clear majority of the respondents stated the EV should be exempt from most taxes due to the environmental benefits provided. They said that a vehicle tax should be calculated based on the level of emissions of the vehicle. The polemic issue refers to the use of ethanol as a main fuel for vehicles in Brazil in 2030 with 44% agreeing and 42% disagreeing, although Brazil is the world leader in the production of ethanol from sugarcane and uses ethanol as fuel for road transportation. The result of this topic reveals the respondents' commitment and harmony with environmental issues, because even though Brazil is a leading country in the production of ethanol for fuel, the respondents understand that EV should be prioritized. In addition, by stating that vehicle tax should be calculated based on the level of its emissions, respondents reveal preference for an option consistent with, for example, the European transport emission mitigation policy.

3.1.4. Convenience of use of EVs

Regarding the convenience of using EVs, 94% of those interviewed agreed that the LDEV offers new advantages compared to the conventional car, and 81% considered the LDEV is a cost-effective affair. This suggests that, if the EV prices are compatible with the ICEs models (with proper conditions of use), EVs could have better acceptance in the Brazilian market (Appendix A, Table A6).

3.1.5. Acceptability of EV

The EVs hold the preference of the respondents followed by hybrid plug-in models powered by electricity and ethanol. When asked "if there were ample supplies of EV in Brazil and prices were aligned to internal combustion models would you buy a LDEV in the next 5 years?" 84% of respondents surveyed answered yes. There is a clear perception that future individual transport will likely be low-carbon, backed first by electricity and second by ethanol. The majority of interviewees (32%) said that society would be

the biggest winner with EV diffusion (Appendix A, Table A7).

The result of the cross-analysis revealed in this topic confirms an economically and environmentally interesting option for the country. This may be a good indication that stakeholders do not perceive EV as a competitor of ethanol but as a complementary technology. i) EV version holds the preference of both men and women, while the plug-in version (ethanol and electric) is the second option, except for the group with jobs related to high levels of "education and information", for whom plug-in (ethanol-electric) should be the first option (the hybrid ethanol-electric vehicle is incipient in Brazil). ii) Both men and women believe that the beneficiaries will be society and consumers. However, for 77% of the respondents "without Higher Education", the biggest beneficiary could be the “government”.

3.2. SWOT analysis

The SWOT analysis revealed the expansion of the EV in Brazil has been characterized by the generation of new business opportunities (e.g. battery industry) associated with the environment (e.g. less greenhouse gas emission) and innovation (e.g. possibility of increasing the use of renewable energy by the use of EV battery and Car-as-a-Service - CaaS). On the other hand, some technical, political and economic threats such as EV resale value, lack of EV legislation and range anxiety were revealed (Figure 2). The analysis also pointed to weaknesses in the social, technological, economic and innovation aspects. Finally, in a discrete way the strengths highlight the economic and technical aspects such as distribution network and high EV efficiency, as shown in Figure 2 (the variables and attributes used are detailed in Appendix A, Table A8).

Regarding the auto industry, public information and promotion of EVs should enable consumers to better evaluate the advantages of buying electric models. The overall opinion among respondents is that EVs are the best option for low-carbon transport in Brazil and therefore should receive government incentives and private sector support for its development. Furthermore, the SWOT analysis revealed that the internal factors were characterized by weaknesses, such as lack of charging infrastructure, and external factors were dominated by opportunities, such as new business and market, as shown in Figure 3.

3.2.1. Analysis of internal factors

The SWOT analysis shows that the Brazilian industry may not be well prepared for EV expansion, as it reveals many important weaknesses (Figure 3) that in the view of stakeholders need to be strengthened. The industry’s few strengths are of little relevance given the transformations that have been taking place with the arrival of EV, i.e. the distribution network (identified strength), with the expansion of online technology, no longer seems to be of equal importance to the automotive sector (Tesla sells cars over the internet and in Brazil internet sales already have a significant vehicle sales share).

The result of the analysis deserves a counterpoint, because the brands that operate in Brazil are from abroad and many of them have EV in their portfolio or have the necessary knowledge to develop it. This finding may be an important component if there are policies to support EV development in the country. The most important variables of the internal factors’ analysis are: i) Socio-technical factors were characterized by technical aspects. Among the four factors identified as weaknesses, the only one in the social area is the information about EVs. The other weaknesses refer to the range and recharge of EVs. The only strengths variable was the efficiency of EVs compared to ICE models (Figure 3). ii) Political-economic factors revealed two strengths and two weaknesses. The respondents considered that the retail system adopted by most traditional automakers (through distribution networks) is more important than the retail model adopted by Tesla (which has its own distribution system), probably because Tesla does not work in Brazil. The respondents highlighted TCO as an important economic aspect of EVs. On the other hand, they pointed out the price of EVs and the battery as weaknesses. iii) Innovation-environmental factors were considered a variable that only has weaknesses. Respondents understand that the development of a charging network for EVs is an important weakness. This vulnerability is similar to the situation observed in other countries that are investing in EV diffusion.

3.2.2. Analysis of external factors

Regarding external factors that may influence the development of EV in Brazil, the stakeholders understand that the automotive industry is well positioned, since many more opportunities than threats were identified. The results show consistency as international automakers have knowledge of EV technology. In addition, the main threats should be overcome if there is a decision to support EV expansion in the country, as they involve regulatory attributes that will be considered in any EV incentive policies, e.g. "tax burden" and "EV legislation".

The analysis of external factors (Figure 3) revealed that the EV diffusion represents more opportunities than threats: i) Socio-technical factors include range anxiety (linked to inadequate charging infrastructure, which is considered an important obstacle to the mass-expansion of EVs), viewed by respondents as an important threat to the creation of a mass-market, and the possibility of charging of EV at home or at work as an opportunity. ii) Political-economic factors are characterized by threats. The absence of government action to support the EV market in Brazil is the main reason for these threats. The lack of government regulation was pointed out as the cause of high taxes and the higher value for acquisition of EVs when compared to the ICE models. Respondents understand that the resale value of EVs is a threat. Automakers can overcome this issue by implementing repo policy for used vehicles, a common practice in the automotive market. On the other hand, the potential for new business opportunities with the expansion of the EV

market is seen as a possible break through. Although political-economic factors have been dominated by threats (Figure 3), a shift in government policy to benefit EVs can turn weak economic aspects into opportunities. iii) Innovation-environmental factors were highlighted as opportunities by almost all respondents. The choices, by the environment perspective, were driven by the possibilities that EVs offer to mitigate climate change due to the reduction of greenhouse gas (GHG) emissions. By the innovation perspective, the possibility to adopt new applications for EV batteries (e.g. vehicle as a backup) was highlighted.

3.3. Social characterization

Regarding the sample description, most of the 144 respondents were male (90%), with ages ranging between 46 and 60 years old (43%), possessing a postgraduate degree (61%), working in the private sector (75%), and living in the southeast region (71%), the most populous and industrialized region of Brazil (Appendix A, Table A1).

3.4. Discussion

The survey revealed some points that deserve to be explored. The most important refers to the priority Brazil should or should not give to the EV, and what features should be the focus of such prioritization. In addition, economic, energy, technological and political issues were highlighted.

3.4.1. Should Brazil invest and even prioritizes the EV?

The survey included seven questions to investigate this issue. A clear majority (57%) said the country should opt for the EV, while 14% pointed out that the priority should be on ethanol and 29% classified it as controversial. One of the seven questions wanted to know if "in 2030, ethanol will be the main fuel for cars in Brazil". This was an issue with balanced responses in which almost half of the people agreed, and the other half disagreed. Another question, "what kind of car should Brazil prioritize?" had 27% choosing EVs and 23% choosing hybrid plug-ins (electric-ethanol), while 14% answered pure hybrid (electric-ethanol).

The only issue in which ethanol has gained wide advantage occurred when respondents were asked whether "by 2030, the LDEV will have inferior penetration only to the flex car?" 57% agreed (35% disagreed and 8% were neutral). Therefore, in general, the survey points out that the country should choose to invest in EVs for the masses and not only in ethanol. This same conclusion has been identified by several studies on EV in Brazil (Costa et al., 2017; Bravo et al., 2014). This can perhaps be explained by the problems the country has faced in keeping ethanol competitive commercially, without compromising the environmental balance (burning and deforestation) and avoiding competition with food production.

3.4.2. What should be prioritized so that the EV enters the market on a larger scale and in less time?

For 35% of the respondents it is necessary that the government regulates the EV market. A total of 33% said an acquisition incentive is required and 22% said there should be a production incentive. Despite the little difference between those who opted for regulation or incentive, the choice for regulation is confirmed as 95% of the respondents identified the "high tax burden on electric vehicles" and 82% identified "no regulation or legislation for the EV market" as the main threats to the expansion of EVs in Brazil. These points are part of the barriers and challenges of the EV in several studies (de Souza Ferreira Filho & Horridge, 2014; Filoso et al., 2015; Gauder et al., 2011) where the problem of regulation and incentives has been overcome.

3.4.3. Should Brazil focus on EVs policies?

The analysis of the set of questions leads to some other reflections for diffusion of EVs in Brazil, which should require a set of appropriate actions and policies. For example, (*1) Is the Brazilian automotive industry prepared for the diffusion of electric mobility?* The automotive industry in Brazil has evolved technologically in the last decades, but it needs to continue to modernize to become internationally competitive, thus shortening the distance in technological terms to similar models from developed countries (Lima, 2016). The Brazilian government program to stimulate automotive sector competitiveness (Inovar-Auto ended Dec. 2017) improved the auto industry but it was not enough to make the automotive industry technologically competitive internationally, being far behind the leading technological countries (industry 4.0). Investments in the production of both LDEV and its components (batteries) will be required (Lima, 2016). Although the Brazilian government has launched a new program to boost the automotive industry ("Rota 2030"), it is hard to say that it will be strong enough to promote EVs in the country."

The demand in Brazil should be for small size LDEV as the largest share of the ICE vehicles are characterized by low cost LDV models ("popular cars"). If so, with smaller batteries, the range of LDEV will be smaller as well, requiring a larger number of charging stations and heavier investment to implement them. Although the international automotive industry has the know-how of the EV, is it feasible to say that this knowledge will be transferred to the Brazilian industry in the short term? Experience with the Brazilian automotive industry reveals that, without government investment, transfer of knowledge can occur only after the EV technology is consolidated internationally. *(2) Will the EV receive suitable government investments to enable its expansion?* The decentralized and environmentally sustainable supply trend focused on consumer empowerment, digitization and connectivity, innovation in technology, and processes should not be ignored. Brazil expects a radical transformation in the electricity sector (with less revenues and an increase in investments) due to the possible increase in distributed generation and the large-scale mix inclusion of renewable sources. The rise defaults, the imbalance

between supply and demand, and the difficulty of recovering investments aggravate the problem for utilities in Brazil. Besides that, there are other challenges in electricity production in Brazil, such as the case of the water crisis which occurred in recent years causing irregular electricity supply in several regions of the country.

The Brazilian government has demonstrated a limitation in its investment capacity in new technologies. Investments in EVs still represent high risk, so if there is a trade off between EVs and ethanol, the government will probably choose ethanol due to the strategic and economic importance of the biofuel industry to the country. Besides that, in 2017, for the first time, the country had a deficit of 445 million litters in ethanol trade balance (ANP., 2018) so the government will have to invest in ethanol production.

3.4.4. Are some identified attributes different from other countries that invest in EV?

Some attributes indicated by stakeholders, such as speed, range, recharge time, measures to support market regulation, EV incentive policies and adequate EV charging network, are not different from those found in other countries that invest in the diffusion of EV (IEA, 2020). These aspects reveal that the future of EV in Brazil is in harmony with more advanced EM markets and may be indicative of the consistency of the results obtained by the study.

4. Conclusion

The research goal of identifying the strengths, weaknesses, opportunities and threats for the expansion of the LDEV in Brazil considering aspects like socio-technical, politic-economic, and innovation-environmental from the SWOT, revealed that the opportunities and strengths for the EV to have rapid market penetration were led by economic and innovation factors. One example of strength is that the diffusion of the EV could provide new economic activities, such as the battery industry, software industry, as well as new business models to explore CaaS activities. On the other hand, the threats and weaknesses for the expansion of EVs are dominated by techno-economic aspects (political issues were cited to a lesser extent), due to the perception that many investments in technological development are needed to mass-market EVs, since, as in countries that encourage EV, some technological issues such as proper charging infrastructure, fast charging time of up to 60 minutes and battery range of around 300 kilometers, need to be provided, allowing the EV to be compatible with the ICE models.

Although ethanol as fuel is a national priority due to its importance to the Brazilian economy, the survey clearly pointed to the option of low-carbon passenger vehicles, with the LDEV being the "first option" and highlight that EV is not an ethanol competitor but a complementary technology. Additionally, the survey showed that society and consumers would benefit most from the expansion of EVs in Brazil, especially due to the environmental aspects (reducing CO_2 emissions and lower energy consumption) and economic issues (EV lower TCO). However, as in other markets, the mass-diffusion of EV depends on effective policies that address various elements, such as financial incentives for consumers, production subsidies, research investment, and tax incentives for developing support infrastructure.

EV mass-diffusion should require large local investments from the auto industry and this can be a trade off between, for example, investing in ethanol vehicles (which has government support) or EV (which does not have the support of the government) which like any new technology offers risks (Liu & Lin, 2017). Therefore, the most likely scenario is that the Brazilian auto industry will wait a little longer for the evolution of EVs in international markets before deciding on their investments.

One feasible route to diffusion of EVs would be if the Brazilian government chooses to slowly expand the LDEV fleet into government and private companies' fleets in which EVs can become economically beneficial and operationally viable. The expansion into the mass-market could occur in a second stage, when the international market of EVs and Brazilian policies would be consolidated.

This research included some limitations, since some interviewees did not receive the survey link due to the blockade of the corporate spam system and firewall software. In addition, our approach to some stakeholders was restricted due to the natural barriers of access to very important people such as company presidents, CEOs, department ministers and other senior government officials. In addition, for the delimitation reasons, the research did not include a set of stakeholders that would be important to obtain information, mainly related to the market, including consumers and service providers. Therefore, we recommend that future studies should survey car owners, companies with large fleets of vehicles, car rental companies, shared transportation companies, and consumers in order to complement the present study with timely information of potential users of EVs in Brazil. In order to deepen the understanding of people's decision-making about buying EVs, these studies should pay attention to the social characterization of respondents (including variables that have been regarded as critical in other countries, such as income and education level). Finally, the findings of this study may provide valuable information for policymakers, investors and stakeholders interested in EM.

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Appendix A

Table A1. Social characteristics of survey respondents.

		Number of individuals	% of the total respondents
Gender	Female	15	10
	Male	129	90
Age	18-30	14	10
	31-45	41	28
	46-60	62	43
	+60	27	19
Education	Less than university degree	8	6
	University degree	47	33
	Postgraduate degree	89	61
Work Sector	Private	105	73
	Public	26	18
	Mix private/public	8	6
	Third sector	5	3
Business segment	Automobile industry	44	31
	Transport-related services	40	28
	Education, research and information	30	21
	Government	19	13
	Electric energy sector	11	7
Job	Decision-makers and top managers	64	44
	Middle managers	45	31
	Consultants, experts and media	35	25

Table A2. Results on the diffusion of EVs.

Question		Answer
What market share do you believe the electric car will have in Brazil in 2030?	Up to 1%	12%
	2-10%	33%
	11-20%	23%
	21-30%	11%
In 2030, in which region of Brazil the LDEV will have more penetration?	Southeast	71%
	South	17%
	Northeast	5%
	North	2%
	Midwest	5%
In 2030, the LDEV will have inferior penetration only to the flex car (gasoline-ethanol).	Agree	57%
	Disagree	35%
	Neutral	8%
What will be the hybrid car plug-in penetration in 2030?	Up to 1%	9%
	2-10%	33%
	11-20%	22%
	21-30%	18%
What will be the pure hybrid car penetration in 2030?	Up to 1%	13%
	2-10%	34%
	11-20%	19%
	21-30%	12%
In 2030, the electrified car (LDEV and plug-in) will have inferior penetration only to the flex fuel car (gasoline-ethanol).	Agree	62%
	Disagree	28%
	Neutral	10%
What should be prioritized for the LDEV increase the market penetration in the shortest time?	Regulation	35%
	Incentives:	55%
	Production	22%
	Acquisition	33%

Table A3. Cross-analysis of the diffusion LDEV by social characterization by views on EV

% of feedbacks	Market-share	Profile
	Plug-in electric vehicle	
39	From 2 to 10%	With bachelor's degree
32	From 2 to 10%	With master and PhD degree
25	From 21 to 30%	No bachelor's degree
25	From 21 to 30%	With bachelor's degree
	LDEV	
90	From 2 to 10%	Between 18 and 45 years old
37	From 11 to 20%	Over 60 years old
55	From 2 to 10%	Electric sector
27	From 11 to 20%	Industry sector
67	Acquisition incentive	By sex
62	Purchase incentive	By sex
40	Production incentive	By sex

Table A4. Result on the performance of EVs.

Question		Answer
What is the speed limit that you consider acceptable for a LDEV?	120 km	41%
	140 km	24%
	160 km	23%
What range do you consider acceptable for a LDEV?	200 km	15%
	300 km	30%
	400 km	26%
	500 km	15%
What is the acceptable charge time the LDEV at home?	Up to 1h	9%
	1-2 h	15%
	3-4 h	31%
	5-6 h	33%
	7-8 h	11%
What is the acceptable charge time for the LDEV at public charging stations?	Less 1 h	73%
	1-2 h	23%

Table A5. Results on environmental issues related to EVs.

Question		Answer
LDEV is the best solution to reduce CO_2 emissions from road transport in major urban centers of the country.	Agree	90%
	Disagree	6%
	Neutral	4%
LDEV is friendly to the environment because it reduces pollution (emissions and noise).	Agree	95%
	Disagree	3%
	Neutral	2%
Being environmentally friendly, the LDEV should be exempt from almost all taxes.	Agree	86%
	Disagree	9%
	Neutral	5%
Car taxes should be based on the level of pollutant emissions rather than engine power.	Agree	89%
	Disagree	5%
	Neutral	6%
By 2030, ethanol will be the main fuel for cars in Brazil.	Agree	44%
	Disagree	42%
	Neutral	14%

Table A6. Results on the convenience of EV use.

Question		Answer
Choosing to use a LDEV is a cost-effective affair.	Agree	81%
	Disagree	11%
	Neutral	8%
The LDEV offers new advantages compared to the conventional car.	Agree	94%
	Disagree	5%
	Neutral	1%
In overall, I believe that the use of a LDEV provides less benefit than the conventional car.	Agree	18%
	Disagree	45%
	Neutral	37%

Table A7. Results on the acceptability of EVs.

Question		Answer
If there were ample supplies of light-duty electric vehicle in Brazil and prices were aligned to internal combustion models, would you buy a LDEV in the next 5 years?	Yes	84%
	No	7%
	Likely	9%
What kind of car should Brazil prioritize?*	Ethanol	11%
	Gasoline	3%
	Diesel	2%
	Pure hybrid (petrol-electric).....	5%
	Pure Hybrid (ethanol-Electric).....	13%
	Hybrid plug-in (gasoline-electric).....	9%
	Hybrid plug-in (ethanol-electric).....	23%
	LDEV.....	27%
	Fuel cell.....	5%
	Others.....	2%
		5%
		2%
Which would be the biggest beneficiaries with the expansion of the LDEV in Brazil?*	Government	12%
	Society	32%
	Industry	12%
	The consumer	23%
	The energy sector	14%
	The service sector	4%
	Others	3%

*Maximum of three options.

Table A8. Consolidated SWOT matrix.

Strengths	Weaknesses
Socio(S)-Technical(T) factors	
Efficiency of EV compared to ICE model (T).	Public information about EV (S); Range of the EV compared to ICE vehicle (T); Charging time connection compared to a ICE supply (T); Loss charging of the EV battery in extreme temperatures (T).
Political(P)-Economic(E) factors	
Distribution network of vehicles (E); Value of use of the electric car (E).	EV battery value in case of spare need (E); Acquisition value of the EV compared to the ICE car (E);
Innovation(I)-Environmental(V) factors	
None	Structuring of specialized technical assistance network in EV (I); Charging infrastructure for EV (I);
Opportunities	**Threats**
Socio(S)-Technical (T) factors	
Possibility of recharging the electric car at home or at work (ST).	Consumer concern about staying on the street with no battery charge - range anxiety (T).
Political(P)-Economic(E) factors	
Industry capacity in the production of components for EV (E); Emergence and exploration of new business and markets (E).	Consumer avoid buying EV because resale value (E); Brazilian government investments in oil and ethanol (E); Inexistence or inefficient regulation to EV market (P); Highest tax burden on EV (PE).
Innovation(I)-Environmental(V)- factors	
Reduction of environmental pollution (V); Insertion of the country into a new sustainable transport technology (I); Climate change mitigation due to the less carbon footprint of the EV (V); Enhancing the use of renewable energies (I); Possibility of charging the EV by self-production of electricity (VI).	None

Appendix B

Table B1. Statement of CO_2 emissions from LDV in Brazil.

*Gasoline "C"	Ethanol	Flex	BEV (Costa, 2019)
			Consumption (24 kWh/135 km) = 0.178 kWh/km
–	–	–	
Liters of fuel to travel 100 km = 8,985 (Leite 2016)	Liters of fuel to travel 100 km = 12,316 (Leite 2016)	Liters of fuel to travel 100 km = 10 (CETESB 2018)	Emissions per unit of energy = 0.0740 $kgCO_2$/kWh
Factor CO_2/km emission = 1,992 (Leite 2016)	Factor CO_2/km emission = 0,409 (Leite 2016)	Factor CO_2/km emission = 1,50 (CETESB 2018)	Emissions per unit distance = 0,01316 $kgCO_2$/km
CO_2 emission for 100 km = 17,7 kg	CO_2 emission for 100 km = 5,0 kg	CO_2 emission for 100 km = 15,0 kg	Emissions per 100 km = 1,316 $kgCO_2$

* Considering 27% anhydrous alcohol mixture in gasoline "A".

Table B2. Description of taxes paid by LDEV in Brazil

Name of tax	Jurisdiction	Aliquots
Imposto sobre produtos industrializados (IPI)	National Government	8%
Programa de Integração Social (PIS)	National Government	2%
Contribuição para o Financiamento da Seguridade Social (COFINS)	National Government	9.6%
Imposto de importação	National Government	Temporarily Exempt for EV (before it was 35%)
Imposto sobre circulação de mercadorias e serviços (ICMS)	State Government	12%
Imposto sobre circulação de mercadorias e serviços, substituição tributária (ICMS-ST)	State Government	From 12% to 18% (Depending on the destination state)
Total		From 43.6% to 49.6%

Source: Nissan (2020b).