# MULTICRITERIA MODEL: ASSISTING IN CHOOSING SUSTAINABLE VEHICLES

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**Abstract:** The objective of this paper is to propose a model to assist in the acquisition of vehicle fleets. The proposal is based on the use of vehicle characteristics such as pollutant emission levels, energy consumption, vehicle category, transmission, and motorization. Idealizing an evaluative process based on multi-criteria analysis, to help decision-making when acquiring vehicles considering several criteria. With the purpose of generating lists of vehicles that support the consumer's choice, regarding the decarbonization of fleets, contributing to the reduction of impacts resulting from gas emissions in large cities.

**Keywords:** Decarbonization, Sustainability, Vehicle.

# MODELO MULTICRITÉRIO: AUXILIANDO NA ESCOLHA DE VEÍCULOS SUSTENTÁVEIS

**Resumo:** O objetivo deste artigo é propor um modelo para auxiliar a aquisição de frotas de veículos. A proposta baseia-se em utilizar características veiculares, tais como: níveis de emissões de poluentes, consumo energético, categoria veicular, transmissão e motorização. Idealizando um processo avaliativo com base na análise multicritério, que ajude à tomada de decisões no momento da aquisição de veículos considerando vários critérios. Com a finalidade de gerar listas de veículos que apoiam a escolha do consumidor, no que tange a descarbonização de frotas, contribuindo na redução dos impactos resultantes das emissões de gases nas grandes cidades.

**Palavras-chave:** Descarbonização, sustentabilidade, veículos.

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## 1. INTRODUCTION

In large urban centers, road transport is identified as the main agent contributing to the worsening of air quality, thus promoting some of the dangers to human health [1]. In addition, it is known that road transportation has also been one of the responsible for the emission of a significant amount of greenhouse gases (GHG) [2]. Reducing the emissions of carbon dioxide ($CO_2$), responsible for the warming of the planet's surface, and nitrogen oxides ($NO_x$), responsible for the reduction of the ozone layer, generators of acid rain [3,4,5].

As a consequence, the challenge of reducing greenhouse gas emissions and promoting urban sustainability in large urban centers appears [6]. On the other hand, electric vehicle technology shows potential to contribute to decarbonization in urban centers [7]. However, there are doubts regarding the sustainability of this technology, such as the environmental impact of energy cells, whether the type of electrical energy source produced GHG, the lifetime of batteries, the high cost of vehicle acquisition and the uncertainties of the charging infrastructure [8,9]. Some authors, in parallel, present uncertainties about the eventual transition of new technologies [10].

In this context, the authors suggest that vehicle electrification in Brazil should occur late, with greater emphasis on hybrid vehicles in the short and medium term, which combine the advantages of electric motorization with internal combustion motorization. Considering that the scenarios described above may not make it feasible to engage in the purchase of electric vehicles, a possible alternative would be to emphasize characteristics in models and versions of vehicles marketed in Brazil with sustainable appeal.

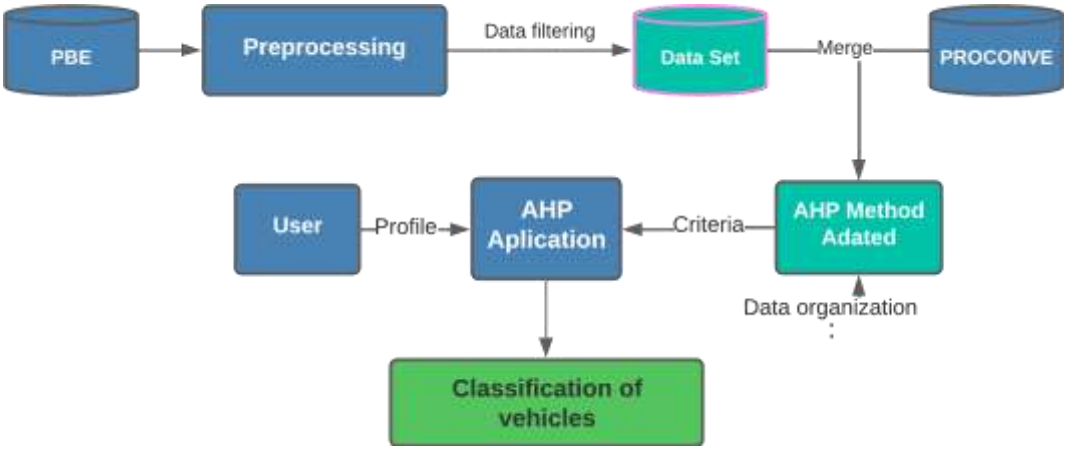
This study aims to propose an alternative process model to help Brazilian society to purchase vehicles based on more climate-oriented criteria without renouncing the desired specificities. For this purpose, multi-criteria techniques were adopted, to evaluate the Brazilian Labeling Program (PBE) vehicle database from 2013 to 2021 [11]. The proposed method generates a list ranking all alternatives, according to the defined criteria and their respective importance.

Since the acquisition of vehicles is a decision that involves several criteria, such as cost, safety, fuel consumption and environmental impact, among others. In this sense, the use of multicriteria models based on Analytic Hierarchy Process (AHP) can assist in decision making more efficiently, considering the relative importance of each criterion and its interdependencies.

## 2. METHODOLOGY

Figure 1, represents a schematic outline with the steps of the methodological process, identifying the data sources and the pre-processing of this raw data, resulting in a new dataset. In order to rank the vehicles, the AHP method was used and, at the end, a list will be obtained with the options for the consumer to choose vehicles based on more climate-oriented criteria.

Figure 1. Schematic outline




## 2.1. Data collection

The vehicle information list is a representation of the National Energy Conservation Seal (PBE) database used for all vehicles sold in Brazil. This database provides information such as vehicle model, category, engine configuration, fuel type, energy efficiency, pollutant emission, and other information [12].

The emission of the range of pollutants represents the Brazilian Vehicle Emission Control Program (PROCONVE), Brazilian Law No. 13,755/2018. Its objectives include the reduction of pollutant emission levels by motor vehicles to meet Air Quality Standards, especially in urban centers. PROCONVE standards are based on the United States of America (USA) and European Union (EU) standards for regulating emission vehicles [13].

## 2.2. Data preprocessing

In this step, the PBE and licensing databases were linked. The licensing data for the period are provided by the National Association of Motor Vehicle Manufacturers (ANFAVEA). Table 1 the number of licenses per vehicle group. A new dataset, formed by year, category, manufacturer, model, version, engine, transmission, fuel, NMHC Emissions, $CO_2$ Emissions, $NO_x$ Emissions, CO Emissions, and energy consumption.

Table 1. Number of the Brazilian fleet of licensed vehicles, adapted [14].

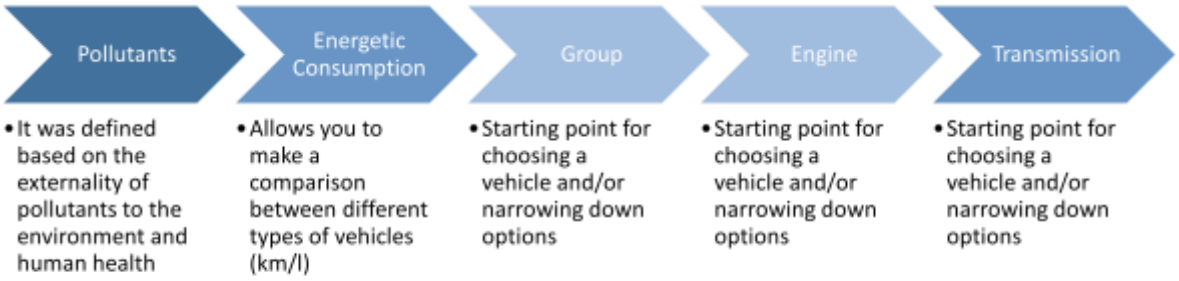
| Year | Number of light vehicles | Number of light commercial vehicles | Number of trucks | Number of buses | Total de Vehicles |
|---|---|---|---|---|---|
| **2013** | 3,040,783 | 539,113 | 154,576 | 32,898 | 3,767,370 |
| **2014** | 2,794,687 | 538,796 | 137,055 | 27,474 | 3,498,012 |
| **2015** | 2,123,009 | 357,523 | 71,652 | 16,792 | 2,568,976 |
| **2016** | 1,688,289 | 300,307 | 50,560 | 11,161 | 2,050,317 |

| | | | | | |
|---|---|---|---|---|---|
| **2017** | 1,856,580 | 319,404 | 51,943 | 11,755 | 2,239,682 |
| **2018** | 2,102,114 | 373,224 | 76,005 | 15,081 | 2,566,424 |
| **2019** | 2,262,073 | 403,510 | 101,335 | 20,932 | 2,787,850 |
| **2020** | 1,615,942 | 338,877 | 89,678 | 13,940 | 2,058,437 |
| **2021** | 1,558,467 | 418,643 | 128,679 | 14,062 | 2,119,851 |

## 2.3. Data Organization

The objective of this step is to structure the parameters to be used in the multicriteria analysis method step. For this, it was necessary to define the criteria and the arguments that prove/justify their parameters. Figure 2 shows the defined criteria and parameters. It can be observed that the analysis cannot be based on a single criterion, because with only one or two criteria there is a tendency to rank the vehicles.

Figure 2. Details of the criteria



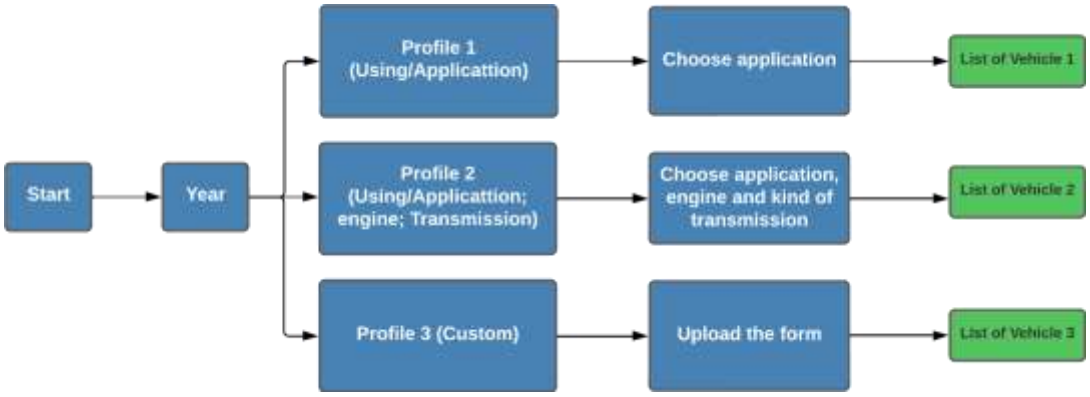

The option used to define the parameters of the emission sub-criteria was to evaluate each pollutant gas individually, as each one has different effects. As the PBE table provides quantitative information on gases and energy consumption, the option chosen to define the sub-criteria was to distribute this information equally in homogeneous groups. Regarding the vehicle categories, the option chosen was to propose a new classification, five groups, considering the similarities, since there is a high number of categories. Regarding the analysis of engines, the option chosen was to propose a new classification into five groups based on the number of engine displacements.

## 2.4. Setting up the algorithm

To develop the algorithm, the entire structure defined by the previous items was respected. In addition, it was defined as a strategy that the classification was generated from few inputs and that these inputs were essential to satisfy the user's needs, making it possible to generate a list of vehicles according to their preferences, without prejudice to the technical analysis.

As a result, three profiles were created to represent user preferences. The first profile was developed to be used to assist in the selection of vehicles based solely on their use or application. The second profile was developed to be used to assist in the selection of vehicles based on their use or application, engine preference, transmission type. The third profile was developed to be used to assist in the selection of vehicles based on all the elements addressed by this analysis. To assist in the development of the algorithm, a flow diagram was constructed to assist in the algorithm construction, as shown in Figure 3.

Figure 3. User flow diagram




### 2.4.1. Memory of calculation

In running the computer simulation, it was necessary to establish values for all the relationships and, consequently, the parameter weights in order to carry out the analysis, and, when defining their value, we sought to respect the conditions and arguments brought to validate the analysis, thus highlighting a limitation of this analysis. For this work, values were defined which can be reviewed.

### 2.4.2. Profile construction

In performing the computer simulation, it was necessary to establish the profile settings to represent the most diverse combinations of user preferences, since the values adopted to perform the analysis were defined. For this, it was defined that some parameter values are constant and others are variable, because from a few inputs and that these inputs were something essential to satisfy the user's needs it was possible to generate a list of vehicles, which highlights the differences between the versions and those with a more sustainable set of characteristics have the best positions.

To propagate the analysis, a resource called profile was used to represent the most diverse combinations of user preferences. As a way of evaluating environmental aspects of vehicle models and versions, reconciling with individual technical specificities desired by the consumer, without the need for extensive understanding of the subject, it was defined that some parameter values were considered constant and others variable.

## 3. RESULTS AND DISCUSSION

Considering the context of promoting vehicle choice, it is evident that the way in which data is offered to consumers fails to make it clear to the consumer what they are buying. To overcome this situation, this work sought to develop a multi-criteria conceptual model, which allowed to evaluate environmental aspects of models and versions of vehicles, reconciling with individual technical specificities desired by the consumer. One of the results was the generation of a ranking of vehicles, which highlights the differences between versions and those with a more sustainable set of characteristics have the best positions, stimulating their purchase. This analysis can be used by a consumer or manager of a fleet of light vehicles to assist in the choice process, especially given the moment when there is a worldwide concern about climate change and the development of a new generation of electric cars.

However, this work has the limitations of being set in Brazil, the time cut of the research and the simplification of some elements. In the following sections, the results obtained and the discussion of the research are presented.

Furthermore, in order to perform the computer simulation, it was necessary to establish values for all the relationships and, consequently, the weights of the parameters to perform the analysis, and, when defining their value, we sought to respect the conditions to validate the analysis, thus highlighting a limitation of this one. The values used for the analysis are described in item 2.4, however, if necessary, these values can be changed.

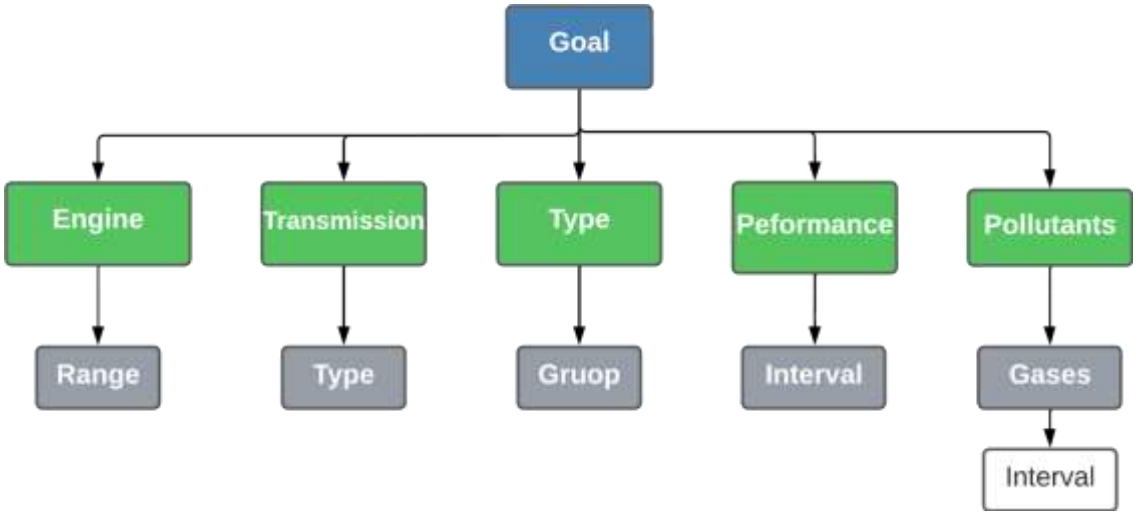
### 3.1. Results obtained

After collecting the data and information on the subject and analyzing them, the results obtained from this conceptual model were:

- Hierarchy;
- Own tables;
- Computer language.

As shown in Figure 4, the hierarchy of the problem establishes how the theme was broken down, showing the parameters that make it up and at what level each item is located.

Figure 4. Graphical Representation of the Hierarchy




In Figure 4, Level 1 (in blue color) represents the target of the study, Level 2 (in green color) informs which were the criteria of this analysis, Level 3 (in gray color) were the Sub-criteria of each criterion, Level 4 (in white color) discloses which were the Sub-sub-criteria of the Emissions criteria.

About the tables developed, in addition to describing the score adopted, it highlights how the organization of the data occurred and also brings two types of consumer profiles to be able to generate a classification based on their options.

Using the computational language, a classification of the vehicles was generated and when analyzing the results and comparing with the classification provided by the PBE, it was found that there were differences between the classifications. The reason for this was the fact that the PBE classifies the versions considering the same parameter, in this case energy consumption, in two conditions: the relative, when comparing vehicles of the same category and the absolute, when comparing vehicles of the same year. However, this comparison classifies in class, not informing the position. The proposed method, in addition to evaluating several criteria, at the end brings the position of each version, thus highlighting the differences between them.

At the end of the analysis, it was possible through the developed multi criteria conceptual model to indicate the order of the most sustainable versions.

### 3.2. Discussion

Through this work it was possible to identify the main elements, determine the relationships between them, through estimates and with the help of AHP quantify their importance, where this process was demonstrated in item 2.3. and the values were demonstrated. Thus, a multi-criteria conceptual model was established that assists decision making at the time of vehicle acquisition considering a set of pre-established criteria. The results suggest that, through a vehicle ranking list, consumers have information about the most sustainable vehicle models and versions. Where, those with a set of more sustainable characteristics have the best positions, thus stimulating their purchase, mitigating externalities and decarbonizing the fleet.

As this paper takes place in the Brazilian market, the vehicles are evaluated according to the Brazilian legislation, but with few adjustments the methodology can be used in other markets, since the analyzed vehicle data are informed and disclosed by several regulatory agencies that ensure vehicle compliance, except for vehicle categories.

Regarding the methodology developed, it stimulates actions to disseminate information about the most sustainable vehicle models and versions, because from this the most diverse consumers understand how the change of model or version affects the classification of vehicles, highlighting the differences between them. Something that was not highlighted by the PBE, because it only evaluates the energy consumption of vehicles.

## 4. CONCLUSION

This work proposes the development of a structured multi-criteria decision-making method, mainly to help fleet managers choose vehicle options based on their preferences. The method creates vehicle classification lists based on information available from processed databases and classifies them according to consumer preferences and respecting vehicle characteristics. The main contribution of the research is to provide information is to provide information on vehicles, so that it becomes more accessible to the consumer to know which vehicles are the most suitable for a given use and/or condition, based on a pre-established technical analysis.

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