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Estimation of CO2 emissions in cabs with 1600 cc cylinder under efficient driving parameters in the city of Cuenca, using the ive model IVE

Estimación de emisiones de CO2 en taxis con cilindradas de 1 600 cc bajo parámetros de conducción eficiente en la ciudad de Cuenca, utilizando el modelo IVE

Orlando Alfonso Lara Medina
MSc. Instituto Superior Tecnológico Simón Bolívar, Guayaquil Ecuador , o_lara@istsb.edu.ec, https://orcid.org/0000-0003-1854-8536

Oscar Fabricio Hicaiza Yugcha
MSc. Instituto Superior Tecnológico Simón Bolívar, Guayaquil Ecuador , o_chicaiza@istsb.edu.ec, https://orcid.org/0000-0002-4170-2186

Carlos Vinicio Beltran Herrera
MSc. Instituto Superior Tecnológico Simón Bolívar, Guayaquil Ecuador , c_beltran@istsb.edu.ec, https://orcid.org/0009-0006-2274-4504

Jonathan Samuel Lozada Pilco
MSc. Instituto Superior Tecnológico Simón Bolívar, Guayaquil Ecuador , j_lozada@istsb.edu.ec, https://orcid.org/0000-0002-2407-0201

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Corresponding Author
Oscar Fabricio Hicaiza Yugcha
o_lara@istsb.edu.ec
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Abstract

Global warming is currently considered to be the main problem on a global scale, which is mainly generated by the concentration of anthropogenic greenhouse gases in the atmosphere. Transportation is responsible for approximately 25% of global CO2 emissions. Based on this reality, the literature proposes several strategies to try to mitigate the generation of these gases in the transportation sector. The results were obtained through a sample of cabs and will be instrumented with GPS and data logger equipment to obtain the parameters that feed the model.

Keywords: Newton of motion, program, arithmetic

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Resumen

En la actualidad el calentamiento global es considerado como la principal problemática de escala global, que principalmente es generada por la concentración de gases de efecto invernadero de origen antropogénico en la atmosfera. El transporte es responsable de aproximadamente el 25 % de las emisiones de CO2 globales. A partir de esta realidad la literatura plantea varias estrategias para tratar de mitigar la generación de estos gases en el sector de transporte. Los resultados se obtuvieron mediante una muestra de taxis y se instrumentarán con equipos GPS y data logger para obtener los parámetros que alimenten el modelo.

Palabras clave Newton del movimiento, programa, aritmética

Introduction

James Cook in 2013 published in the scientific journal Environmental Research Letters an article entitled "Quantifying the consensus on anthropogenic global warming in the scientific literature" where he analyzed the existing literature on climate change the consensus on the anthropogenic influence on this phenomenon, coming to determine that of 12 000 publications 97.1% point to the fact that climate change is a direct consequence of human activity and its greenhouse gas (GHG) emissions and in particular carbon dioxide (CO2) (Justin D. et al., 2016)..

In 2015, around 1.1 billion vehicles were in circulation worldwide and it is expected that by 2 025 this figure will increase to 2 billion (Justin D. et al., 2016, p. 204).. According to the international organization of automobile manufacturers the growth rate of the vehicle fleet worldwide is 4 %, as a consequence of that in 2017 reached the figure of 100 million vehicles produced in one year (OICA, 2015). In Ecuador, the rates are higher since there is a growth rate of 15.5 % per year and in 2017 it reached over 2 million registered vehicles (Baldeón, 2016).. This has resulted in Ecuador's transportation sector being the sector with the highest energy demand with about 45 million barrels of oil equivalent. (Renobable, 2019)..

For this reason, there is a need for strategies and policies that contribute to the mitigation of fossil fuel use in transportation and therefore to the reduction of GHGs. There are several strategies such as modal shift in transportation, eco-driving or carpooling and also several policies such as green taxes, vehicle traffic taxes or incentives for electric vehicles that have shown good results. (L. I. Rizzi and C. De La Maza, 2017)..

To generate a baseline of CO2 emissions, direct (directly at the tailpipe) and indirect (simulation) measurement techniques can be used. Direct measurements can be done through laboratories or on-board measurement systems (PEMS), however, the problem with these is the related costs. On the other hand, there are the indirect methods that are responsible for estimating emissions from parameters that feed mathematical models the main advantage of these measurements is that they do not incur high costs in their implementation. (Kumar, 2017)

With this background, some questions arise that must be addressed in the importance of providing partial solutions to the great problem of energy consumption and emissions from transportation, questions such as.

What is the average CO2 emissions factor for a specific fleet, by what percentage can fuel consumption and CO2 emissions be reduced through the implementation of a strategy or policy?

With respect to indirect emission estimation methods, several studies conclude that for countries complying with EURO 3 regulations, the best option is the International Emissions Model (IVE), since it adapts to these technologies, and also allows the information on driving habits to be loaded directly into the program, through the VSP Bines (Cossio, 2012).

There are several studies in countries such as China, India, Mexico, Peru, Chile, among others, in which the IVE model has been used to determine emission factors and emission inventories, as well as databases for climate control and air quality control (Davis D. et al., 2005). (Davis D. et al., 2005).

Methodology

Study area

This research was conducted in the city of Cuenca located in the center of the province of Azuay. Reporting the following data as: latitude between 2° 53' 57", temperature of 16.1 C ° and with an altitude of 2 500 meters at sea level.

Materials used

The following materials were acquired to implement the cab fleet:

ELM 327 interface

Smart Phone with TORQUE PRO application

SOTFWARE IVE

Cab fleet

The method applied was based on the review of literature on CO2 emission factor estimation models. For this activity a literature review was carried out in the databases of indexed journals of the Universidad del Azuay, the search was concentrated in the SCOPUS and DOAJ databases. Once the largest amount of literature was reviewed, the most relevant articles in reference to the estimation of CO2 emissions factors were selected. According to a preliminary literature review, the methodology used by the IVE Model was determined as one of the most appropriate for the quantification of emission factors.

Methodology selection

Based on the evaluation of the different methodologies, one of them was chosen to be applied to the local cab fleet. It is important to highlight that the previous literature review and analysis work has defined the IVE model as a relevant method for the determination of the CO2 emissions factor. The methodology was analyzed in depth. In this case, the IVE model was evaluated to understand how it works, how it is used, the characterization of the variables demanded by the model and the results delivered by the application. In order to define the model for estimating emission factors, it was necessary to have information on how the ECO-Driving efficient driving parameters were carried out. For this purpose, literature on the subject was searched and the most relevant was analyzed in order to define the driving method in the cab fleet, and in this activity the type of strategies or techniques used for the implementation of efficient driving in the established fleet was selected.

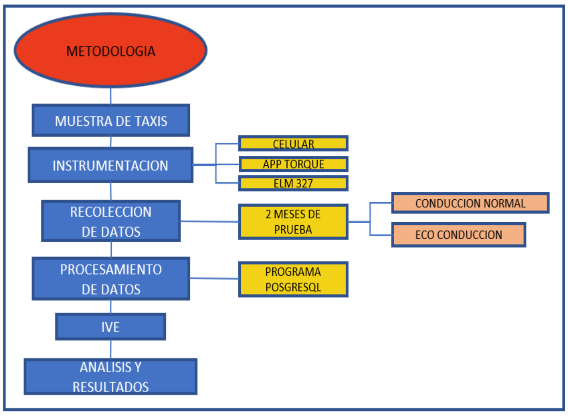

Figure 1. Process flow diagram of the methodology.

In the flowchart presented in Figure 1. Details the sequence performed in the process of the methodology developed in the research of CO_2 estimation in the cab fleet of 1600cc. With eco-driving parameters.

2.4 Techniques for the application of efficient driving.

Several techniques were applied to obtain an efficient driving of the vehicle. In this way, a decrease in fuel consumption and pollutant emissions can be evidenced.

Starting the engine without depressing the accelerator pedal, on an electronic throttle regulates the ignition conditions.

Shift gears as soon as possible, and be aware of the number of revolutions at which you are going to change gears at low revolutions. For gasoline engine vehicles, change gear before 2 500 revolutions per minute.

When shifting gears, the manner of application of the accelerator pedal must be carried out as necessary to continue the acceleration process of the vehicle.

Maintaining a uniform speed, when the vehicle is accelerated and has sudden braking, energy is lost at the time of restarting the car, the transformation of energy by propulsion results in higher fuel consumption and increased pollutant emissions. (Larrazábal, 2004)

The sample of the cab fleet to be used for the data collection was determined. For this purpose, models were established that comply with the established displacement and have the capacity to support the necessary instrumentation for the data collection. The number of cabs expected to be used is 18 vehicles (9 of 1400 cc and 9 of 1600 cc) that circulated 24 hours a day.

Vehicle fleet instrumentation

The IVE model basically uses GPS parameters. For this purpose, each cab was installed with a cell phone with the torque pro application and the ELM 327, since in this way the information from the cell phone can be stored for later processing. The advantage of having the ELM is that apart from the latitude, longitude and altitude data, it also provides information on fuel consumption, which is used to evaluate autonomy and savings.

Definition of variables that will feed the IVE model requires environmental parameters such as humidity and temperature, as well as some variables such as fuel type and composition, all these variables will be obtained from current regulations and local government information. The IVE model also included information on fleet technology and the type of maintenance of the fleet, for which information was collected from each of the vehicles involved.

To develop the road tests with the instrumentation implemented in each cab, the information will be collected during a period of two consecutive months in order to obtain as much information as possible. The logistics of storing the information for its later processing was in charge of the teacher on a weekly basis.

In order to carry out the driving tests efficiently, a training workshop was held. The drivers carried out this mode of driving in three days, so that in the second month of data collection the same process would be developed in order to collect the information from the first month; however, the second month is characterized under the parameters of efficient driving.

Information processing

The emissions estimation procedure in the IVE model consists of processing a series of correction factors that are adapted to estimate pollutants in a wide variety of cars and types of technologies.

Determine the base emissions factor recorded in the fleet input data, i.e. vehicle technology, air conditioning. Add pollution factor data by technology. In addition, the locality input data must be adjusted. Calculation by temperature, slope, vehicle maintenance, distance and location. It is advisable to make adjustments for fuel quality also important is the record of distribution of Soak driving patterns.

The emission factor data is multiplied by the curves factor by filtering correction by the distance traveled by each vehicle for each technology, this equation multiplies the base factors (B) by the series of correction factors (K) to estimate the base emission factor (Q) for each type of cab the correction factors can be recorded in several categories also depends on the value of each of the correction factors by the selected entries in the locality file in the model as indicated in (1). (Center, 2008).

$$Q[t] = B[t] * K(1)[t] * K(2)[t] * \ldots\ldots K(x)[t] \quad (1)$$

Driving patterns.

The important variables for determining driving patterns depend on the speed, acceleration and deceleration of the cab fleet, thus increasing the emissions generated by the vehicle.

The emissions caused by the vehicle is generated by a function of the power and stress of the engine present these variations that can increase CO2 emissions which is the importance of this study in applying efficient driving parameters in the cab fleet prior training of drivers. (Center, 2008, pp. 10-15)

The patterns depend on two important parameters, which are:

Vehicle Specific Power (VSP).

Engine stress.

These two parameters are obtained by determining the type of vehicle, the variables such as altitude, speed per second, if the slope is added it can be presented or assumed as zero in the equation as indicated in (2).

VSP = v[1.1 + 9.81 (atan(sin(slope)))+0.132]+0.000302v3 (2)

Where: Slope = (ht = o - ht = -1) vt =1 to o seconds

V = velocity (m/s)

a = acceleration (m/s2)

h = altitude (m)

Speed data can be collected on the fleet of cabs instrumented with location unit (GPS). Speed information is organized by congestion levels, type of roadway, time of day.

Soak starting patterns

Soak periods occur before a start occurs. In the IVE model, a start is referred to as a cold start, which means that the engine is completely cold. A cold start causes an increase in emissions because the engine has to reach its warm-up point.

Once the data collection was completed using the ELM327 device, we proceeded to the creation of a database. In the first instance, the files (SCV) were classified according to the cab from which they come, and then proceeded with a filter of empty cells or erroneous data, which was done programmatically due to the large number of files.

A database was created and stored in PostgreSQL, which is a program for advanced data support and supports a high level that optimizes good storage performance and data processing, thus an application was programmed in Matlab capable of importing, sorting the data, transforming the units if necessary and saving them in a database table. The database consists of approximately 20.5 million rows of data, each row containing vehicle identification information, date and time, GPS position, altitude and vehicle operating parameters. In this study, CO2 emissions will be analyzed in two scenarios: first, a scenario with favorable traffic conditions and second, a scenario in which there is traffic, ordered from lowest to highest.

The average velocities of each hour of data checking that they correspond to a normal distribution.

The best scenario corresponds to the first quartile of the normal distribution of the data sample there is an analysis of the 1,600 cc cab fleet by efficient driving parameters that was performed at the second month where the information process was carried out.

The worst case scenario corresponds to the third quartile of the normal distribution of the data sample. They are represented in quartiles so that the data results are close to the most realistic ones.

The speed and altitude data from the representative runs go through an outlier filter and curve smoothing before being processed for VSP bin calculation.

Figure 2 shows an example of the procedure where the filtering and smoothing of the curve was performed by determining the speed and time variables.

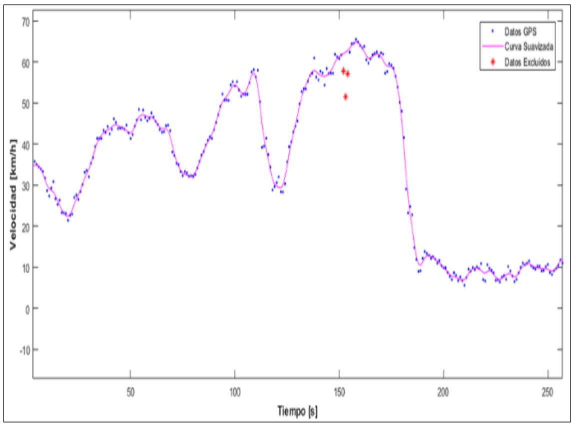

Figure 2. Filtering and smoothing of the velocity/time curve.

Figure 3. Represents the filtering and smoothing variables of the altitude and time curve, using information processed in the IVE model.

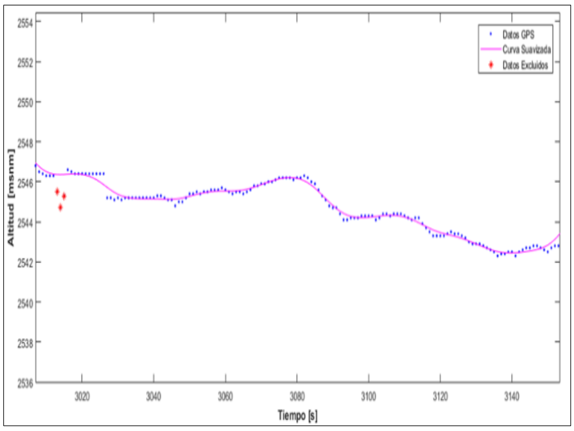

Figure 3. Filtering and smoothing of the altitude/time curve.

2.9 Calculation of CO2 emissions through efficient driving parameters.

To calculate CO2 emissions, the IVE model software was used: First the VSP bins are calculated, with the help of a tool developed at the University of Azuay, by entering information in the IVE model, the vehicle fleet corresponds to the vehicle fleet technology 127, (this is the most commonly used vehicle technology among cabs in the city), which describes a light gasoline vehicle, multipoint injection, with anti-pollution systems such as catalyst, EGR exhaust gas recirculation and PCV Carter Positive Vent Valve.

A temperature of 16.1 °C and a relative humidity of 60 % were also used, which correspond to the average record for the city. (EMOV, 2017)

For the fuel quality data, the stipulations of the Ecuadorian technical standard NTE INEN 935 were considered; this standard establishes the maximum limits for the different components of gasoline in Ecuador. The sulfur content is set at 650 ppm, the benzene content is 1 %, it does not contain lead and the oxygen content is 2.7 %. (INEN, 2016)

Cabs 1600 cc efficient driving

A sample of 1,286 data on average speeds for each hour of travel was evidenced, the distribution of data is shown in Figure 4.

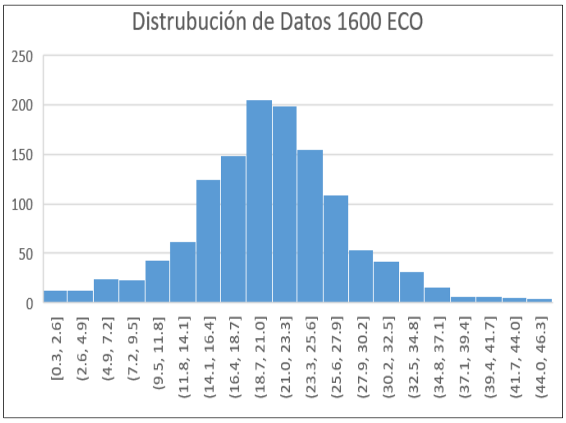

Figure 4. Distribution of average speeds of the 1600cc cab fleet by efficient driving.

The best scenario corresponds to the data recorded on July 20, 2019 between 15:00 and 16:00, in the vehicle '''Taxi-16''' consists of 3120 recorded data.

The worst-case scenario corresponds to data recorded on July 22, 2019 between 8:00 to 9:00, in the vehicle '''Taxi-16''' and consists of 3600 of recorded data.

We proceeded to calculate the VSP bins vehicle specific power shown in Figure 5. We obtained a distribution of 57% of bins of 1600cc cabs through efficient driving parameters by averaging the best and worst case scenarios obtained in the data recorded in the cab fleet.

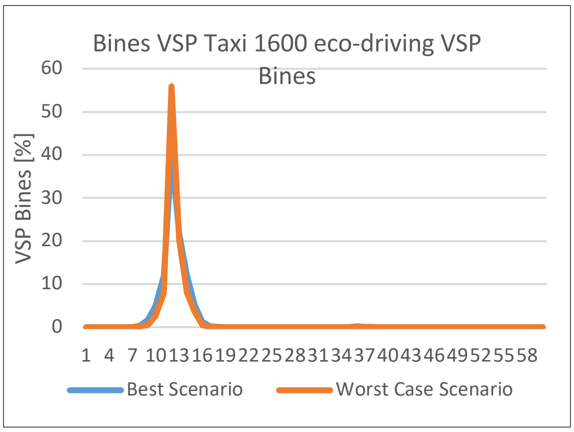

Figure 5. Distribution of VSP Bines of cab 1600 eco-driving cabs.

CO2 emission factors

Analysis: Figure 6 shows an average CO2 emissions factor in the best case scenario of approximately 220g, while the worst case scenario shows an average of 290g equivalent, so the worst case scenario increases the CO2 emissions factor.

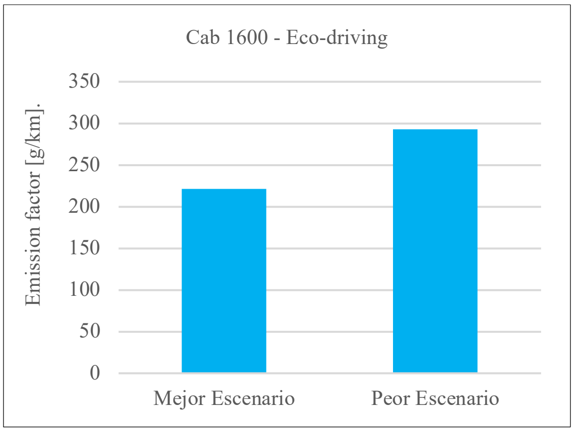

Figure 6. CO2 emission factors of 1600 cc cabs through efficient driving.

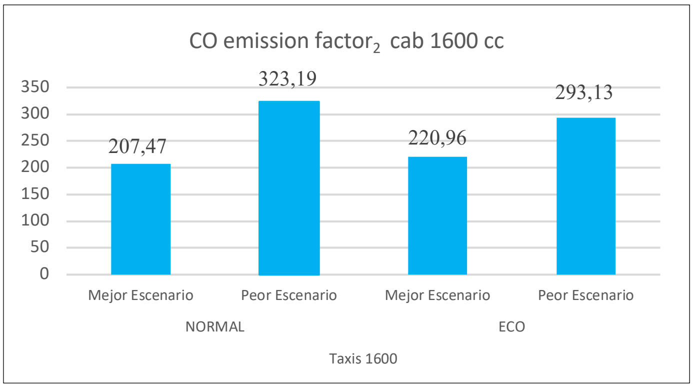

Figure 7. Comparison of CO2 emissions in normal cab driving and eco-driving.

In the comparison of CO2 emissions in cabs with normal driving and eco-driving, the following values were obtained as shown in Figure 7, where the best scenario 207.47g and the worst scenario 323.19g normal driving were analyzed, with the results in the best scenario 220.96 g, and the worst scenario 293.13g, these results were obtained through efficient driving parameters, reflecting a high value in the best scenario with eco-driving, this could be because the drivers did not apply the efficient driving techniques.

In Table 1. Demonstrates the CO2 emissions factor in grams per kilometers traveled, obtained in the best and worst scenario in normal and eco-driving tests in the 1600cc cab fleet the selected value was 293.13g scenario with higher vehicle flow.

Table 1. Results of CO2 g/km emissions factor estimation.

CO emission factor₂ [g/km].			
Cabs 1600cc			
NORMAL		ECO	
Best Scenario	Worst Case Scenario	Best Scenario	Worst Case Scenario
207.47	323.19	220.96	293.13

Results

To analyze the CO2 emissions results it is necessary to import and sort the data, transform the units if necessary and store them in a database table. The database consists of approximately 20.5 million rows of data, each row containing vehicle identification information, date and time, GPS position, altitude and vehicle operating parameters.

Analysis: The results shown in Table 1. They reflect estimates of the CO2 emissions factor in grams per kilometers traveled by the vehicle fleet, obtaining the following scenarios through efficient driving in 1600 cc cabs, the best scenario having a value of 220.96g/km of CO2 emissions and in the worst scenario a result of 293.13g/km is obtained with these results of the two scenarios can be determined averages of daily, monthly and annual estimates of CO2 emissions estimates of the vehicle fleet.

Figure 8 shows that the CO2 emissions factor levels increase significantly between the other scenarios using different modes of normal driving and efficient driving. In this way, the different calculations were made to estimate the CO2 emissions factor, observing that in the emissions results there is no variation between the driving modes. This problem was a consequence of collecting data in several cabs with several drivers, where the way of driving is not the same, in this case the driver did not correctly apply the eco-driving techniques.

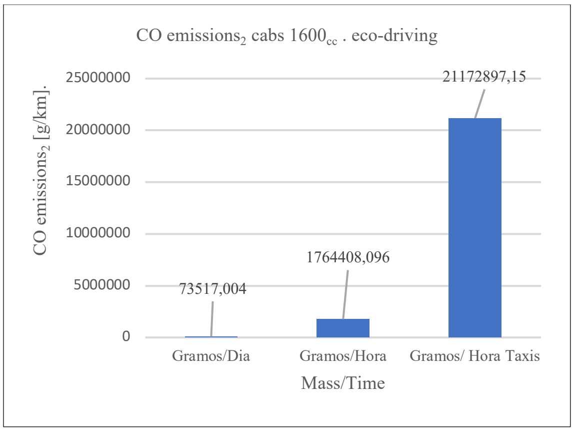

Figure 8. CO2 g/hour emissions results.

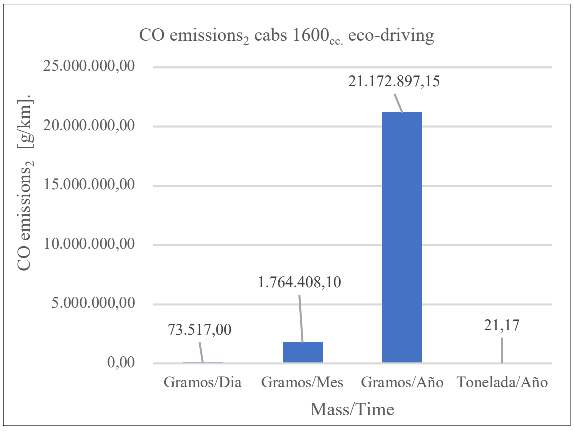

Figure 9. Average CO2 emissions estimates.

Figure 9 shows the result of CO2 emissions, taking into account the worst scenario, giving an average in the first bar 73 517g/km in one day, in the second bar in one month we have 1'764 408.10g/km in the third bar obtaining an estimated value of 21'172 897.15g/km per year, in the last bar presents an average of 21.17 tons of CO2 per year.

In these results, the average CO2 emissions were estimated by obtaining the worst-case scenario value shown in Table 1. Applied to the 1600cc cab fleet by eco-driving.

Table 2. Average calculation of estimated CO2 emissions.

Worst case scenario			
Cabs 1600cc. Eco-driving			
Total, emissions in one day [g/km].	Total emissions in one month [g/km].	Total, emissions in one year [g/km].	Total emissions in one year [t/km].
73 517,00	1'764 408,10	21'172 897,15	21,17

In Table 2, the calculation of CO2 emissions was made by averaging 73 517.00g in a day. Traveled in 250.8Km this value was calculated by the average speed of travel in an hour of 20.9 km and multiplied by an estimate of 12 hours that a cab works in the day. Obtaining an average in the month of 1'764 408.10g. In which 6 019.2 km were traveled. Having 21'172 897,15g. In a year where 72 230.4km were traveled, thus reflecting a result of 21.17 tons in the year of CO2 emissions, taking as a reference the worst case scenario in 1600cc cabs. Eco-driving.

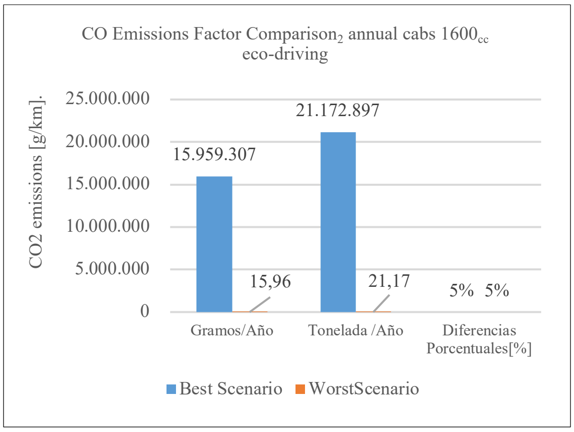

Figure 10. Comparison of CO2 emissions factor using the best and worst case scenarios.

The results obtained in Figure 10 analyze the comparison of the CO_2 emissions factor per year, reflecting in the best scenario "less vehicular traffic" 15'959,307g/km, giving a value of 15.96 tons. In the worst scenario "more vehicular traffic" the amount of 21'172.897g/km is obtained, thus having a result of 21.17t of CO_2, per year, showing a comparison of 5% between the two scenarios.

Table 3 presents the results of pollutant emissions such as carbon dioxide and carbon monoxide, these two emissions are calculated in grams. Particulate matter and nitrogen oxide are calculated in milligrams, the values reflect the worst case scenario with more traffic and the best case scenario with less vehicular flow.

Table 4. Results of fuel consumption in eco-driving cabs.

Cab 1600 eco-driving		
Fuel consumption	Worst Case Scenario	Best Scenario
Traveled consumption [l] [l	1.81	1.98
Distance [Km].	16.70	21.28
Consumption [l/100 Km].	10.83	9.28

Table 4 shows the fuel consumption in 1600cc cabs with efficient driving, the calculation was made in consumption per trip in liters, using the distance in kilometers, in addition to the consumption in liters per 100 Km. The worst case scenario was taken as a reference.

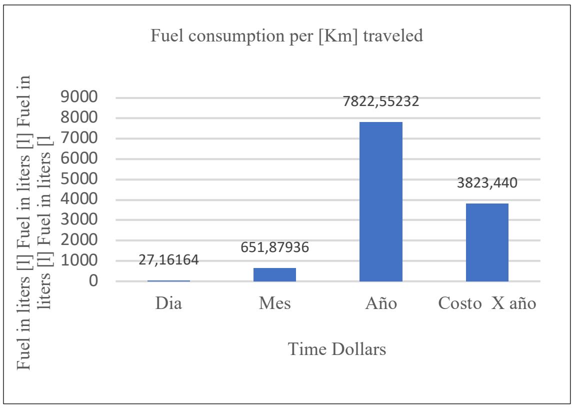

Figure 11. Calculation of fuel consumption of the cab fleet with eco-driving.

Figure 11 shows the calculation of eco-country fuel consumption in liters in the first bar that refers to the consumption in one day, applying the worst scenario, showing the results 27.1616 liters, in the second bar a monthly consumption of 651.8793 l. in the third bar reflects a consumption of 7822.5523 l. per year. Making the respective calculation to know the total cost of consumption per year is $ 3 823.44cent, calculation made with the value of the liter of fuel Eco country ($0.48cent).

Conclusions

The importance that influences the characteristics of the cab fleet on emissions depends on the type of technology, engine capacity and application of eco-driving techniques.

In the estimation of CO2 emissions, a baseline was obtained as a result for the study of pollution of the city of Cuenca by greenhouse effect emissions, analyzing the CO2 emissions in two scenarios which correspond: first a scenario with lower vehicle traffic conditions and a second scenario with more traffic, for this purpose, the average speeds were recorded from lowest to highest, through each hour of data determining a normal distribution, the best scenario corresponds to the first quartile of the data sample and the worst scenario corresponds to the third quartile of the normal distribution of the data sample, for the worst scenario was obtained 293.13 g/km of CO2, compared to the best scenario that obtained 220.95 g/km, with a percentage difference of 5%.

The CO2 emissions per year generated by the 1600cc efficient driving cabs, for the best scenario "less vehicular traffic" 15'959 306.88g/km in the worst scenario "more vehicular traffic" 21'172 897.15g/km resulting in a percentage difference of 5% and in tons are 15.95t for the best scenario and 21.17 t for the worst scenario.

The fuel consumption in the best scenario with favorable traffic is 9.28 l/100km and the worst scenario with more vehicular traffic is 10.83 l/100km, resulting in a percentage difference of 8%, i.e., in the worst scenario there is higher fuel consumption due to more vehicular traffic at the time of the trip.

Comparing the CO2 emissions factor in the best scenario 220.9 g/km, with the technical data according to the Environmental Protection Agency (EPA), of the Hyundai Accent 1.6, 4cil. With 6 speeds, manual where it indicates that emit 172 g/km, obtaining a difference of 7%, this is due to the geographical location of the city of Cuenca.

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