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# ANALYSIS OF THE FEASIBILITY OF CONTROLLED AND PROGRAMMABLE ACCELERATION OF ELECTRIC VEHICLES

**Fabio Vaz**
**Diego Alves de Miranda**
University of the Region of Joinville – UNIVILLE, Norberto Eduardo Weihermann, 230 - São Bento do Sul - SC.
fabiovaz@arateck.com, diegoalves_klx@hotmail.com

***Abstract:*** *Unnecessary expenditure on electricity has directly impacted higher vehicle costs. However, with the advancement of technology, automated systems were being inserted into people's daily lives, in order to reduce unnecessary costs and thus making it possible to manage, monitor and reduce these expenses. In this premise, the purpose of this work is to analyze the energy expenditure of the prototype vehicle for Energy Efficiency competition used by the UNIVILLE campus São Bento do Sul team, using an Arduino microcontroller, in the automatic acceleration system. In order to increase the vehicle's autonomy, tests were carried out in several speed ranges to verify the average consumption with automatic acceleration compared to manual acceleration. The tests carried out showed that the automation of the prototype vehicle is 5.52% more effective than manual acceleration. The tests carried out contributed to the improvement of electronic systems, encouraging the improvement of new studies and development of new technologies for the automation of manual systems.*
***Keywords:*** *Automation, Electric Vehicle, Arduino, Automatic Acceleration.*

## 1. INTRODUCTION

According to Lopes (2012), technological evolution provides the use of tools equally with the increased analysis potential of the simulatory resource. This allows the input of computational programming, which enables the evaluation of a proposed solution to define the system parameters reaching the requested objectives (PLINTA & KRAJČOVIČ, 2016). The advancement of technology in the means of generating and transforming electrical energy has been promising for a long time, especially with regard to electric propulsion for vehicles of this medium (NOCE, 2009). Among the benefits of using an electric vehicle is the reduction of waste that acts on environmental pollution. Antunes (2018) states that despite the use of different energy sources, such as thermoelectric plants, the emission of pollutants is concentrated only in the generating source.

In another approach, it is clear that the evolution of computer systems is always requiring means to promote the reduction of excessive consumption of energy generated by electronic equipment. This encourages the conscious use of computational resources, acting directly on environmental preservation and cost reduction in IT infrastructure (Information Technology), being the main characteristic to try to repair and calibrate this consumption (SILVA, BRITO & FILHO, 2012).

Within the scope of migration of the energy matrix, the autonomy of electric vehicles is also relevant in terms of sustainability. The technology employed in this environment is one of the examples of incentives, in addition to safety, resistance and comfort, for studies of autonomous vehicles. According to Souza and Pereira (2019), these types of specific vehicles can operate independently of a pilot, using integrated and synchronized technological equipment.

Faller and Junior (2019) reported that there is a significant increase in the launch of electric vehicles in Brazil, as a result, manufacturers of brands with great emphasis on the market are in a race to present a position in this niche, which has been proving to be very profitable. Kmiecik (2020) explains that autonomous driving is already a reality, after some stages of automation, vehicles needed less and less pilot action.

In this context, this work aims to analyze and compare the energy efficiency gain of the electric prototype vehicle of the Univille energy efficiency competition, comparing consumption with manual and programmable acceleration. The vehicle contains a 350W motor and a 36V, 16A lithium battery. An Arduino microcontroller was used, which acted in the process of accelerating the car automatically and programmably, where the vehicle executed predetermined routes. Consumption information was collected to compare and validate the study objective in question.

## 2. METHODOLOGY

The automation of the electric car had as its main purpose to reduce the consumption of electricity, as according to Baran (2012), one of the main points raised in relation to electric vehicles is autonomy in the second year. This premise served as the basis for this study to try to reduce too much energy, where the use of the Arduino micro-controller emerged as a proposed solution.

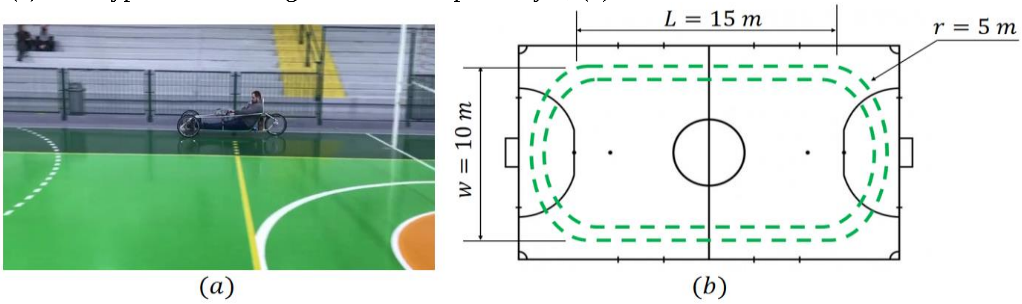
### 2.1. Project Features

The method used to analyze the efficiency of the implementation of the automatic acceleration system is done by measuring the energy consumption of the battery using a wattmeter unit measured in (Watt/h). Figure 1 shows the Wattmeter model used to collect data from the tests carried out, it is an electronic device that provides data regarding power, voltage and current.

Figure 1. Wattmeter.


The vehicle will have its consumption notes after being placed on the track, this track was created in the gymnasium of the campus of the University of the Region of Joinville – Univille. Figure 2 shows the prototype vehicle being tested in the sports gym, in order to collect data in a closed environment, due to the covid-19 pandemic.

Figure 2. (a) Prototype vehicle being tested at the Sports Gym, (b) Sketch of the course on the court.

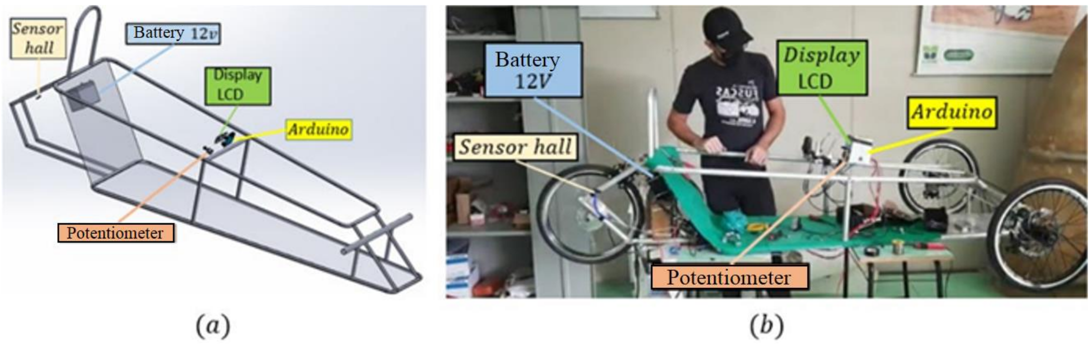



To carry out the data collection, the vehicle must travel the same number of laps, which will be 10 laps. With acceleration being performed automatically and being performed manually, within a minimum speed range of 10 (km/h) and a maximum of 15 (km/h).

### 2.2. Vehicle Design and Automation

Univille's electric vehicle, which is the subject of this study, was developed by the energy efficiency team of the University of Joinville Region - São Bento do Sul campus, between 2017 and 2021, in which it has already been the subject of some studies such as Pacheco and Miranda (2019), Weiss (2019) and Narcizo and Miranda (2019). Aiming to follow the automotive market trend of electric cars, it is a rear-wheel drive tricycle, mounted on a tubular chassis made of aluminum, designed to achieve low weight and safety for those who pilot it. The chassis was designed in CAD (Computer-aided design) software SolidWorks, which means computer-aided manufacturing, are tools used by engineers to assist in the development of projects. Figure 3 represents the developed chassis model.

Figure 3. Prototype Vehicle Design (a) CAD designs of the prototype vehicle structure. (b) Prototype vehicle assembled.

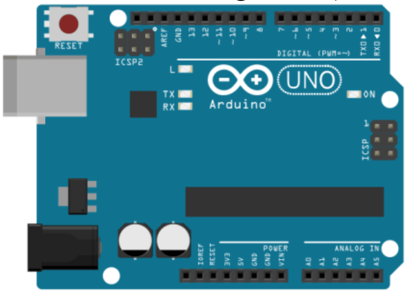



In Figure 3.a, it is possible to visualize the tubular aluminum chassis developed by the software, developed by teams from previous years of the Univille energy efficiency project, while in Figure 3.b, it is possible to visualize the assembled vehicle, with the implementation of the automation system with Arduino to carry out the consumption tests.

## 2.3. Arduino installation

The Arduino used was the Uno model, The Arduino Uno is a microcontroller board, it has 14 digital input/output pins, 6 of which can be used as PWM outputs and the other 6 analog inputs. To program it, just connect it to a computer through a USB port or turn it on with an AC/DC adapter (direct current and alternating current) or use it with battery to start. Figure 4 represents the Arduino model used for programming the automatic acceleration system.

Figure 4. Arduino Uno Atmega328P. (Monk, 2017).



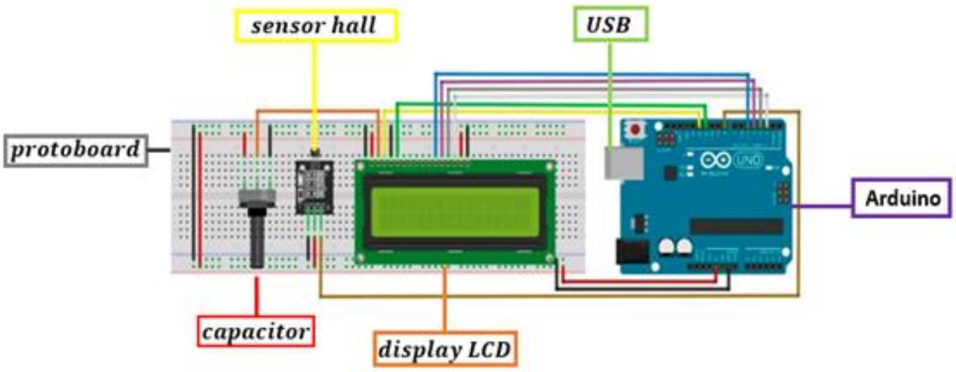
The electrical power connectors will be used to power the external boards and modules installed in the Arduino to add simple and reliable functionalities, the serial connectors will be used to carry out the communication of the components with the programming performed, the digital connection pins will be used for outputs PWM (Pulse width modulation), which will be responsible for receiving the signals from the hall sensor and the potentiometer, thereby sending a voltage signal between 0 volts and 5 volts, after data processing, for the motor to accelerate, the connector USB (Universal Serial Bus) will be responsible for making the communication of the computer program with the Arduino, that is, it will import the computer programming to the Arduino. The components used to make the prototype vehicle accelerate automatically were:

Table 1. Implemented components.

| Amount | Name | Measurements (mm) | Price (R$) |
|---|---|---|---|
| 1 | Arduino UNO Atmega 328p | 70x55x15 | 56.90 |
| 1 | Potentiometer de 10K ohm | 30x15x15 | 19.90 |
| 1 | Sensor Hall (KY-003) | 31x14x4 | 10.00 |
| 1 | Jumper Cables | 50x1x1 | 20.00 |
| 1 | Battery 12V-6A | 70x99x47 | 120.00 |
| 1 | Bicycle Speedometer Magnet | 16x12 | 27.80 |
| | | **Total** | **254.60** |

The components described in Table 1 were selected based on the need for the electric car to accelerate automatically. Figure 5 shows the installation scheme carried out on the prototype vehicle, where the hall sensor captured the wheel position through an installed magnet and from the data obtained it was possible to program the Arduino so that the time that the wheel took a turn was converted, at the speed at which the vehicle was.

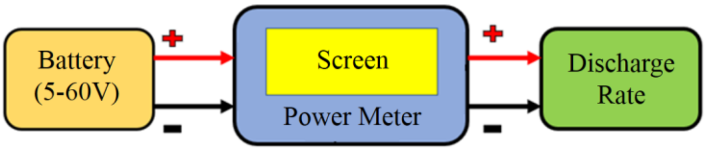
Figure 5. Electronic system installation diagram.



## 2.4. Consumption Measurement

Like the voltmeter and the ammeter, the ideal wattmeter will measure voltage without deviating any current flow, measuring current without introducing any voltage drop to its terminals. A wattmeter will be installed in the electric car, which was made available to Univille's energy efficiency project team. The installation of the wattmeter in the electrical circuit will be carried out according to data provided by manufacturers, as shown in Figure 6.

Figure 6. Wattmeter wiring diagram.




As shown in Figure 6, the positive and negative pole of the battery must be connected to the side indicated as source and the positive and negative pole of the electric motor designated as discharge load connected to the side indicated as load, generating a series connection of the device to the circuit. The energy that comes out of the battery when the accelerator is activated will pass through the wattmeter before going to the electric motor. In this way, the entire load consumed will be processed by the device, ensuring accuracy in the data provided.

## 2.5. Panel Assembly

The maximum speed that the prototype vehicle reached is 25 km/h, both in manual acceleration and automatic acceleration, speed predetermined by the manufacturer, the effective speed of the electric car starts from 2 km/h to the maximum. Figure 7 shows in the first line the speed at which the vehicle was, and the second line is represented by the speed determined by the pilot, in this case where the speed of the prototype vehicle is lower than the programmed speed, the system accelerated the engine to to reach the desired speed.

Figure 7. Dashboard of the prototype vehicle.

## 2.6. Statistical Control of Samples

With the samples to be obtained, the statistical model of the normal distribution is indicated to define the probability of the current installation for the proposed automation installation. For the construction of the Gauss chart, Equations 1 to 3 will be used. Equation 1 will be used to take the average between the collected samples.

$$\overline{C} = \frac{C_1+C_2+C_3...+C_n}{n} \quad (1)$$

For Oliveira (2017), the standard deviation is a dispersion pattern of the mean. With it, it is possible to calculate the variability between the values that will be collected, and the average between these values may contain a systematic error, in case the values differ from each other. Calculating the standard deviation of the system consumption error, the linear projection can then be calculated by:

$$\sigma = \sqrt{\frac{\Sigma(C_i-\bar{C})^2}{n-1}} \quad (2)$$

Where (Σ) represents the sum of the number of nominations minus the average number of nominations squared, $\bar{C}$ represents the arithmetic mean of the series in (km/h), $C_i$ represents the value of the series in (km/h), n means the sample size and finally the σ that represents the error in (km/h). Equation 2 demonstrates the formula used in the standard deviation calculations, where the samples taken from the Univille prototype vehicle are related, were retained from 5 consumption samples for each speed, where the same had its analysis interval between 10 km/h to 15 km/h. Table 2 shows the range of consumption measurements for each type of acceleration that will be carried out, with this it is possible to stipulate the maximum and minimum values that the tests could bring, therefore, a more assertive result can be obtained in the values analyzed in the graph consumption.

Table 2. Tests at each interval.

| **Tests** | **Manual Acceleration** | **Auto Acceleration-1** | **Auto Acceleration-2** |
|---|---|---|---|
| Velocidade (km/h) | 10, 11, 12, 13, 14, 15 | 10, 11, 12, 13, 14, 15 | 10, 11, 12, 13, 14, 15 |

## 2.7. Residential Consumption Calculation with Arduino implementation

According to Santos and Gasperini (2019), with the implementation of an automated system in a residence, it will be possible to reduce the consumption of electricity, based on the data that will be collected, energy saving calculations will be made. For the calculation of electric energy savings in automated systems, Equation 3 will be used.

$$E = C_2 - C_1 \tag{3}$$

Where E represents the savings value in (Watt/h), $C_2$ represents the energy consumption of the automated system in (Watt/h) and $C_1$ represents the energy consumption of the conventional or manual system in (Watt/h).

## 2.8. Electronic System Programming

According to Kmiecik (2020), from the programming and installation of the electronic system that will be carried out by it, the processing of the information generated and represented by the vehicle's panel, presents a good efficiency, comparing with data from a human exercise tracking application, STRAVA, it will be possible to collect and compare data for the feasibility analysis.

# 3. RESULTS AND DISCUSSIONS

The work in question analyzes systems installed in the electric car of the Univille energy efficiency project.

## 3.1. Consumption Validation

The prototype electric vehicle, according to Weiss (2018), is similar to that of a bicycle, which advocates the use of the same engine and the same model of wheels as this urban transport model. With this, it is possible to obtain comparative parameters regarding energy efficiency, analyzing Table 3 and Table 4, it is possible to identify the similarity regarding the configurations and evaluate the accumulated power between the two types of vehicles.

Table 3. Prototype vehicle consumption.

| VEHICLE | MOTOR | VEHICLE MASS | TRAVELLED DISTANCE | ACCUMULATED POWER | AVERAGE CONSUMPTION |
|---|---|---|---|---|---|
| UNIVILLE PROTOTYPE | 360 Watts 36 V | 25 kg | 9450 m | 136914 Joules - 0,038032 KWh | 248Km/KWh |

Table 3 shows the data provided by the organization of the ATEEI INVENTUM event, referring to the best result that the energy efficiency team at UNIVILLE – Campus São Bento do Sul was able to achieve. From Table 3, the total consumption is visualized based on the distance traveled. presents data from an analysis of the consumption of an electric bicycle for comparative purposes.

Table 4. Consumption of an electric bicycle.

| VEHICLE | MOTOR | VEHICLE MASS | TRAVELLED DISTANCE | ACCUMULATED POWER | AVERAGE CONSUMPTION |
|---|---|---|---|---|---|
| ELECTRIC BICYCLE | 250 Watts 36 V | 26 kg | 8020 m | 197244 Joules - 0,05479 KWh | 146 Km/KWh |

Comparing the values obtained in Tables, the prototype vehicle from UNIVILLE -Campus São Bento do Sul was approximately 69% more efficient than the electric bicycle analyzed. With these comparisons, it is possible to attest to the consumption analysis, and from that analysis to test gains or losses in relation to the automatic acceleration programs.

### 3.2. Consumption in Residences

Santos and Gasperini (2019) allow the possible proof of the reduction of energy consumption using a home automation system, from a microcontroller system, the Arduino, where in tests carried out, an initial saving of R$ 0.011828385 was noted, with a comparison made in a period of one month, this saving was approximately R$ 0.3863, a value considered very low, but the tests were carried out with only one lamp and 26 watts, for a period of 6 hours.

### 3.3. Data from Programming

Following the tests, the vehicle was subjected to an analysis of accumulated power, which was dedicated to specifying how much power was consumed by the electric motor. Table 5 presents the results of the tests. At which each speed was collected five samples of 500 m. Then, the averages were calculated by Equation 2, and the standard deviations were calculated from Equation 3.

Table 5 shows the data obtained from the tests carried out with the first programming carried out, speeds above 15km/h were not worked on, for safety reasons due to the test space not being large for speeds above this. After this first test run, we have the values in relation to the second schedule. Table 6 shows the data obtained from the tests carried out with the second programming performed. From the data obtained by Tables it is possible to compare the savings that each program will achieve by inserting the values in Equation 3.

Table 7 presents the fuel savings generated for the two evaluated schedules, where it was verified that in the first schedule the best average consumption is found at 15km/h, while in the second schedule it is noticed that the economy remained constant for 10km/h, 11km/h and 15km/h.

Table 5. Data collected from 5 samples at each speed with the first setting at 500 m.

| $U\ (km/h)$ | $\bar{C}_1\ (W/h)$ | | $\sigma\ (W/h)$ | $\bar{C}_2\ (W/h)$ | | $\sigma\ (W/h)$ |
|---|---|---|---|---|---|---|
| **10.00** | 3.58 | ± | 0.083666 | 3.34 | ± | 0.167332 |
| **11.00** | 3.70 | ± | 0.070711 | 3.50 | ± | 0.122474 |
| **12.00** | 3.94 | ± | 0.114018 | 3.68 | ± | 0.083666 |
| **13.00** | 4.12 | ± | 0.083666 | 3.96 | ± | 0.114018 |
| **14.00** | 4.38 | ± | 0.083666 | 4.10 | ± | 0.070711 |
| **15.00** | 4.86 | ± | 0.114018 | 4.48 | ± | 0.083666 |

Table 6. Data collected from 5 samples at each speed with the second schedule at 500 m.

| $U\ (km/h)$ | $\bar{C}_1\ (W/h)$ | | $\sigma\ (W/h)$ | $\bar{C}_2\ (W/h)$ | | $\sigma\ (W/h)$ |
|---|---|---|---|---|---|---|
| **10.00** | 3.58 | ± | 0.083666 | 3.38 | ± | 0.130384 |
| **11.00** | 3.70 | ± | 0.070711 | 3.50 | ± | 0.122474 |
| **12.00** | 3.94 | ± | 0.114018 | 3.84 | ± | 0.114018 |
| **13.00** | 4.12 | ± | 0.083666 | 3.94 | ± | 0.114018 |
| **14.00** | 4.38 | ± | 0.083666 | 4.22 | ± | 0.083666 |
| **15.00** | 4.86 | ± | 0.114018 | 4.66 | ± | 0.114018 |

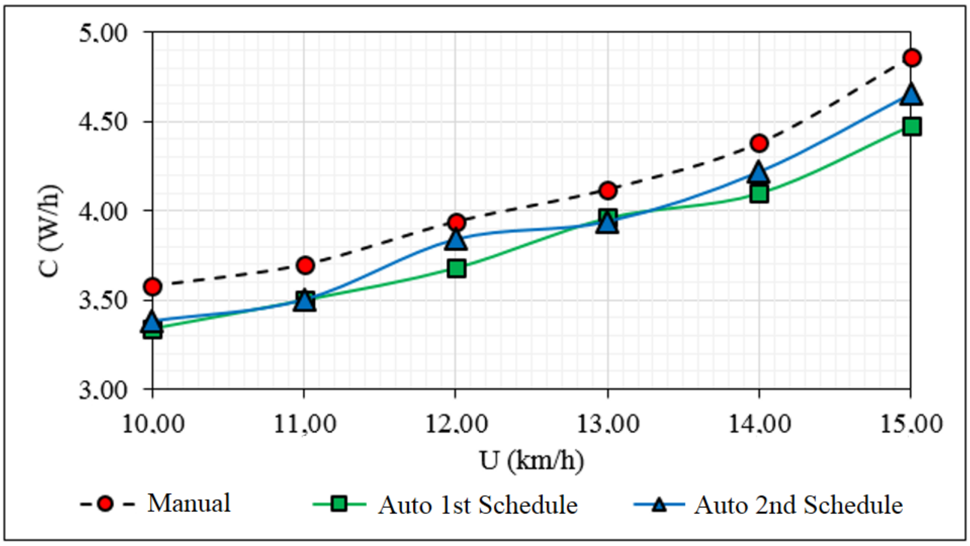
Table 7. Average consumption data comparison.

| $U\ (km/h)$ | $E\ (W/h)$ **1st Schedule** | $E\ (W/h)$ **2nd Schedule** |
|---|---|---|
| **10.00** | -0.24 | -0.20 |
| **11.00** | -0.20 | -0.20 |
| **12.00** | -0.26 | -0.10 |
| **13.00** | -0.16 | -0.18 |
| **14.00** | -0.28 | -0.16 |
| **15.00** | -0.38 | -0.20 |

From the average consumption for each configuration, it is possible to evaluate the result through a graph, where we can verify the efficiency of each type of acceleration, as shown in Figure 8, where the blue line indicates manual acceleration, the orange line indicates automatic acceleration-1 and the gray line automatic acceleration-2. energy with the automation system of the Univille prototype vehicle. With an average energy efficiency gain of 6.55% in automatic acceleration-1 and an average gain of 4.48% with automatic acceleration-2. From the obtained results, it is possible to identify a general average increase in the performance of energy efficiency of 5.52% comparing the automatic acceleration-1 and automatic acceleration-2 obtained by the prototype vehicle, result of the set of electronic components with the programs carried out.

Figure 8 shows the average consumption of each type of test, where the blue line indicates manual acceleration, the orange line indicates automatic acceleration-1 and the gray line automatic acceleration-2. energy with the automation system of the Univille prototype vehicle.

Figure 8. Average consumption.




With an average energy efficiency gain of 6.55% in automatic acceleration-1 and an average gain of 4.48% with automatic acceleration-2. From the obtained results, it is possible to identify a general average increase in the performance of energy efficiency of 5.52% comparing the automatic acceleration-1 and automatic acceleration-2 obtained by the prototype vehicle, result of the set of electronic components with the programs carried out.

## 4. CONCLUSIONS

The energy efficiency study had a very satisfactory result, as it is a low-cost project, with good functionality and handling of tests for the operation of the electronic accelerator.

From the results obtained, it was possible to validate the objective of this study, proving the effectiveness of the automation of the prototype vehicle, result of the set of electronic components with the evaluated programs. One should also consider the efficiency of the processes developed by Univille's energy efficiency team.

According to table 7, it was possible to verify that energy savings were obtained in both programs, where in all tests with manual acceleration, none resulted in lower consumption than with the automation of the prototype vehicle.

For future work, persistence in the research project is indicated regarding ways to improve the energy efficiency of the prototype vehicle, such as the search for programs that bring results with a higher level of effectiveness, as well as the automation of commands that act directly on consumption of electrical energy.

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