TRANSITION TO ELECTRIC MOBILITY IN BRAZIL: INSTITUTIONAL DEVELOPMENT AND ADVANCEMENT OF NEW TECHNOLOGY IN THE STATE OF SÃO PAULO

ABSTRACT: The technological route of vehicle electrification has emerged as one of the most promising options for reducing emissions in the transportation sector and driving the energy transition and decarbonization of urban mobility systems. However, being a disruptive technology, this process faces resistance, which is being overcome through public policies. This article employs an analytical framework designed specifically to analyze Institutional Thickness from an inter-scalar perspective, with the aim of identifying the design and form of institutional instruments implemented to promote vehicle electrification in the State of São Paulo, Brazil. To do so, we operationalize the typology of public policies for three São Paulo cities (Campinas, São José dos Campos, and São Paulo) that are among the municipalities in São Paulo that stand out on the topic. The results point to the lack of articulation and interrelation among institutional instruments, both those implemented at the national level and those implemented by local government. The absence of structured public policies at the federal level has contributed to an unequal and unregulated expansion of electric mobility in Brazil; even in regions that stand out in the electrification theme, limits to its full expansion are observed, marked by the absence of goals and fragile coordination.

KEYWORDS: Electromobility; Transition to Sustainability; Institutional Thickness; Public Policy.

1. INTRODUCTION

Electric mobility has emerged as one of several technological options aimed at reducing or eliminating greenhouse gas emissions (GHGs) and other pollutants in the transportation sector, and advancing the global commitment to achieve NetZero by 2050 (IEA, 2021). Characterized by the interface between the automotive sector and various economic sectors (electric, charging infrastructure, mineral resource extraction and battery manufacturing, among others), electric mobility implies a tangle of new articulations and actors involved in promoting Electric Vehicles (EVs), in their various configurations (hybrid, plug-in and 100% electric) and modes (cars, motorcycles, buses and trucks) (Consoni et al, 2021). This new electrification-dependent technological system is one of the possibilities for competing for the future of urban and interurban mobility, based on the concepts of sustainability and environmental resilience. On the other hand, EVs are technological options proposed by the current economy, by actors in the automotive industry or at its borders, being one of the ways to follow the current standards of comfort and consumption, but with a new technical basis.

In 2020, the transport sector accounted for 31.2% of total GHG emissions in Brazil, behind only the industrial sector, with 32.1% (Energy Research Company, 2021). However, the country is facing many uncertainties and questions about the choice of technological routes for decarbonizing vehicles. Specifically, regarding electric mobility, there is no national plan or strategy for promoting this technology, in a trend opposite to what is happening in several Latin American countries (Rodríguez, 2022) or in the countries that lead the world market.

In Brazil, policies to encourage electric mobility continue to be indirect, fragmented and intermittent, and are often included and mixed with efforts aimed at promoting "clean" or "sustainable" technologies (Consoni et al., 2018; 2021). On the other hand, there are public policies and actions that are independent of a central planning of the federal government, the actions taken by municipalities and states, which represent the start of the transition process, but these lack the necessary robustness to guide choices in the field of automotive electrification at the national level.

The absence of a federal institutional framework equipped with regulatory apparatus and economic mechanisms to direct and incentivize electric mobility means that some cities/municipalities undertake actions and implement institutional instruments in this direction atomistically. And it is through this voluntarism that we can identify a diversity of actions that sporadically appear in some Brazilian areas, and in this flow, we have considerable advances in vehicle electrification. Some of these highlights are observed in cities located in the state of São Paulo (ESP), a region that accounted for 32.52% of electric vehicle registrations in circulation in 2022 (ABVE, 2023).

Within the presented context, the objective of this article is to advance in the understanding of these initiatives and the designs of public policies aimed at promoting electric mobility, based on the experience of three municipalities in the state of São Paulo, in the southeastern region of Brazil: Campinas, São José dos Campos and the state capital itself, São Paulo. To do so, a mapping of institutional initiatives focused on vehicle electrification is undertaken, which are being emulated by different forces and with multiple and unaligned public policy designs.

The article has six sections that address, respectively, the methodological aspects, the discussion on transitions to sustainability, and the development of institutional support for the dissemination of electric mobility in São Paulo and in southern global realities. The research presents georeferenced data on the diffusion of EVs and systematized information on public policies at the state and municipal levels, concluding with final considerations on the contributions of the study to the electromobility segment.

2. METHODOLOGICAL APPROACH AND RESEARCH ACTIONS

The research consists of several subsequent and complementary stages, which go from the general to the particular and back to the general. That is, the article starts with an understanding of the e-mobility segment, maps and analyzes the actions developed by the selected cities in the state of São Paulo in a particularized way (Campinas, São José dos Campos, and São Paulo), and finally, based on the policy analysis categories developed by Hood (1983) and Hood & Margetts (2007) and reinterpreted by various authors (Vabo and Røiseland, 2012; Henstra, 2016; Capano, Giliberto and Lippi, 2017; Mukhtar-Landgren et al. 2019; Capano and Howlett, 2020; Oliveira Filho et al., 2022), characterizes the institutional framework developed by the local government. This effort allowed for observing how this sociopolitical actor, the public sector, relates to e-mobility and enables progress towards the transition to a new socio-technical system in its area of administration - in urban areas of the city.

The research was organized into 5 stages. Table 1 indicates each one and puts into perspective the data and bibliographic sources used in this investigative process.

Table 1. Outline of research and databases consulted.

Stage	Description	Database and information
1	Literature review	Systematic literature review conducted using search equations (keywords and Boolean operators) in the scientific article databases Scopus and Web of Science.
2	Mapping of institutional instruments	Reading and selection of institutional materials published on the official websites and official gazettes of the Brazilian Federal Government, São Paulo State Government, and Local Governments, specifically of the municipalities of Campinas, São José dos Campos, and São Paulo, in the period from 2012-2022.

3	Collection and analysis of secondary data (EVs)	Collection and creation of a database with the numbers of registered vehicles in Brazil, by geographical region, by states, and by municipalities, taking into account the different types of fuels and propulsion technologies. The numbers of registered vehicles were provided by the Ministry of Infrastructure, Brazilian Federal Government, in the SENATRAN database (National Traffic Secretariat). These are correlated and confirmed by the data of registered electric vehicles (EVs) periodically counted by the Brazilian Association of Electric Vehicles (ABVE). The institution provided support for the research to confirm the data quality. Creation of Geo-Intelligence. Process of spatialization of the numbers of registered EVs through geoprocessing techniques, using the free software QGIS.
4	Operationalization of the NATO Framework	The NATO Framework was used as analytical lenses, organizing and categorizing the different types of institutional instruments found in public repositories throughout the period 2012-2022 (across the three scales). Thus, an analysis of the functions, rationality, and purposes of institutional instruments is created, which ultimately is the way the government interacts with society. This analytical process follows the methodological and procedural contributions of previous works, which aim to uncover how governments act to emulate new processes in society. Therefore, we methodologically based ourselves on Hood (1983); Hood and Margetts (2007); Vabo and Røiseland (2012); Henstra (2016); Capano, Giliberto & Lippi (2017); Mukhtar-Landgren et al. (2019); Capano and Howlett (2020) and Oliveira Filho et al. (2022) developed an adapted framework specifically focused on government efforts to promote electromobility. To operationalize our case study, we utilized the typology of public policies for EVs as an analytical structure for both mapping institutional instruments and analyzing the institutional framework, including characterization and comparison of cases.
5	Comparative analysis and characterization of cases (cities)	After categorizing the public policy instruments implemented by the different scales of the Brazilian government, we proceeded to characterize the inter-scale institutional framework developed, which constructs an institutional thickness in the urban space that can advance or setback actions of socio-political actors within a technological pathway or common purpose. Finally, we compared what each territory (city) did and how it mobilized (or not) the categories of the NATO Framework. Thus, we were able to identify and qualify the Brazilian efforts, specifically in the cities of São Paulo state, in the transition process to electromobility.

Source: prepared by the authors.

2.1. Methodological approach: a perspective on Institutional Thickness

The concept of institutional thickness has been used to explain the spatial inequality of the transition processes towards electric mobility (Coenen; Benneworth; Truffer, 2012; Zukauskaite; Trippl; Plechero, 2017), which allows us to reflect on the relational assets developed in the interrelation between the local and the national. In this way, we have layers of institutional instruments that are created by governments, which reflect the articulation and power of sociotechnical change agents at different levels of action. To organize the mapped public policy instruments, we employed the NATO Framework, a methodology already tested and used in previous works (Oliveira Filho et al., 2022). Another guiding concept for the analysis is the Transition to Sustainability, a sociopolitical process that aims to promote forms of development that are less impactful on natural resources and the biosphere.

In order to identify and characterize the Institutional Thickness developed in the selected cases, a qualitative analysis approach was used, based on the rationality of public policy instruments implemented by the government, at the federal, state, and local (municipalities) level (Marletto, 2014; Dijk, Wells and Kemp, 2016; Hodson, Geels and Mcmeekin, 2017; Mukhtar-

Landgren et al., 2019; Di Giulio et al., 2021). A comparative study strategy was also employed, observing the particularities of the municipalities of Campinas, São José dos Campos and São Paulo (Wesseling, 2016; Kuokkanen and Yazar, 2018).

In this approach, there is a focus on the content and directions of public policy instruments implemented in the last 10 years, both at the state and local (municipal) level. Table 2, in Section 4, provides a synthesis of the relationship between institutional mechanisms and the emergence of concrete actions related to new electromobility technologies in the urban space of some regions of the state of São Paulo.

Public policies are understood here as all the means and instruments through which the government, in an institutionalized way, conducts its interventions and directs the whole of society and its resources. The mission is to advance a segment/sector or to solve/alleviate a problem in their municipality, state, or country.

These public policy instruments found in the process of mapping the São Paulo cases are analyzed following the taxonomy of Public Policy Analysis presented by Hood (1983) and Hood and Margetts (2007), a conceptual framework named NATO, an acronym formed by the first four letters of the key concepts: Nodality; Authority; Treasury; Organization. The NATO Framework understands the government as a set of administrative tools that are used to shape our lives and discipline the uses of territories (Hood, 1983; Hood and Margetts, 2007; Capano and Howlett, 2020). This quality is inherent to governments, regardless of their scalar (national or local) and ideological cut.

Thus, all governments have four essential and specific resources of the "nature" of the public power, which can be accessed to detect useful information for their activities or to carry out concrete actions in society as a whole, which affect individuals' lives and the course of the development of territories (Hood and Margetts, 2007).

The four "toolboxes" provide a methodological and practical framework for monitoring the evolution or condition of the institutional thickness developed around a particular issue, in this case, electric mobility. Thus, these tools allow identifying and classifying public policies that promote the mobility of people and goods through a new technology,

The four "toolboxes" provide a methodological and practical framework for monitoring the evolution or condition of institutional thickness developed around a particular issue, in this case, electric mobility. Thus, these tools allow for the identification and classification of public policies that promote the mobility of people and goods through a new technology, electric vehicles (Capano, Giliberto and Lippi, 2017; Oliveira Filho et al. 2022; Capano and Howlett, 2020).

- **Nodality:** The government holds a central and strategic position in collaboration networks, strengthening communication and coordination among actors through institutional instruments.
- **Authority:** The possession of legal or official power, supported by the institutional framework of the nation-state, which allows public authorities to prohibit or permit actions through norms, regulations, and laws.
- **Treasury:** The possession of economic resources, ranging from the granting of social benefits to fiscal incentives for financing local projects.
- **Organization:** The control and management of assets used in direct or indirect action on an initiative, reflecting the government's treatment of a specific group or area of the country or city, related to the provision of welfare to citizens, including facilities, staff, and public services.

Using the NATO, we shed light on the constituent elements of the original idea of Institutional Thickness, as exposed by Zukauskaite et al. (2017). By operationalizing the NATO's analytical categories, the institutional robustness or weakness of the studied territories is shown. Understanding the rationale behind the choices made by the public authorities, based on the NATO, is essential to discover the disconcerting complexity of governments' day-to-day operations. Considering that these organizations act on various issues, ranging from industrial development to the care of school-age children's food (Vabo and Røiseland, 2012; Rogge and Reichardt, 2016).

Governments have many responsibilities and fronts of action for their diverse functions, relying on different types of institutional instruments within the dimensions of Nodality, Authority, Treasury, and Organization. Thus, at specific moments, they use monetary incentives (fee exemptions) to stimulate social actors to adhere to a trajectory, while at other times, they use legal restrictions (laws, decrees, and penalties) to restrict movements and the use of technologies that are harmful to the environment or national interests. Oliveira Filho et al. (2022) schematically expose and synthesize the toolboxes (public policy dimensions) and the tools themselves (the typology of public policies used to advance electromobility).

We understand the various actions of the public authorities as variations of their basic resources (Nodality, Authority, Treasury, and Organization). In this case, activities become applications of a relatively small set of essential tools, infinitely repeated in particular combinations and varied thematic contexts. This resource, based on this analogy between institutional framework and tools, allows us to understand **what the government does and how it does it**. In this case, how the Federal, State, and Municipal public authorities act on the issue of electromobility.

3. THE ROLE OF INSTITUTIONAL THICKNESS IN ELECTRIC MOBILITY TRANSITION INITIATIVES

According to Avelino et al. (2016), Sustainability Transitions are social change processes grounded in responses to persistent socio-environmental challenges and problems, in which their persistence is attributed to the dependence on dominant paths, practices and structures imposed by the productive process (i.e., the dominant regime). Resolution requires structural and long-term changes (Hodson; Geels; McMeekin, 2017; Johnstone; Newell, 2018), for example: profound changes in technology or individuals' consumption patterns, which can trigger alterations in the form and quality of key life-supporting services, such as food production, energy generation, production of non-durable goods, mobility of people and goods in urban space.

It is important to bear in mind that changes occur intricately within sociotechnical systems, as described by Geels (2004). Thus, when we use the feminine noun "transition," we are referring to a transformation process towards more sustainable modes of reproduction of our material life, which certainly involves such so-called eco-innovations, green technologies, or clean technologies.

However, transitions towards sustainability are not just economic or determined by technological choices; they must be interpreted as the result of incremental or radical socio-spatial dynamics that are influenced by normative expectations. Public policies (regulations, guidelines, incentives) are identified by international literature as important factors to emulate and direct sustainability transition initiatives (Markard; Raven; Truffer, 2012; Fastenrath; Braun, 2018; Johnstone; Newell, 2018; Bush, 2020). What is observed in cities and countries is the movement of a "green shift" in gestation or consolidation (Aronoff; Cohen; Riofrancos, 2021), in which social actors conduct tests, developments, and introduce new technologies or routines into production systems that aim to drive more sustainable ways of eating, traveling, dressing or caring for themselves and others.

In other words, tacitly and also in the face of accumulating socio-environmental problems, companies, governments, and social actors articulate around concrete actions and new knowledge that aim to solve problems with this new (sustainable) rationality. In this context, Electric Vehicles and the development of electromobility as a new mobility system represent an example of transition initiatives, as they aim to contribute to the elimination of GHG emissions, reduction of air pollutants in urban areas, noise, and also to develop more energy-efficient transport systems.

According to Coenen & Truffer (2012), questions about where and why sustainability transition initiatives occur are provocative of the emergence of the Geography of Transitions to Sustainability (GeoST), a research area that we aim to contribute to with this article, as these inquiries remain eclipsed in the field of sustainability transitions studies (Hodson and Marvin, 2010; Coenen; Benneworth; Truffer, 2012; Ravena; Schota; Berkhoutb, 2012; Mans, 2014; Hansen and Coenen, 2015; Boschma et al., 2017; Fastenrath and Braun, 2018; Köhler et al., 2019; Binz et al., 2020). This new research agenda allows us to understand how location-based factors

potentiate or restrict the emergence of sustainability transition initiatives. In fact, institutions, local actor networks, infrastructure, natural resources, among other elements that make up the territory, are not just circumstantial. Instead, they are contextual data that impose previous conditions and shape the choices and relationships of social actors in these areas.

The ability of the public sector to mobilize resources, people, and knowledge for transition initiatives is called Institutional Thickness and can be measured according to the performance of public agents in providing conditions for external and local actors to carry out technological innovations towards sustainability or transition to sustainability. This institutional capacity translates into essential issues for urban space, such as urban mobility and public transportation. This capacity is not innate, but rather must be built. Coenen, Benneworth and Truffer (2012) indicate that Institutional Thickness explains why some places are good at supporting innovation, being able to advance towards new technical and economic trajectories, while others are not.

The concept of Institutional Thickness, present in Economic Geography and Innovation Studies, explains the relationship between institutions and regional development, influencing the transition to sustainability and reflecting geographical inequalities. These processes are shaped by institutional structures (Hansen and Coenen, 2015; Fastenrath and Braun, 2018a). For Amin & Thrift (1994), institutional and cultural manifestations of a locality promote the simultaneous collectivization and cooperation of economic life. Thus, the relationship between institutions and economic growth is endogenous; institutions and economic activities co-evolve with changes in skills and improvements in governance, which contribute to the development of economic activity and vice versa.

It is worth noting that economic activities are institutionally situated. They cannot be explained solely by individual, atomistic motivations of the company or entrepreneurship. They are understood to be embedded in broader rules, procedures, social conventions, and political relationships (Hodson and Marvin, 2009; Boschma and Martin, 2010). Institutions enable or constrain innovation in spatially differentiated ways. There is institutional incorporation in the territory that results from the materiality of social and power relationships (Santos, 2020).

The institutional instruments created by governments reflect the power of sociotechnical change agents in territories at different scales. These instruments can be implemented in a complementary and coordinated way to establish more equitable conditions for new technology to compete with the existing regime. Institutional thickness is formed by relational assets resulting from pressures and demands from local and extra-local actors and provides comparative and lasting advantages for specific cities or regions. This institutionalization is shaped by the territorial structure and reflects the actions of social and governmental actors on a particular technological path.

The electrification of vehicles and the implementation of a new urban mobility system face both technical and sociopolitical challenges, ranging from the availability of public charging infrastructure to battery recycling. These challenges involve the search for solutions that mitigate or eliminate the resistance of established industries, such as those involved in the production of combustion engine components. Moreover, the adaptation and change in user behavior also poses a challenge as the responsibility for refueling the vehicle lies with the user, who typically charges the vehicle at home.

These challenges, along with other typical obstacles encountered by green technologies, are being successfully navigated by territories that implement a range of institutional supports that address the diverse aspects of the new sociotechnical system. Thus, the involvement of the public sector is essential for the development of institutional thickness, which involves the creation of an institutional framework capable of effectively managing both the technology and the social actors involved.

4. RESULTS

4.1. Electrification of Transportation in Brazil and in the State of São Paulo

Electric mobility is a process that is currently developing in several countries around the world. In 2022, the global stock of electric vehicles totaled more than 26 million, an increase of

60% compared to 2021, and the trend is expected to continue to grow steadily in the coming years (International Energy Agency, 2022).

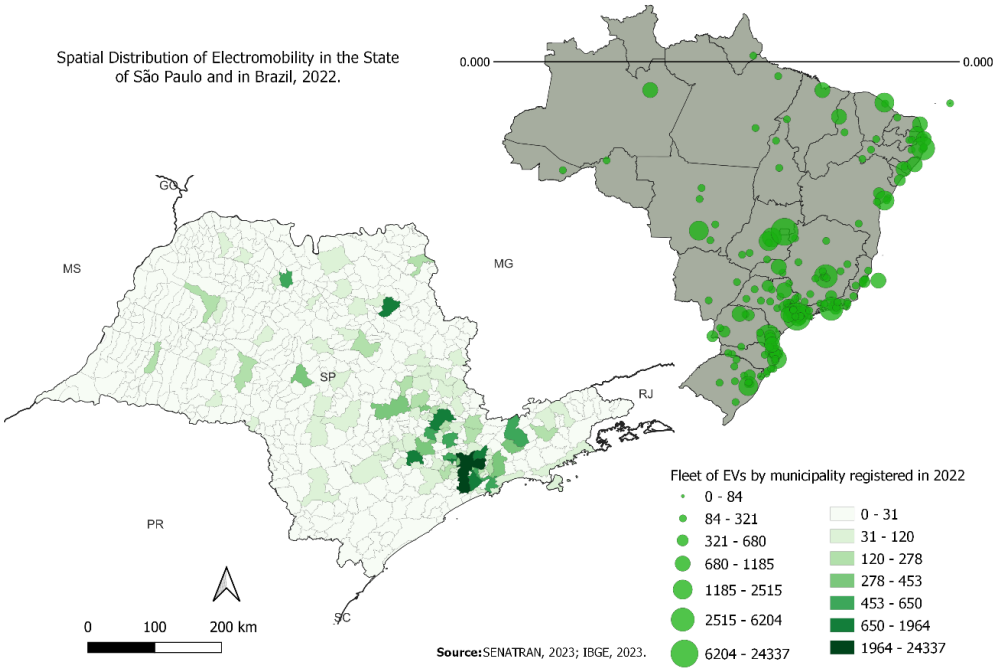
In this context, the Brazilian market for electric vehicles is still in its early stages and presents modest numbers compared to countries that lead the global market. China had 7.8 million electric vehicles in circulation in 2021, and the participation of electric vehicles in the European market is also noteworthy. According to 2021 data, new electric car sales reached 86% in Norway, 43% in Sweden, 30% in the Netherlands, and 19% in France (IEA, 2022). These markets have implemented a strong institutional apparatus over the last 10 years (Consoni et al., 2018).

The current market share of EVs in Brazil is 2.5%, with a total of 126,504 units registered from 2012 to 2022, of which about 70% of sales are represented by hybrid vehicles not connected to the electric grid (Revista Pesquisa, 2023; ABVE, 2022). These numbers indicate that the country has modest figures and still has a long way to go in the implementation of EVs. Since 2018, the country has had higher numbers of EVs and the penetration process in the national territory has accelerated. In 2019, 11,858 vehicles were registered, and after three years, in 2022, this number jumped to 49,245 registered EVs, presenting an extraordinary growth of 315.29%, according to ABVE data (ABVE, 2023).

The electric vehicle market in Brazil has particularities compared to other global markets, with a majority share of HEVs (Hybrid Electric Vehicle), divided into HEVs and flex-fuel HEVs, with the latter being internal combustion engine-powered vehicles that are fueled by gasoline and/or ethanol, which provides kinetic energy from the movement to produce electricity for the vehicle.

The diffusion of this technology is unevenly spread across Brazil, being concentrated in certain regions (southeast, south, and coastal regions of northeastern Brazil). Such a format of the technological transition process can be justified due to issues related to the high value of electrified vehicles, the lack of charging infrastructure, and essentially the absence of government incentive policies. Map 1 shows the distribution of light electrified vehicles licensed in Brazil (BEV, HEV, PHEV) in 2022, by state, and also provides a breakdown of the spatial distribution of EVs in the state of São Paulo, highlighting the number of EVs per municipality in São Paulo.

Map 1. Spatial distribution of Electric Vehicles in Brazil and in the state of São Paulo, accumulated from January to December 2022.



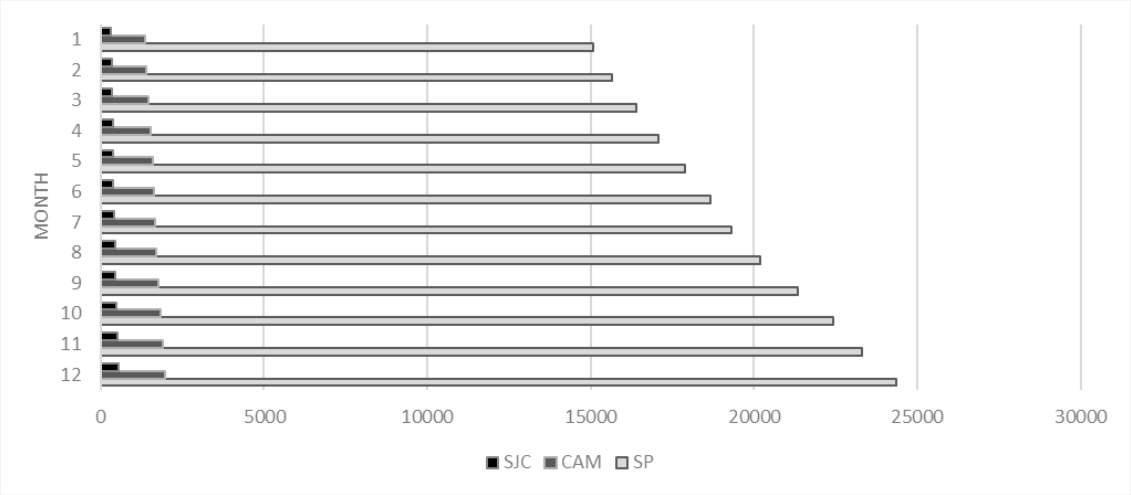
Source: prepared by the authors.

In 2022, the state of São Paulo accounted for approximately 65% of electric vehicles in the Southeast region (ABVE, 2023). This can be justified by the fact that São Paulo is the most populous state and has the largest economy in the country, covering 645 municipalities in an area of 248,219 km2. The circulating fleet in the state, also in 2022, was 15,202,143 vehicles, with 47% concentrated in the metropolitan region of São Paulo (São Paulo, 2020).

The distribution of electric vehicles in the state of São Paulo is neither uniform nor equitable among municipalities and areas of the state. The capital of the state, São Paulo, stands out the most in the context of electric mobility. In the 12 months of 2022, it accounted for 7,482 electric vehicle registrations, which represents approximately 47% of all registrations in the state and 15% of all registrations in Brazil in the same period. These percentages express the relevance of the state and the city of São Paulo for the technological transition process of the transportation sector.

The Map 1 shows details of electromobility in the main cities of the state and allows for comparing the progress of this technology in the mesoregions of São Paulo. Within the national logic of diffusion of EVs, it should be noted that: i) the total volume of EVs is 16,015; ii) Map 1 shows a large concentration of EVs in the metropolitan region of São Paulo and within a radius of 100km from the city of São Paulo/SP, following the state highways *Anhanguera* towards Campinas/SP and the *Presidente Dutra* towards São José dos Campos/SP - following a spatial trend of concentration of advanced sectors of capitalist economy in the "V" of São Paulo's development, as characterized by Lencioni (2015) and Silveira (2015); iii) graph one highlights the numbers and evolution of vehicle registrations that occurred in the selected cities, showing the quantities of EVs and a growing trend in the capital city of São Paulo, with the numbers increasing throughout 2022.

Graph 1. Number of registered EVs during the year 2022 in the selected cities of São José dos Campos (SJC), Campinas (CAM), and São Paulo (SP).



Source: SENATRAN, 2023.

Through the cartogram of electric mobility in the state of São Paulo and Graph 1, it can be observed that the vast majority of municipalities still have a low penetration of EVs, which are in the range of 0 to 84 vehicles. The highlight is the city of São Paulo, which is in the range of municipalities with 6,240 to 24,337 vehicles. Through institutional actions, the municipality has promoted means to encourage the acceptance of these vehicles and ensure that the necessary infrastructure is present to serve part of the population. The union between the municipal and state governments has become a key factor for the representation of the city and state of São Paulo

compared to other states in Brazil, which reinforces the premise developed in this article, that the electric mobility process requires the support of public policies to gain strength and greater adherence among society in general.

4.2. Institutional Actions to Promote Electric Mobility in the State of São Paulo

To check and monitor the development of institutional thickness in the State of São Paulo regarding electric mobility, we used the NATO Framework, as proposed by Oliveira Filho et al. (2022). Table 2 provides a summary of the actions carried out by the federal, state, and municipal governments regarding the new sociotechnical system of mobility.

Consoni et al. (2018; 2022) and Oliveira Filho et al. (2022) have shown that the Brazilian institutional framework aimed at promoting low-emission mobility does not rely on a problem situation that drives the definition of clear goals and objectives by the federal government regarding electromobility or "pulls" actions in pro-VE public policies. This is compounded by the current scenario in which Brazilian public policies are not anchored to a national strategic plan for promoting electric mobility or any technology that aims to replace the sociotechnical system of combustion engine dependent on fossil fuels.

Table 2. Public policy instruments implemented in the state of São Paulo for pro-electromobility, 2012-2022.

Nato- Framework	Brazil				
	RFB	ESP	SP	SJC	CAM
Nodality					
Public-Private Partnerships					
Interdepartmental collaboration (between secretariats or ministries)					
International cooperation networks					
Specific campaigns and/or actions to raise user awareness					
VE experimentation					
Monitoring system (Traffic, Emissions...)					
Authority					
Electric Mobility Plan/Strategy/Law					
Climate Change Plan					
Urban Mobility Plan	They don't mention EVs				
R&D Program					
Emissions targets					
Legislation (Regulation of public space, requirements)					
Legislation for Electric Charging Stations					
Legislation with Requirements for new buildings (with EV provisions)					
Traffic and Circulation Regulation					
Public Transport Bidding					
Treasury					
Public Fleet					
Exemption from Road Fees					
Tariff exemption for EVs					
Reduction of Import Taxes for EVs and Infrastructure					
Benefits for the circulation of EVs in urban areas					
Tax incentives for sectors of the economy related to EVs.					

Organization					
Pilot projects					
Public parking for EVs					
Public area concession					
Establish demonstration areas for EVs					

Source: prepared by the authors.
Note: In protuguese, RFB (Federative Republic of Brazil); ESP (State of São Paulo); SP (São Paulo); SJC (São José dos Campos); CAM (Campinas)

In Brazil, there is no national plan for electric mobility, nor are there structured policies that encourage the consolidation of this segment in the country, unlike what has happened in several Latin American countries that have already taken a stance on this matter (Consoni et al. 2018; Oliveira Filho et al., 2022). As a result, there are public policies and actions scattered among Brazilian municipalities that are independent of a central planning by the federal government and that lack direction and robustness, necessary elements to promote a rapid insertion and guidance of the country in the debate and choices involving automotive electrification.

The institutional instruments implemented at the federal level are considered transversal to the stimulus for low-carbon mobility, indirect policies. These policies can support electric mobility in Brazil, but were not designed for this purpose. These institutional actions are scattered in time and in the institutional construct of the federal government, meaning that there are actions that do not communicate with each other, implemented by different public entities, ranging from the Ministry of Economy to the Brazilian National Agency for Petroleum, Natural Gas, and Biofuels. This fact is not a problem in itself; the challenges lie in the absence of national consensus regarding technological options and the ability to make different instruments add up and converge energy and resources in the same direction.

The **state of São Paulo** has significant actions in the theme of low-emission mobility, which include electric vehicles (EVs). By reading Table 2, we can perceive general characteristics of the developed institutional framework. The first highlight is the recent nature of the state's public concern with electric mobility. Measures that explicitly mention EVs date back to 2019; for reflection purposes, the state of California in the USA has presented direct actions and concerns with the sector since the 1990s with the Zero-Emission Vehicle (ZEV) Program.

Another characteristic is that the institutional instruments are not focused solely on EVs, repeating a deficient feature observed at the federal level. Public policies present an incentive or direction character for multiple technologies, leaving the market and social actors free to choose technological routes. This fact, in contexts of low investment or high uncertainties (characteristic of present-day Brazil), ends up reinforcing less innovative routes and reinforcing already consolidated technological options that do not represent ruptures, such as flex-fuel vehicles or hybrids.

The "Climate Action Plan of the State of São Paulo (Net Zero 2050)", developed in 2022, shows itself as an important effort to change the actions of the state government, using some considerations about the design of this policy that directly encompass EVs as an option to achieve decarbonization objectives.

The main objective of the plan is to achieve net zero greenhouse gas emissions (NET ZERO), regulated by the Kyoto Protocol, by the year 2050. Thus, among the goals and strategies chosen by the plan, some directly impact the electromobility segment, such as: i) progressively increasing investments in Research and Development (R&D) in the climate area, reaching up to 2% of São Paulo's GDP. The total investment (public and private) is estimated to be 5% of São Paulo's GDP by the year 2050; ii) stimulating the implementation of gigafactories in São Paulo,

covering batteries and electronic components of significant strategic value for the light and heavy electric vehicle chain; iii) adopting zero and ultra-low emission buses; iv) promoting the use of shared electric mobility, providing fueling infrastructure; v) contracting and renewing public fleets through EVs; vi) supporting municipalities in the development of local Urban Mobility Plans, which must present low-carbon strategies, considering electric micromobility as one of the paths; vii) increasing the number of electric charging stations along São Paulo's highways.

These points open up possibilities for advancement in electromobility and, depending on the developments, contribute to mitigating the regional inequalities seen in these early steps of electromobility in the state (see Map 1). Starting from a multiscale institutional analysis, we selected the municipalities of São Paulo, ***São José dos Campos***, and ***Campinas***. These present different levels of effort in supporting electromobility.

The table 2 highlights the actions of municipalities in this new sociotechnical system, which brings valuable insights into the institutional support dynamics for electric mobility in the state of São Paulo. These actions allow us to understand how territorialized efforts are advancing in the mission of transitioning to electromobility. Initially, there is a weak or rhetorical articulation between what happens in the municipalities and what is set at the state or even federal level. This situation occurs in all three municipalities. The documents implemented or planned by the municipalities do not refer to the documents of the "higher" scales or even add efforts to the objectives or provisions of the instruments already implemented by other federal entities.

Another important general aspect is to perceive how these municipalities are in different stages and levels of maturity, a situation that is not correlated with the size of the fleet or even the economic power of the municipality. This local framework ultimately aims to allocate EVs as technical devices in the daily life of public management and city life, using them as part of a strategy to solve socio-environmental problems or emulate new business opportunities. Thus, institutional thickness ranges from elaborate to non-existent (remaining only in intention).

In the case of Campinas, we have the most concrete-lacking situation regarding institutional development. No public policies have been identified that explicitly refer to electric vehicles (EVs) or indirect policies that extend to EVs. This fact is striking, considering that the city has a significant number of EVs and a set of ongoing initiatives by private actors and the State University of Campinas (UNICAMP) to promote electric mobility. Furthermore, Campinas was the first municipality in Brazil to implement a fleet of electric buses, with 15 units, almost 10 years ago, and is home to the energy company CPFL (Paulista Company of Energy), a pioneer in R&D projects focused on the topic of vehicle electrification, such as the EMOTIVE project (Carvalho, 2018).

The city of São Paulo, the most important in the country, has significant actions, particularly regarding public transportation (technical cooperation with C40 and ICCT in the ZEBRA Project and the Transformative Urban Mobility Initiative (TUMI)). However, its efforts are discontinuous and are not developed on a scale compatible with the size of the city. Regarding the first statement, we can say that Law 14.933/09 (Climate Law) provided that: "municipal programs, contracts, and authorizations for public transportation must consider a progressive reduction in the use of fossil fuels, with a progressive reduction target of at least 10% per year from 2009 and the use of non-fossil renewable fuels by all public transportation buses in the Municipality in 2018." However, this law was not complied with, which is why Article 50 was modified by Law 16.802/2018, requiring fleet operators in the city to promote the progressive reduction of CO2, NOx, and particulate matter over periods of 10 and 20 years.

Another fact is when we compare the city of São Paulo to Bogotá (Colombia) regarding electric bus fleets. We know that territorial specificities are important, but it seems difficult to justify that the richest and most developed city in the southern hemisphere cannot come close to actions taken by the capital cities of South American countries. By the end of 2022, São Paulo had only 18 electric buses in operation out of a total of 14,400 buses, while Bogotá had 1,485

battery-electric buses out of a fleet of 11,026 buses. Both cities participate in the same international partnerships, such as the TUMI project (Ramos, 2023).

The municipality of São José dos Campos is the city that appears to be the most advanced in the transition process to electromobility, as it presents continuity and evolution in the implementation of public policies, updating and advancing the design of institutional instruments (see table 2, as instruments occupy spaces by NATO categories).

Another point that draws attention is that the local government acts institutionally in both the light and heavy EV segments. Actions range from establishing places and rules for car sharing with EVs to implementing public fleets with battery-powered electric vehicles. These vehicles are being used in the everyday services of the Municipal Civil Guard (GCM). With regard to electric buses, there is the definition of exclusive corridors for them and an articulation for the implementation of the new business model, with Supplementary Law No. 620/2019 and the bidding process for electric buses in SJC (2022).

The way the municipality carries out actions in public space to enable new businesses with a more sustainable mobility character should be emphasized. For example, the operation of shared EVs in partnership with the company Beep Beep, which involved the creation of specific public parking spots for EVs, as well as adaptations to the rules of public space and vehicle circulation in the city - as in Law No. 9,684/2018 and Decree No. 17,462/2017 and Decree 18,350/2019.

In addition, the municipality has designed instruments that seek to take advantage of the positive externalities of the city, with the presence of important universities and research institutes - *Instituto Tecnológico de Aeronáutica (ITA), Universidade Estadual Paulista (UNESP), Instituto Nacional de Pesquisas Espaciais (INPE).* An example is the Innovation Law 9.563/2017, an instrument that strengthens the innovation ecosystem in the sustainable route, since it prioritizes low-emission sectors and provides benefits in this area.

5. DISCUSSION

5.1. Institutional Thickness for Electric Mobility in the State of São Paulo: Territory, Inter-scale Relations, and Public Policies

Through the diffusion data of electric vehicle registrations in the state of São Paulo and also with information extracted from the mapping of public policies, the situation of electromobility in the state of São Paulo can be characterized as incipient and low in penetration throughout the territory. Furthermore, we can perceive explanatory elements in two directions of the studied phenomenon, electromobility in São Paulo.

Firstly, the aspects of regional inequalities and limitations of technological diffusion in the state of São Paulo are evident. It is clear that electric vehicles (VEs) are limited to a few areas of the state, mainly concentrated in large urban centers such as the city of São Paulo, the metropolitan region, and the city of Campinas. It is important to note a high concentration in bedroom communities, where high-end condominiums are located, such as Barueri near São Paulo and Jacareí, a neighboring municipality of São José dos Campos. In other words, the paths of electromobility reinforce and follow the tracks of our inequalities and limitations of territorial planning.

The distribution of VEs is much lower compared to conventional vehicles and is insignificant compared to international countries and regions, even those of corresponding equivalence, such as Latin American countries like Chile, Colombia, and Costa Rica (Rodriguez, 2022; IEA, 2022).

A second explanatory line is based on institutional efforts, through an "undernourished" Institutional Thickness, that is, when we observe the cases from an inter-scalar perspective, we

do not identify synergies between the propositions of the local level with the federal or state level. Furthermore, when we look at the subspaces individually (national, state, and municipal), we realize that they do not use the policies offered by NATO's dimensions. This is because the efforts of the Brazilian government have been confined to few support tools for new technology, making more relevant use only in the Nodality dimension, a group of tools that are important but do not have the strength to support or direct transition initiatives. This is because this dimension includes actions that remain in the realm of circulation and obtaining information and influences, do not establish common goals or objectives, do not invest monetary resources, or impose rules that should guide the behavior of companies and users.

On the other hand, by following the federal sphere, we can see that it is failing to fulfill its role as an emulator of long-term institutional actions, providing a normalization gap in relation to electromobility, as it does not have a national Plan or Strategy for this approaching sociotechnical phenomenon. This conclusion is supported by the works of Consoni et al. (2018), Oliveira Filho et al. (2022), and Bermúdez (2022), which show that Latin American countries that are advancing in electromobility already use national strategies/plans specifically focused on the new segment, which function as an "umbrella" for subsequent instruments that aim to achieve goals.

The instruments implemented up to 2022, both in Brazil and in the state of São Paulo, are somewhat spasmodic responses to specific pressures from interested actors. As a result, the region with the greatest economic potential in the country has not moved away from the previously assumed models (incentives for combustion vehicles, mainly in the flex-fuel modality). This finding is in line with the conclusions of Wesseling (2016), who identifies that countries/regions with experience in the automotive industry tend to focus on strategies for the development and production of EVs, rather than the process of technology diffusion.

However, regarding the institutional framework established so far, it cannot be affirmed that in the state of São Paulo, there is cohesion and readiness of the government to reorient the current industrial base; there are movements in this direction, but no public policies have been identified with the character of updating the productive base. Perhaps a turning point will be given by the implications of the São Paulo State Net Zero 2050 Climate Action Plan of 2022, which outlines an articulated strategy between sustainability and a new industrial base, as well as establishing intermediate goals for both emissions and the replacement of part of the vehicle fleets, aiming to achieve energy efficiency levels that require the introduction of new technologies.

The government, at the local and regional level, is mobilizing resources related to the dimensions of Nodality, Regulation, and Organization (see Table 2) with greater intensity. These governments establish relationships with cooperation networks and play an essential role in circulating information, making users aware of new technologies and environmental benefits, especially in the case of São José dos Campos.

Regulatory flows from local governments are linked to the objectives of cities, mainly institutional tools related to vehicle circulation (fluidity or restriction). Using their authority over urban space, local leaders can give advantages to vehicles with new technology (i.e., EVs). For example, in São José dos Campos, there are specific public and semi-public parking areas and the updating of the São Paulo municipality's building code with Law 17,336/2020, which requires the provision of solutions for charging EVs in residential and commercial buildings (condominiums) in the city. This solution must provide for the mode of EV charging according to Brazilian technical standards and also individual measurement and billing of consumed energy, following the procedures of the concessionaires.

Another example of this characteristic is the creation of exclusive lines for electric buses. A state example of regulation is Decree 41,858/1997, which regulates Law 9,690/1997, which

establishes the Program for Restriction on the Circulation of Motor Vehicles (rotation) in the Metropolitan Region of Greater São Paulo - electric vehicles are exempt from this measure.

Regarding institutional tools resulting from the Organization dimension, we highlight pilot projects, the granting of public areas, and public parking for EVs. Regarding pilot projects, it is worth noting that the local government participates as a manager or partner, usually providing some asset or resource for the project, such as public areas or the implementation of public fleets. It differs from participation on a national scale, which only acts indirectly through independent agencies, and not as a manager or partner of the project itself.

Finally, a local government action that significantly expanded the diffusion of EVs in São Paulo was the bid for the collective public transportation system. When analyzing the selected cases, we can say that one of São Paulo's focuses is the electric bus segment. All cities presented pilot projects with electric buses and initiatives to support their use, even Campinas, a municipality that does not have really implemented institutional instruments, presents this type of transition initiative, given by the synergy between local agents (companies in the segment and educational and research institutions). For example, the case of the fleet of internal shuttles of the Transport Services Directorate (UNITRANSP - UNICAMP), financed by the company *CPFL Energia* and produced by the Chinese company BYD, based in Campinas.

6. CONCLUSÕES

The diffusion of electric mobility and the need for institutional development in the State of São Paulo to promote it are issues that are being debated and bring up related questions about institutional thickness and the transition to sustainability. The State of São Paulo is a pioneer in the country in terms of electric mobility diffusion. Municipalities such as São Paulo and São José dos Campos have begun to introduce public policies, mainly at the state and municipal levels, which allow the technological transition process to occur with government support and incentives, rather than only organically or intuitively, as seen in the municipality of Campinas.

As a way of summarizing, we highlight three characteristics of the institutional framework in the State of São Paulo. First, local and state emission goals and national goals are not aligned and are far from international standards. This issue seems to justify specific actions (scattered initiatives in the territory - ranging from car sharing to electric buses), but they are not strong enough to compel economic actors and individual users to change technological directions.

Second, the industrial legacy did not work in favor of electromobility. In mapping instruments and actions, actors linked to the automotive industry are not the object of institutional instruments (did not receive any specific incentives or commands towards electromobility). Finally, in analyzing the institutional framework developed so far, we perceive a lack of articulation and interrelation between the instruments, both those implemented at the national level and those implemented by the local government.

The panorama observed in the State of São Paulo and in the selected municipalities for analysis (São Paulo, Campinas, and São José dos Campos), which are the most advanced in Brazil, allows us to arrive at a harsh reality regarding electric mobility diffusion in the country. The process is expanding unevenly and unregulated, a consequence of the absence of direction in federal public policies, which, together with state and municipal policies, should articulate and promote incentives, as well as meet a national plan for promoting electric mobility, with goals and objectives.

Given the scenario of change and the need for technological transformation, Brazil needs to improve multilevel governance structures for sustainability transition processes because, in addition to the absence of robust institutional instruments, there is no confluence of ongoing initiatives. This does not mean that there are no federal entities for this or that we do not have ongoing or recent initiatives. What we aim to do with this work is to present a proposal for a path

to be followed, guided by the function of governments (Hood, 1988; Hood & Margaret, 2007), and an operationalizable analytical structure to identify and act on multiple institutional and territorial scales, articulating social actors to achieve common objectives, such as mitigating climate change, industrial transformation, energy transition, or electromobility.

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