# Statistical Study of Eco-Efficiency in Compact and Average Cars (Chevrolet, Ford, VW, Fiat, Renault) in Brazil Based on the Metro Table in 2019

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**This article aimed to identify the most efficient and ecological car models. Based on the analysis of cars classified as "light vehicles" in 2019 by INMETRO data in Brazil. A program in C helped analyze the frequency distribution of the variables of $CO_2$ emission and mileage per liter, allowing us to evaluate the efficiency of the compact and medium models of the "light" class. At the end of the study, there was an emphasis on the eco-efficiency of the vehicle assemblers Fiat and Renault.**

**Keywords: INMETRO. Program in C. $CO_2$ Emission. Eco-Efficiency. Vehicle Assemblers.**

## Introduction

The environment and sustainability are themes widely discussed nowadays. In that regard, the discussion about the use of fossil fuels becomes relevant to the current reality. Major international bodies and nations around the globe, like Germany, are already alert to the weakening of this market in the long term since they depend on finite and polluting resources. On the other hand, using electric vehicles has become popular, and great business people like Elon Musk have increasingly invested in the area.

Bringing this discussion to the Brazilian scenario, replacing vehicles powered by fossil fuels with electric cars is still a distant reality. The need for more public policy and government relaxation in the face of environmental problems, for example, delay the adoption of this international trend by decades. According to the Greenhouse Gas Emission System, in 2019, Brazil emitted more than 2 billion tons of $CO_2$ into the atmosphere.

That number could be reduced by using green technologies in vehicles [1]. With that in mind and the reading of the article "*Carros menos poluidores e Mais econômicos, escolha*" by João Mesquita [2], the team came up with the conclusion that it is possible to determine which vehicles are running in the national territory can be considered more "ecological". Therefore, the INMETRO's [3] light vehicle table, with manufactured automobiles and their configurations, was essential for the execution of this study. Furthermore, the data collected was used to continue the primary research, generating tables and statistical figures about which brands, engines, and cars show better results in the face of sustainability.

Many discoveries were made in the development of this article, going even beyond what had been planned. The in-depth analysis proved efficient and brought curious information about the automakers operating in the country. The conclusions will be discussed in this document, supported by the data collected, and available for consultation.

## Materials and Methods

In the Methos, an audit trail was initially carried out, where two Renault models that did not fit the data standards were excluded from the analysis. After processing the data, the team created a program in C, taking advantage of their knowledge of Computer Engineering and

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gathering data more reliably. We used concepts learned in the classroom and mathematical models to add class, amplitude, and types of frequency to these values.

In the Methods, the type of study, site, population (in case of field research), period, technique, and data analysis, as well as ethical standards followed (in case of human research), should be explained. In short, describe all the method(s) used to perform the study.

The code can be explained. First, the user is asked to impute the number of elements or terms he will work with (n). The entire program used this integer value, from which the class number calculation is generated, which is also an integer. After obtaining the class, the user is asked to put all the values that can be decimals, ending with the number zero. Then these numbers are put into a vector (A variable that has a specific number of empty spaces that can store multiple values). Working with vectors, we can make calculations and comparisons for all numbers and generate tables with a large amount of data without much effort. The Figures present some steps of this creation. An example is where the program compares three vectors that have all the values(n) and the two that delimit the beginning and end of each class, adding one more to "phi", which determines the absolute frequency value in each class.

This program evaluates the question related to the proximity of the amplitude. One of the formulas used in statistics to verify if the amplitude is correct to aggregate all classes is that we must add 1 to the amplitude if the product between the number of classes and the value of amplitude added to the number of the smallest value is less than the most significant value.

We generated a standardized table with the final result of obtaining data for one of the tables, in the code, with the approximation of one decimal place based on the output formatting. This table only needs to be copied to Excel without the necessity to do any calculations by hand or format the program's cells with different formulas.

## Results and Discussion

The following statistical step was the presentation of the data. We used "pseudo tables" created previously by programming in compilers to generate the frequency tables of the $CO_2$ emission of the Compact and Medium cars and their respective mileage per liter in the Chevrolet, Ford, VW, Fiat, and Renault brands (Tables 1-4). These were useful in allowing a more excellent perception of group discussion and the creation of the figures illustrated in this article.

### Data Presentation and Debates

The boxplot model chart was chosen based on the team's previous knowledge acquired in class and on the recommendation of teachers Aloísio Santos and Roberto Coelho. This model allowed for better analysis and more accurate conclusions from the data collected. Also, the model presents central tendency and dispersion measures clearly and precisely [4]. Figures 1 and 2 present the results of the graphs.

The graphs' analysis was obtained by verifying data from the tables of the National Institute of Metrology, Quality and Technology (INMETRO) and the Brazilian Labeling Program (PBE). We conclude that through the graph of fossil $CO_2$ emission (g/km) in compact cars of the brands: Chevrolet, Ford, VW, Fiat, and Renault in 2019. The Chevrolet cars automaker have the lowest average of fossil $CO_2$ emission (g/km), but the automaker that has the car with the lowest emission rate is Fiat, which also has the car with the second-highest emission rate analyzed. On the other hand, Renault has the car with the highest emission rate, in addition to having the highest average emission in its cars, among the analyzed automakers. When examining the same compact cars, this time by the mileage per liter graph in cars that use diesel or gasoline in the city, the automaker Renault has the cars with the highest and lowest mileage per liter of all the analyzed cars, revealing a trend of extreme variance. While the Chevrolet automaker's

**Table 1.** Frequency distribution of $CO_2$ emission (g/km) in compact cars of the brands: Chevrolet, Ford, VW, Fiat, and Renault.

| g/km | Frequency | Cumulative frequency | fri. | Fri. |
|---|---|---|---|---|
| 90 |— 97 | 8 | 8 | 19.51% | 19.51% |
| 97 |— 104 | 13 | 21 | 19.51% | 51.22% |
| 104 |— 111 | 14 | 35 | 34.15% | 85.37% |
| 111 |— 118 | 3 | 38 | 7.32% | 92.68% |
| 118 |— 125 | 2 | 40 | 4.88% | 97.56% |
| 125 |— 132 | 1 | 41 | 2.44% | 100% |
| - | 41 | - | 100% | - |

**Table 2.** Frequency distribution of $CO_2$ emission (g/km) in medium cars of the brands: Chevrolet, Ford, VW, Fiat, and Renault.

| km/L | Frequency | Cumulative frequency | fri | Fri. |
|---|---|---|---|---|
| 91 |— 99 | 14 | 14 | 26.92% | 26.92% |
| 99 |— 107 | 16 | 30 | 30.77% | 57.69% |
| 107 |— 115 | 17 | 47 | 32.69% | 90.38% |
| 115 |— 123 | 3 | 50 | 5.77% | 96.15% |
| 123 |— 131 | 1 | 51 | 1.92% | 98.08% |
| 131 |— 139 | 0 | 51 | 0% | 98.08% |
| 139 |— 147 | 1 | 52 | 1.92% | 100% |
| - | 52 | - | 100% | - |

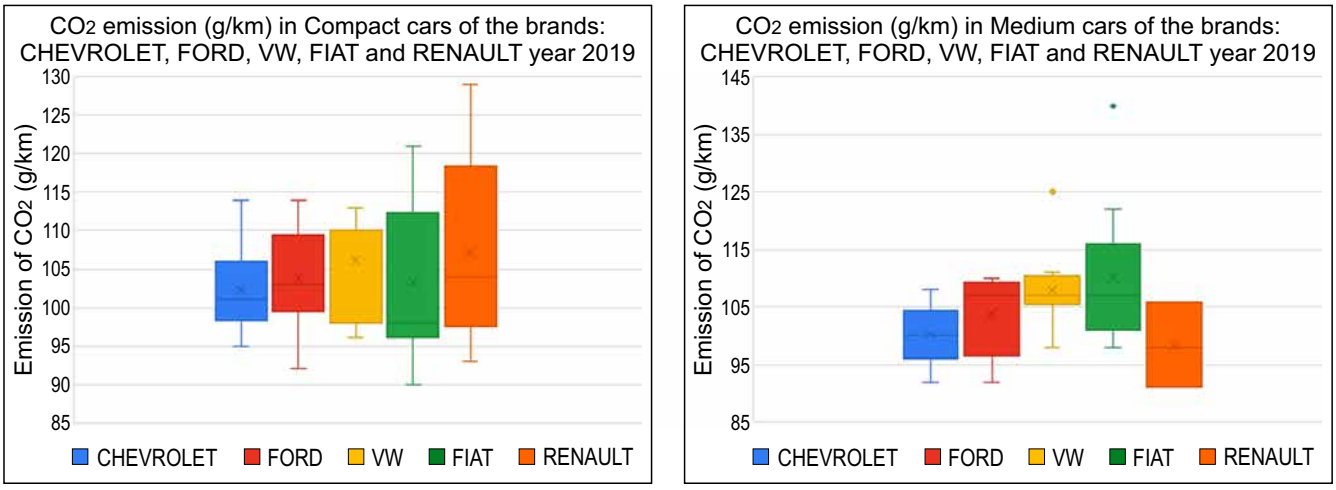
**Table 3.** Frequency distribution of km per liter in compact cars from brands that use diesel or gasoline in the city: Chevrolet, Ford, VW, Fiat, and Renault.

| km/L | Frequency | Cumulative frequency | fri | Fri. |
|---|---|---|---|---|
| 9.90 |— 10.72 | 4 | 4 | 9.76% | 9.76% |
| 10.72 |— 11.53 | 10 | 14 | 24.39% | 34.15% |
| 11.53 |— 12.35 | 9 | 23 | 21.95% | 56.10% |
| 12.35 |— 13.17 | 14 | 37 | 34.15% | 90.24% |
| 13.17 |— 13.98 | 2 | 39 | 4.88% | 95.12% |
| 13.98 |— 14.80 | 2 | 41 | 4.88% | 100% |
| - | 41 | - | 100% | - |

**Table 4.** Frequency distribution of $CO_2$ emission (g/km) in Medium cars of the brands: Chevrolet, Ford, VW, Fiat, and Renault.

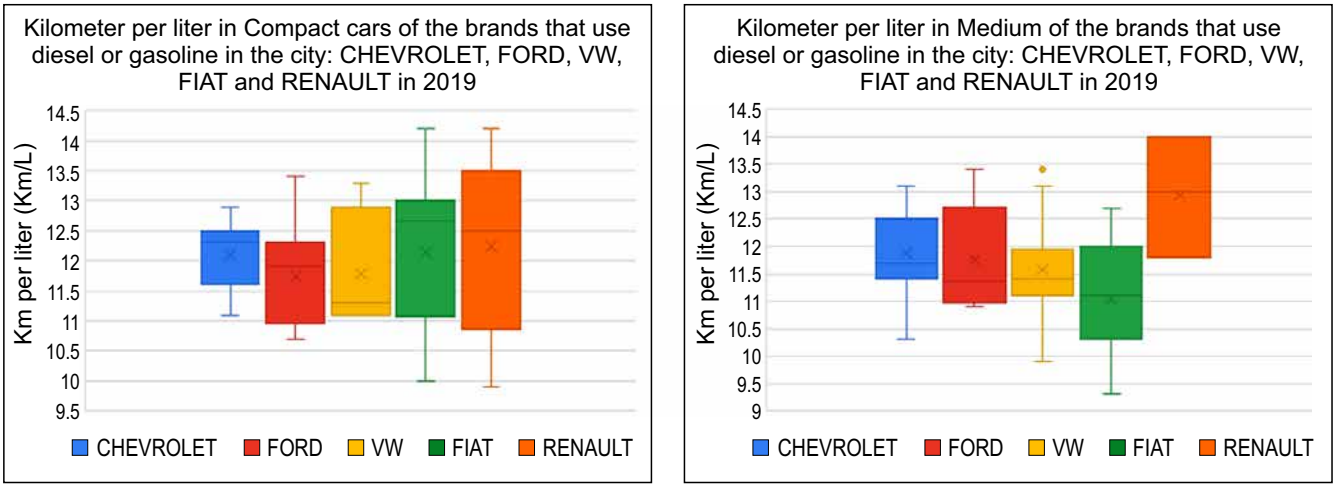
| g/km | Frequency | Cumulative frequency | fri | Fri. |
|---|---|---|---|---|
| 9.30 \|— 10.07 | 2 | 2 | 3.85 % | 3.85 % |
| 10.07 \|— 10.84 | 6 | 8 | 11.54% | 15.38% |
| 10.84 \|— 11.61 | 19 | 27 | 36.54% | 51.92% |
| 11.61 \|— 12.39 | 10 | 37 | 19.23% | 71.15% |
| 12.39 \|— 13.16 | 12 | 49 | 23.08% | 94.23% |
| 13.16 \|— 13.93 | 2 | 51 | 3.85% | 98.08% |
| 13.93 \|— 14.70 | 1 | 52 | 1.92% | 100% |
| - | - | 52 | - | 100% |

**Figure 1.** Boxplots statistical charts $CO_2$ emission.




Source: Personal file created from INMETRO data year 2019.

**Figure 2.** Boxplots statistical charts kilometer per liter consumed.




Source: Personal file created from INMETRO data year 2019.

cars present a constant with average values, not presenting more economical cars or expensive cars.

However, when looking at the values of the fossil $CO_2$ emission graph (g/km) in average cars of the brands: Chevrolet, Ford, VW, Fiat, and Renault of the year 2019, the automaker Renault shows a predominance of cars that emit a low rate. of fossil $CO_2$ (g/km), while Fiat cars are the ones with the highest emission rates, among those analyzed, even showing cars that are significantly out of the curve. In congruence with the emission of fossil $CO_2$, the automakers that present a lower emission rate in their cars also present a higher mileage per liter in the city: like Renault, which has a predominance of more kilometers traveled per liter in its cars. Among the automaker, Fiat has the least economical cars of all the automakers analyzed.

Interpretation Measures of Central Tendency and Degree of Dispersion

One of the final steps of the research was to explore measures of central tendency and measures of dispersion. The expression of the arithmetic means of the classes in the frequency tables was used to produce the graphs, generating data on $CO_2$ emission and kilometers traveled per liter of Chevrolet, Fiat, Ford, and VW cars, in the compact and medium categories to obtain the averages totals, reaching the limits in the scatterplots. The equation has been adapted so that $\overline{x}_i$ is equal to Midpoint, $f_i$ is equal to Absolute Frequency, and n is equal to the number of medium or compact cars.

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n}(\overline{X_i} \cdot f_i) \quad (1)$$

Scatterplots, widely used in statistics, are based on graphically representing an association of different measures for further analysis to find a connection between the data. For example, the same graphs might help obtain a possible answer to the initial question about the relationship between the kilometers per liter and the $CO_2$ emission of the automakers' vehicles in 2019. It was also possible to compare the disparities between compact and medium models by placing the data side by side.

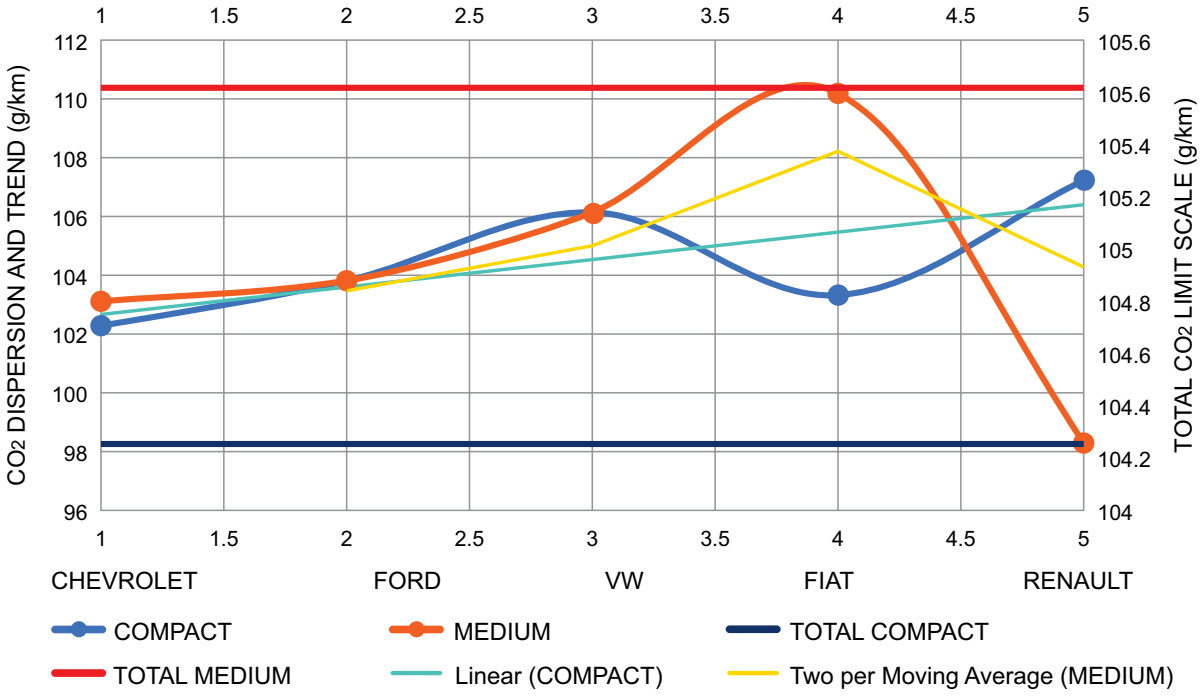
The scatterplots showed the averages for each automaker, with the orange line referring to compact cars and the yellow line the tendency per average moving, the light blue line and the green line are the averages among medium cars, and it is a Linear trend (Figures 3 and 4). In addition, an overall average was included in the graphs to improve the visualization of which vehicle assembles are the most eco-friendly.

We observed that among compact cars, the automaker FIAT has the most financially economical example, the ARGO model, DRIVE version, which runs 14.2(km/L) in the city, and it is also the car that emits less $CO_2$ fossil(g/km). On the other hand, as for the medium-sized cars, the most economical is the Renault, model Logan, Authentique / Expression version, which runs 14(km/L) in the city, and is also the one that emits less $CO_2$ fossil(g/km). With these observed data, it becomes clear that if someone is aiming to buy an economical way to transit in a city and at the same time pollute less, compact cars are a better option than medium cars.

## Conclusion

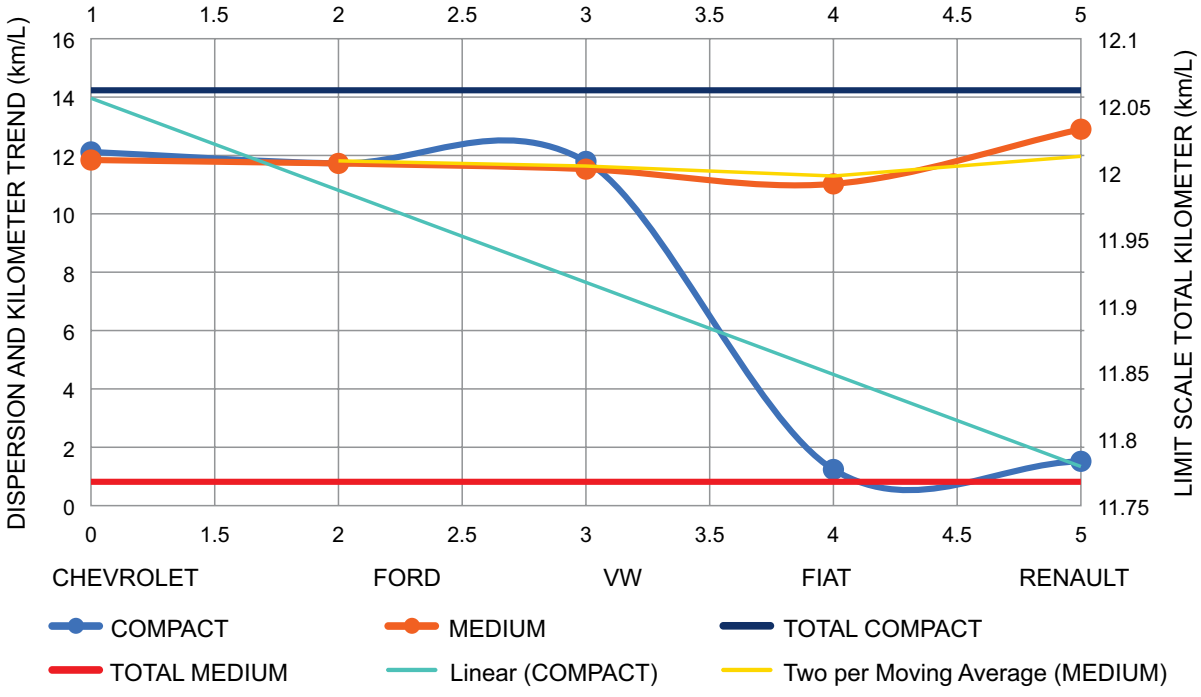
In short, through research and analysis of the car proficiency study, it became possible to: raise frequency tables; analyze central and dispersion measures; generate different statistical structures, such as Boxplot and dispersion measurement graphs, through data provided by the National Institute of Metrology, Quality, and Technology (INMETRO), and together with the knowledge acquired in the classes, it was also possible to carry out an audit trail, facilitating the analysis of defects, which made it possible to discuss the results closer to reality. Finally, there is the possibility of using the knowledge in statistics added to the knowledge of programming, which is highly studied in Computer Engineering, serving in this way to optimize the works with large numbers of data, as the works in "BIG DATA" in the technology area portrayed.

**Figure 3.** Dispersion measures in fossil $CO_2$ emission (g/km) between compact and medium cars in each brand:.Chevrolet, Ford, VW, Fiat, and Renault.




Source: Personal file created from INMETRO data year 2019.

**Figure 4.** Dispersion measures of diesel/gasoline (km/L)by medium cars of each brand:.Chevrolet, Ford, VW, Fiat, and Renault.




Source: Personal file created from INMETRO data year 2019.

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