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ANALYSIS OF POSSIBILITIES FOR THE INTRODUCTION OF ELECTRIC VEHICLES IN THE URBAN TRAFFIC OF SÃO PAULO CITY: AN APPROACH THROUGH THE MORPHOLOGICAL ANALYSIS

Alexandre Silveira Pupo
TechCast Virtual Think Tank
alexandrepupo@yahoo.com.br

ABSTRACT

Fuel market is facing political, economic, social and environmental problems that are fuzzing the future of fossil energy sources and in face of these facts, countries are looking for hybrid and electric vehicles as part of solution in transportation sector due to the fact of electric vehicles use few or no fossil fuel. The objective in this article was to identify options until 2020 to introduce electric vehicle in the urban traffic of São Paulo city and to develop this study the method of literature review in secondary sources was used to present electric vehicle technologies and to identify parameters that were assessed through morphological analysis technique. In morphological analysis, sets of values were defined by the author for these parameters, possible combinations were structured, clearly impractical deployment options before 2020 were discarded and some viable solutions were analyzed in details. These analyses concluded that there are viable options for actual days in São Paulo city, but important requirements regarding technology, politic, market, infrastructure and innovation in products and services still need to be addressed and it is the main reason of electric vehicle remain unnoticed by consumers as an viable option. The challenges are great and the actors who are willing to solve them will find a promising market to explore.

Key-words: Electric vehicles. Morphological analysis. Urban traffic.

RESUMO

As instabilidades político-econômicas e as pressões socioambientais que afetam o mercado de combustíveis têm tornado nebuloso o futuro de médio e de longo prazo das fontes fósseis de energia e, diante dessas incertezas, muitas nações estão buscando soluções como os veículos elétricos ou híbridos para a questão do transporte, pelo fato de demandarem pouco ou nenhum combustível fóssil. Neste trabalho objetivou-se identificar possibilidades válidas e aplicáveis até 2020 para a introdução de veículos elétricos no trafego urbano da cidade de São Paulo. No desenvolvimento do estudo foi usado o método de pesquisa bibliográfica em fontes secundárias para a apresentação das tecnologias e a identificação das variáveis que, posteriormente, foram avaliadas pelo método de análise morfológica para a estruturação das opções identificadas. Na análise morfológica, o autor selecionou as variáveis para análise e definiu conjuntos de valores para elas. As combinações de tais conjuntos de valores foram estruturadas, opções claramente impossíveis ou pouco viáveis até 2020 foram descartadas e as possibilidades desejáveis ou viáveis foram analisadas de forma mais detalhada. Dessas análises, concluiu-se que existem opções viáveis para a atual realidade da cidade de São Paulo, mas importantes requisitos tecnológicos, políticos, de mercado, de infraestrutura e de inovação em produtos e serviços ainda não foram atendidos e, por isso, os veículos elétricos continuam não sendo percebidos pelos consumidores como uma opção viável aos veículos com motor de combustão interna. Os desafios ainda são grandes e os atores que se dispuserem a resolvê-los encontrarão um mercado promissor para explorar.

Palavras-chave: Veículos elétricos. Análise morfológica. Tráfego urbano.

1 INTRODUCTION

The economic, technological, sociocultural and environmental changes through which society has been undergone seem to indicate a change in vehicles role. In former times the vehicles that used to play a role of social differentiation, currently seem to be turning into tools whose function is to transport people or loads causing the least possible impact on economic, social and environmental terms.

Rezende, Mota and Duarte (2010, p. 23) show that the Brazilian automotive industry has largely evolved, reaching the point of providing the world's 6th place for country in terms of scale, the 5th place in terms of consumer market, the 12th in terms of export and the 13th when it comes to imports, being leader in the production of vehicles using renewable fuels. Erber (2010, p. 105) presents the estimates of Table 1 for electric vehicles sale in Brazil for the next 20 years.

Year	Total Vehicles (electric and non-electric)	Hybrid Electric Vehicle	Battery and Plug-in Electric Vehicle
2010	2,8	-	-
2015	3,6	0,10	0,04
2020	4,2	0,73	0,30
2025	4,9	1,39	1,31
2030	5,6	1,65	2,47

Table 1: Estimates of electric vehicles sales in Brazil (in million units)

Source: Adapted from Erber (2010, p. 105)

Inserted within this transformation scene that occur in a market of considerable size and potential, electric vehicles play a very significant role and, although historically they are not considered an innovation, they can be classified as an evolution of current internal combustion engines models since, in accordance with Velloso (2010, pp. 7-8), their energy capacity are more efficient, they are technologically more advanced, they are less harmful to the environment, they are more economical in terms of use and maintenance, and their integrability to the urban systems is much higher in several ways and, in accordance with Sacchi (2010, p. 9), they feature a 150% greater energy efficiency.

Despite all these positive aspects, Coutinho, Castro and Ferreira (2010, p. 33) state that there are well known challenges not restricted to Brazil only, which prevent the faster development of electric vehicles and they are related to the high price, the battery lifetime and the need to set up a specific infrastructure for commercialization, operation and maintenance of vehicles and batteries.

Currently, the dominant technology in the area of batteries for electric vehicles is the ion-lithium battery and the largest producers are located in Asia, according to Velloso (2010, p. 11). From the price viewpoint, even with all the advantages over the internal combustion engine vehicles, electric vehicles still do not receive any government incentive in Brazil and, according to the example provided by Coutinho, Castro and Ferreira (2010, p. 33) the vehicles are taxed based on the higher excise tax (IPI) rate, which is of 25% today. With regard to infrastructure requirements, there are issues related to the way and availability of recharging stations, with pricing models and especially with the need of new electric system organization in order to cope with the management of energy supply and demand, which would become larger, more dynamic and better distributed.

The World Energy Outlook report projections (International Energy Agency, 2010, p. 10) estimate that electricity should be the ultimate form of energy having in view the world stronger growth up to 2035 and that their generation has been undergoing changes caused by technological advancements, by the increase in fossil fuel prices and by the governments actions that direct incentive policies for the development of safer and lower environmental impact energy solutions. The report also mentions the concerns with the reduction of the environmental liabilities generated in the last few centuries, saying it would require a profound transformation of the generation and distribution energy system so that it could contribute to the achievement of the reduction target of 2ºC in the estimates of global temperature rise.

With regard to the amount of vehicles, the São Paulo city entire fleet presented a daily average growth of 0.0091% between January and December 2011, ending 2011 with 7,186,724 units (State Traffic Department of São Paulo, 2011). This percentage seems to be small, but in quantity of cars it represents 644 new vehicles introduced in the city traffic every day. When only cars and motorcycles are considered, the average daily growth drops to 0.0079% (State

Traffic Department of São Paulo, 2011), but yet represents the significant number of almost 480 vehicles introduced in the municipal fleet on a daily basis.

Given this scenario in terms of energy matrix, production and consumption in the automotive sector and in terms of environmental and socio-cultural changes, the electric vehicles provide advantages in all these aspects and the country has to take opportunity of all these advantages together with intelligent models that enable the adoption and use of such vehicle in Brazil.

Although being seen as an evolution in relation to internal combustion engine vehicles, electric vehicles are still placed on the market by using technological and commercial approaches based on the fossil model and ecosystem. The proposed objective of this article is to identify and analyze technological possibilities, vehicles configuration, their application, as well as commercialization models that can be used to make feasible the introduction of the electric vehicles in the urban traffic of São Paulo city until 2020 so that Brazil, besides not losing a historical opportunity, can also build up mechanisms to help identify solutions for a major problem in large urban centers around the world – the low quality and inefficient traffic, which generates externalities and negative environmental impacts.

The electric vehicles taken into account for analysis in this article are only the cars and the small and medium-sized motorcycles. The work structure consists of bibliographical research on electric vehicles, the methodology presentation, the development of the identified possibilities analysis and the final considerations.

2 ELECTRIC VEHICLES - HISTORY AND CONCEPTS

Despite being presented to the public as a kind of newness compared to the current models of cars, electric vehicles are, according to Larminie and Lowry (2003, p. 1), an invention of 1830 which used non-rechargeable batteries and became commercial by the end of XIX century when the rechargeable batteries reached an industrial scale – as depicted in Figure 1, which shows a taxi from the New York city in 1901.

Figure 1: Electric vehicle used as a taxi in New York City in 1901

Source: Larminie and Lowry (2003, p. 2)

Larminie and Lowry (2003, p. 3) state that, despite their advantages over competitors with steam engines or internal combustion engine at that time, electric vehicles started losing ground as from 1910 due to low autonomy of batteries, the fall in fossil fuel prices and the internal combustion engines development. They also mention that, ironically, batteries and electric motors have become the set of components for the drive starting of the internal combustion engines – presently known as engine starters.

According to Baran and Legey (2010, p. 215), there were initiatives to bring in electric vehicles to the market in the 1970s and 1980s due to the oil crisis, the environmental issues and the concerns brought about by the report "The Limits to Growth", published by the Club of Rome in 1972, but both, industry and society of that time were not ready for a paradigm shift.

However, almost two centuries after being invented, electric vehicles are coming back, due to problems with environmental issues and the worldwide increasing risk of fossil fuels running out.

Gomes (2010, p. 10-19) mentions the purely electric vehicles, the hybrid electric vehicles, the hybrid battery electric vehicles whose batteries are rechargeable as from the power grid and fuel cell vehicles as the four types of electric vehicles available today.

The purely electric vehicles or Electric Vehicle (EV) are so called because they have only the battery as the power source. In terms of performance, the EVs have already reached the same level as vehicles with internal combustion engine, but the greatest obstacles to this technological approach are still autonomy, the recharge time and cost. Representatives of this category are the Model S sedan, of Tesla Motors, and the Leaf, of Nissan.

The Hybrid Electric Vehicles (HEV) are those in which there is a combination of the EVs concept with internal combustion engine vehicles concept in different settings. In the serial configuration, an internal combustion engine drives a generator which charges the battery or drives an electric motor responsible for moving the vehicle. In the parallel configuration, the internal combustion engine works together with the electric motor to drive the vehicle and such electric motor can also serve as a generator in some situations. And in the serial-parallel configuration, the vehicle is capable of using the advantages of both configurations, but the mechanical complexity and the system cost are greater. Representatives of this category are the Prius, of Toyota, the Fusion Hybrid, of Ford, and the S400 Hybrid, of Mercedes-Benz.

The hybrid electric vehicles rechargeable as from the power grid or Plug-in Hybrid Electric Vehicle (PHEV) show the same characteristics of HEVs, but they have an extra feature – inherited from EVs – which is the possibility of direct recharge the battery from power grid. Alexander (2006, p. 13) defines PHEVs as hybrid vehicles that get part of their operational energy from the electricity and part from the conventional chemical fuel and a representative of this category is the Volt, of Chevrolet.

Vehicles powered by fuel cells or Fuel Cell Electric Vehicle (FCV) use hydrogen as the energy source to drive the vehicle or for battery charging, and in light of these features they could even be categorized as HEVs in the serial configuration in which the internal combustion engine has been replaced by the fuel cell. The major obstacles for the popularization of FCVs are the fuel cells technology, the price and the hydrogen supply chain. Representatives of this category are the FCX Clarity, of Honda, and the BMW Hydrogen 7, of BMW.

Specifically talking about EVs, the National Energy Technology Laboratory

(2002, p. 7) mentions that classify these vehicles as zero emission can be misleading because there are indirect emissions in the electricity generation processes, but the impact caused by the simple fact that the vehicles emit little or no pollution directly has a great appeal from the ecological point of view and the problems associated with fossil fuels. Being respected the proportions and specificities, this reasoning can also be applied to the HEVs, PHEVs and FCVs.

3 RESEARCH METHODOLOGY

In this article, the first research method serves as the starting point for the second.

The first method consists of the bibliographical research in secondary sources aiming at the author's survey about variables used by the second method, which is morphological analysis, where the analyzes about the possibilities of introducing the electric vehicles in the urban traffic of São Paulo City until 2020 are developed..

The bibliographical research in secondary sources, according to Gil (2010, p. 29) can be defined as a research carried out on materials already published and, according to Yin (2001, p. 24), aims to answer questions such as "who", "what", "where", "how many" and "when", focusing on past and present events.

Acevedo and Nohara (2007, p. 48) define bibliographical survey as the search for information in studies already published and that, according to Medeiros (2006, p. 46), they are found in the public or corporate archives, scientific or education institutions, or in private collections categorized by Vergara (2003), in terms of types of materials, in the form of books, databases, journals, newspapers and other sources of information that can be accessed through the Internet.

The second method used in this study is the morphological analysis, proposed by Zwicky (1969, p. 4) and defined as a technique designed to evaluate all facts that need to be considered when the goal is to find alternatives not biased in pursuit of solutions for a problem, since Zwicky argues that it is only possible to choose the best solution after evaluating all possibilities.

Porter, Roper, Mason, Rossini and Banks (1991, p. 65) mention that morphological analysis is a method classified as structural because the alternatives found out take into account the relationships between technologies and the contexts in which they are inserted and because the method tests these relationships in the process of searching for solutions.

For Johnson, Wright and Guimarães (1987, p. 3), Porter et al. (1991, p. 106), Ribeiro (1997, p. 76) and Zwicky (1969, p. 106), morphological analysis allows exploiting possible futures in a systematic way and in some cases in an automatic way as from the analysis of large amounts of combinations that result from the decomposition of systems and aims not only show possible new processes or products, but also enable the development of scenarios, the abandonment of preconceived patterns, the accomplishment of lateral analysis, the identification of interdisciplinary solutions and the creative speculation.

According to Silva (2011, p. 24), morphological analysis has as its basic assumption the dismemberment of complex problems into fundamental variables, so that it is possible to perform more detailed analyzes aiming at the generation of state sets or alternative values sets.

In this paper, morphological analysis has as subsidy the results of the bibliographical research for identification and selection of the variables that the author considers influence the choices related to electric vehicles. This bibliographical research is the result of the analysis of texts in books, theses, essays, magazines, and scientific articles of institutes involved in the subject, as well as the documentation kindly provided by Professor Dr. James T. C. Wright – coordinator of Future Studies (Profuturo) and of the research project titled Introduction of Electric Vehicles in the Urban Traffic of São Paulo City: Impact Analysis in Multiple Scenarios and Contributions to the Sustainable Urban Mobility, funded by CNPq and FINEP.

Once identified the variables, the author defines sets of values relevant to them and analyze the generated combinations, discarding those clearly unfeasible and analyze more accurately those that present feasibility or are distant from preconceived standards.

When analyzes are completed, the author closes the article displaying considerations about the possibilities that were found out.

4 DEVELOPMENT OF MORPHOLOGICAL ANALYSIS

For Johnson, Wright and Guimarães (1987, p. 3), morphological analysis can be characterized as a non-quantitative method which promotes the inter-relationship of verbal concepts through a systematic analysis. Shurig (1984, cited by Porter et al., 1991, p. 66), mentions that the method is capable of testing the problems as from the structural point of view aiming at the generation of ideas on innovation and breakthrough processes.

Such features enable the use of the method in the treatment of the variables identified by the author in the literature review to investigate the combinatorial possibilities in generating proposals for the introduction of small and medium-sized electric cars and motorcycles in the urban traffic of São Paulo city until 2020.

4.1 FEATURES ANALYSED

During the phase of bibliographical review the variables of Figure 2 were identified and, although such set of variables is not exhaustive, it has a direct impact on how the electric vehicles will be introduced in the urban traffic of São Paulo city until 2020, both from the manufacturers and suppliers point of view as the consumers' viewpoint.

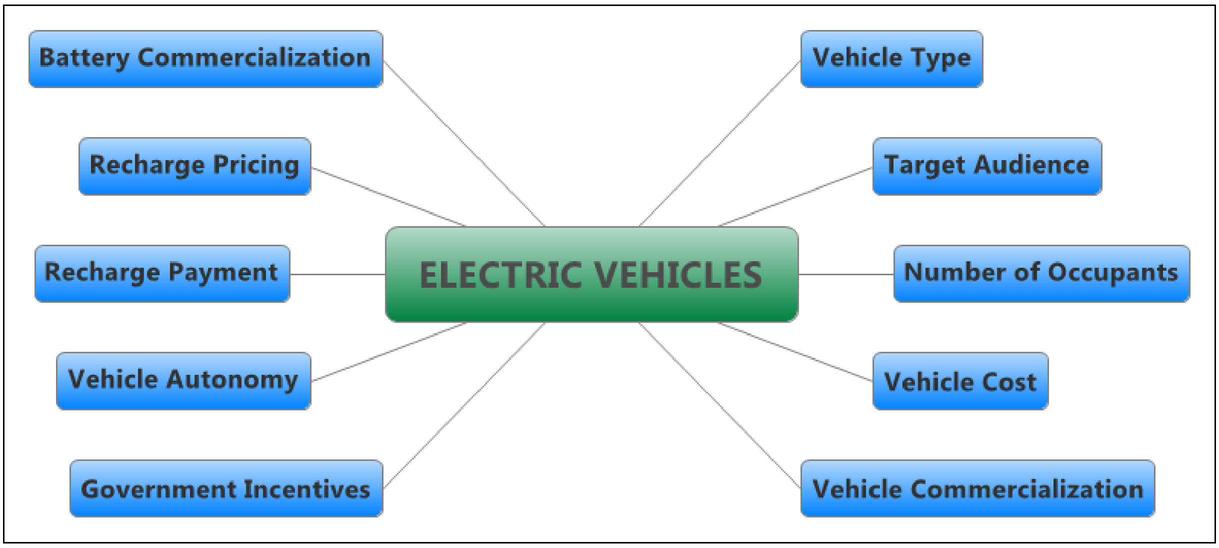

Figure 2: Variables identified for analysis of the possibilities for the introduction of electric vehicles in the urban traffic of São Paulo city until 2020

Source: Prepared by the author

After being selected, each variable has had one set of values defined and used in the drawing up of analyzes, as shown in Figure 3.

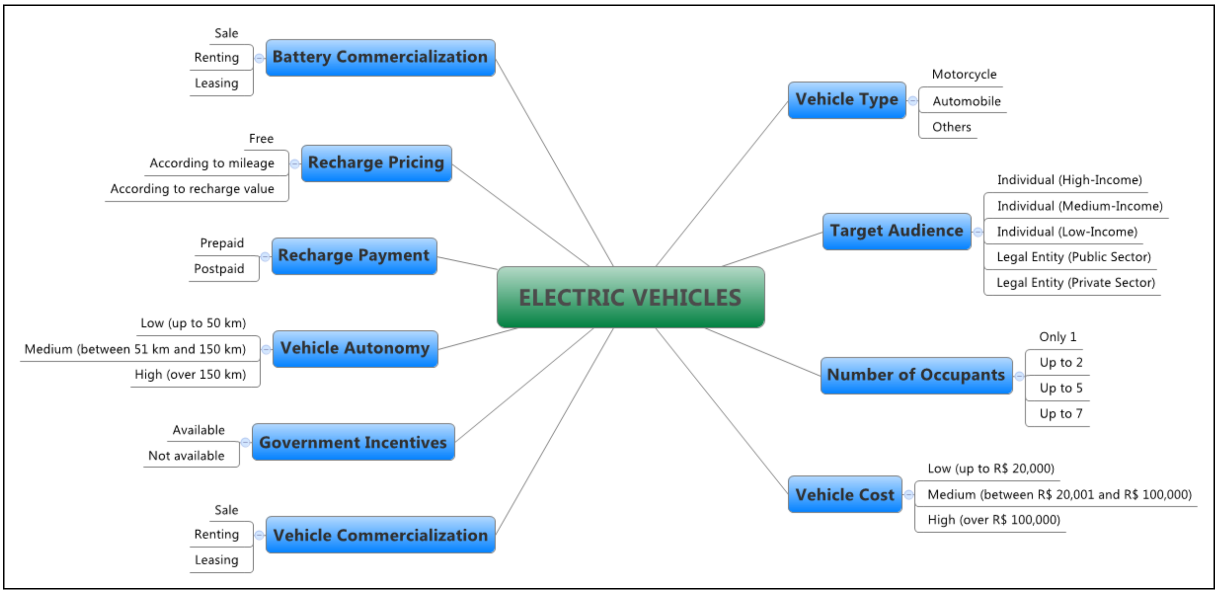

Figure 3: Variables identified for analysis of the possibilities for the introduction of electric vehicles in the urban traffic of São Paulo city until 2020, with the respective values

Source: Prepared by the author

4.2 MORPHOLOGICAL MATRIX DEVELOPMENT

In this paper the variables have been selected exclusively through bibliographical research carried out by the author, but in structured methods such as the scenario building developed by Profuturo (Wright & Spers, 2006, pp. 17-18), they can be identified by methods such as Delphi.

Although Figure 3 presents a more interesting way of visualizing the morphological analysis scope, as well as the variables and their respective set of values, such a distribution does not allow for an easy accounting of total number of possibilities. For this reason the structure remodeling has been made in a matrix format.

As it can be seen in the list of values in Table 1 and calculations of Table 2, the number of possible combinations – given by the sharply increasing number of possible values of all variables – is very large.

SCOPE	VARIABLES	VALUES				
ELECTRIC VEHICLES IN SÃO	Type of Vehicle	Motorcycl e	Automobile	Others		
	Target Audience		Individual	Individual	Legal	Legal

PAULO CITY UNTIL 2020		Individual (High-Income)	(Average-Income)	(Low-Income)	Entity (Public Sector)	Entity (Private Sector)
	Number of Occupants	Only 1	Up to 2	Up to 5	Up to 7	
	Vehicle Cost (R$)	Low (up to 20.000)	Average (between 20.001 and 100.000)	High (over 100.000)		
	Vehicle Commercialization	Sale	Renting	Leasing		
	Government Incentives	Available	Not-Available			
	Vehicle Autonomy (km)	Low (up to 50)	Average (between 51 and 150)	High (over 150)		
	Recharge Payment	Postpaid	Prepaid			
	Recharge Pricing	According to recharge value	According to mileage	Free		
	Battery Commercialization	Sale	Renting	Leasing		

Table 1: Matricial Distribution of identified variables for the analysis scope of the possibilities for introduction of electric vehicles in the urban traffic of São Paulo city until 2020, with the respective values

Source: Prepared by the author

Electric Vehicles in São Paulo city until 2020	=	Type of Vehicle x Target Audience x Number of Occupants x Vehicle Cost x Vehicle Commercialization x Government Incentives x Vehicle Autonomy x Recharge Payment x Recharge Pricing x Battery Commercialization
Electric Vehicles in São Paulo city until 2020	=	3 x 5 x 4 x 3 x 3 x 2 x 3 x 2 x 3 x 3
Electric Vehicles in São Paulo city until 2020	=	58.320

Table 2: Combinations for the possibilities of introducing electric vehicles in the urban traffic of São Paulo city until 2020

Source: Prepared by the author

The generation of large number of combinations is one of the features that somehow limit the use of morphological analysis without the assistance of other methods to check the identified possibilities because it is virtually impossible to analyze all of them without running the risk of disregarding some viable or interesting combination.

After a second analysis of the variables made by the author in an isolated way, some values were deleted or modified, as outlined in the new list of Table 3 and in the combinations recalculation in Table 4.

SCOPE	VARIABLES	VALUES			
ELECTRIC VEHICLES IN SÃO PAULO CITY UNTIL 2020	Type of Vehicle	Motorcycle	Automobile	Others	
	Target audience	Individual (High-Income)	Individual (Average-Income)	Individual (Low-Income)	Legal Entity (Public and Private Sector)
	Number of Occupants	Only 1	Up to 2	Up to 5	Up to 7
	Vehicle Cost (R$)	Low (up to 20.000)	Average (between 20.001 and 100.000)	High (over 100.000)	
	Vehicle Commercialization	Sale	Renting	Leasing	
	Government Incentives	Available	Not-Available		
	Vehicle Autonomy (km)	Low (up to 50)	Average (between 51 and 150)	High (over 150)	
	Recharge Payment	Postpaid	Prepaid		
	Recharge Pricing	According to recharge value	According to mileage	Free	
	Battery Commercialization	Sale	Renting	Leasing	

Table 3: New matricial distribution of the identified variables for the scope of possibilities for introduction of electric vehicles in the urban traffic of São Paulo city until 2020, with the values eliminated (in red) and those modified (in yellow)

Source: Prepared by the author

Electric Vehicles in São Paulo city until 2020	=	Type of Vehicle x Target Audience x Number of Occupants x Vehicle Cost x Vehicle Commercialization x Government Incentives x Vehicle Autonomy x Recharge Payment x Recharge Pricing x Battery Commercialization
Electric Vehicles in São Paulo city until	=	2 x 4 x 3 x 3 x 3 x 1 x 3 x 2 x 3 x 2

2020		
Electric Vehicles in São Paulo city until 2020	=	7.776

Table 4: Combinations for the possibilities of introduction electric vehicles in the urban traffic of São Paulo city until, after removal and modification of values

Source: Prepared by the author

The option "Other" was removed from the variable "Type of vehicle" because, although there are vehicles with innovative design and conceptual approaches such as the concepts 3R-C of Honda, i-REAL, of Toyota, or Moovie, of Peugeot, the urban traffic of São Paulo city has not perspectives of becoming friendly enough until 2020 – either in terms of infrastructure, or in terms of actors' behavior - to accommodate vehicles of these types.

The public and private sectors were unified under a single form of legal entity in the variable "Target Audience" as they both have very similar characteristics in terms of purchasing power and scale.

The options of vehicles with capacity for more than five occupants was removed from the variable "Number of Occupants" because the study has only small and medium-sized cars and motorcycles as the focus and also because electric vehicles with capacity for over five occupants are rare due to the current technological infeasibility or of costs.

The absence of incentives has been excluded from the variable "Government Incentives" because they are essential for adopting of electric vehicles. These incentives can be direct, such as differentiation or the exemption from Property Tax Vehicle (IPVA); indirect, such as exemptions for producers in the chain, or even incentives other than tax incentives, such as preferential access to public parking and roads for users, as exemplified by Hensley, Knupfer and Krieger (2011, p. 3).

The leasing option was moved from the variable "Battery Commercialization" because according to Kampman, Braat, Essen and Gopalakrishnan (2011, p. 25), they have high cost, and a shorter life cycle in relation to the vehicles that use them.

4.3 POSSIBILITIES WITH LOW FEASIBILITY

While generating a large amount of possibilities and although Zwicky (1969, p. 107) recommends checking all of them, it is noticeable that the morphological analysis has the benefit of showing very clearly inappropriate values and unfeasible arrangements for the variables combinations.

Among the combinations generated by the survey from the already filtered variables of Table 3, some of them have made up unfeasible or impossible proposals, as shown in Table 5.

	ELECTRIC VEHICLES IN SÃO PAULO CITY UNTIL 2020			
	Proposal 1	**Proposal 2**	**Proposal 3**	**Proposal 4**
Type of Vehicle	Motorcycle	Automobile	Motorcycle	Automobile
Target audience	Individual (Low-Income)		Legal Entity (Public and Private Sector)	Individual (Average-Income)
Number of Occupants		Up to 5	Up to 5	
Vehicle Cost (R$)	High (over 100.000)	Low (up to 20.000)		High (over 100.000)
Vehicle Commercialization			Renting	
Government Incentives		Available		
Vehicle Autonomy (km)	High (over 150)	High (over 150)		Low (up to 50)
Recharge Payment			Prepaid	
Recharge Pricing		Free		According to mileage
Battery Commercialization	Sale			

Table 5: Unfeasible or impossible settings for the introduction of electric vehicles in urban traffic of São Paulo City until 2020

Source: Prepared by the author

The first proposal is unfeasible because it is based on a high cost and large autonomy motorcycle for a low-income audience and there is not yet any kind of government incentive to subsidize the acquisition.

In the second proposal, it is presented a low cost model of car, however unfeasible, because it defines large capacity and large autonomy, points which are not of easy resolution in terms of technology and cost-effectiveness in the short term.

On the third option, there is the proposal of a model based on a inexistent kind of vehicle for technical issues and also because of market positioning.

At the fourth proposal, there is the cost versus autonomy issue. In that situation, the car would be commercially unfeasible because there are already solutions for greater autonomy on lower cost.

4.4 FEASIBLE POSSIBILITIES

In addition to enabling the quite clear identification of inappropriate values for the variables and of unfeasible or impossible combinations, the morphological analysis has as another major benefit the capability of generating feasible, interesting and distinguished combinations, as mentioned by Porter et al. (1991, p. 105). In Table 6 it can be seen some interesting proposals generated from the values of variables in Table 3.

	ELECTRIC VEHICLES IN SÃO PAULO CITY UNTIL 2020			
	Proposal 1	**Proposal 2**	**Proposal 3**	**Proposal 4**
Type of Vehicle	Motorcycle	Automobile	Motorcycle	Automobile
Target audience	Individual (Low-Income)	Individual (Average Income)	Pessoa Jurídica (setor público ou privado)	Individual (Average Income))
Number of Occupants	Only 1	Up to 5	Up to 2	Up to 2
Vehicle Cost (R$)	Low (up to 20.000)	Average (between 20.001 and 100.000)	Average (between 20.001 and 100.000)	Low (up to 20.000)
Vehicle Commercialization	Sale	Leasing	Renting	Sale
Government Incentives	Available	Available	Available	Available
Vehicle Autonomy (km)	Average (between 51 and 150)	High (over 150)	Average (between 51 and 150)	Average (between 51 and 150)
Recharge Payment		Pos-paid		Pre-paid
Recharge Pricing	Free	According to mileage	According to mileage	According to recharge value

Battery Commercialization	Renting	Renting	Renting	Renting

Table 6: Examples of feasible or desirable settings for the introduction of electric vehicles in the urban traffic of São Paulo City until 2020

Source: Prepared by the author

At the first proposal, an overview is given for the replacement of motorcycle with an internal combustion engine for electric motorcycles in short distances displacements – as in the small-sized regional service sector wherein the seat for the second occupant in the motorcycle would be used for cargo transportation. Such replacement of motorcycle with an internal combustion engine for electric motorcycles is desirable because, according to the Ministry of the Environment (2010, p. 19), the national cars and motorcycles fleet accounted for 83% of carbon monoxide (CO) emissions from the Brazilian automotive sector in 2009.

The fact that they do not launch gases directly to the atmosphere and because they move at slower speeds – polluting less and reducing the number and severity of traffic accidents –serves as an argument to support the government incentives granting as well as the exemption of batteries recharging pricing.

On the second proposal, there is an approach of what is emerging as a sort of standard for the adoption of electric vehicles.

Based on small to medium car in terms of size, price and autonomy and relying on a consumer audience willing to pay prices higher than those of internal combustion engine vehicles with similar characteristics, this proposal is based on the granting of direct or indirect government incentives – as occurred in the National Programme for Alcohol (Proalcohol), according to Puerto Rico (2007, p. 102) – for the acquisition of vehicles without batteries and, in most cases, through leasing.

Because it is the most expensive item on the car and because it has a different lifetime, in this proposal, the battery would be provided by companies specialized in the rental of this component, and these companies would render services through exchanging and recharging stations chains.

On the third proposal, it is taken into account the replacement of internal combustion engine motorcycles for electric motorcycles in specific niches of corporate services with higher added value – in both the public and the private sectors – where price is not the determining factor but the high quality of the vehicles is a prerequisite.

Examples of such niches are the delivery service, as mentioned by Kley, Dallinger and Lerch (2011, p. 11), the escort service or the security service in the private sector and the fleet for public safety services of municipal, state and federal power.

On the fourth proposal, there is a scene in which the owners would have the electric car as a vehicle of secondary use for displacements of short and medium distances, mostly in urban districts.

In this scenario, it would be possible the union of the battery rental services with the parking services, so that the owners did not need to keep the car at home and if they thought advisable, they could still make vehicles available for rental. Additionally, with the smart grid technologies in operation, the cars could have a second purpose which would be to work as energy storage being charged in periods of low demand and used as an energy source in times of high demand.

5 FINAL CONSIDERATIONS

Electric vehicles are a promising option for the transportation future in cities holding the characteristics of São Paulo and have gained strength worldwide given the scenario changing to fossil fuels.

In Brazil, despite the size of the automotive sector and the favorable energy matrix, the initiatives are still incipient, and the trend is that the introduction of electric vehicles in the traffic of cities occurs in a timely manner and at a speed lower than expected by experts and enthusiasts.

The method of morphological analysis proved to be an effective tool for identifying possibilities because, by implicitly taking into account the issues related to the structure of the analyzed problem, it allowed the enumeration of viable options – conventional or not – and the survey of unfeasible or unlikely configurations to be adopted in the city of São Paulo within the period proposed in this paper.

In order to make feasible the adoption of electric vehicles in Brazil, preserving the due proportions, the government should foster actions similar to those taken during the Proalcohol in terms of incentives; as for the society it must – whether in the economic or environmental perspective – push the sector players so that the production and the acquisition of electric vehicles can be achievable.

From a technological viewpoint, one of the most important aspects of electric vehicles is the fact that they are the first mobile electric charges of high power introduced into the electrical system and this feature creates the need for changes manageable only with the adoption of smart grid technologies for the fair and efficient pricing and for the effective management of supply and demand of mobile energy power.

Due to this need for more modern management tools for the electrical system, it is possible to view a much larger integration of the urban infrastructure so that in the long term, there will be the possibility of arising truly intelligent cities where the electric vehicles would be fully integrated into the electric system which, in turn, would be integrated onto other systems that make up the infrastructure of a region, thus allowing a truly dynamic urban configuration or reconfiguration based on more reliable forecasts.

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