Definition of Urban, Highway and Combined Driving Cycles for the city of Quito - Ecuador

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Abstracts: The use of driving cycles is a widely accepted method for evaluating fuel consumption and vehicle emissions under specific local conditions. The primary objective of this study was to obtain updated driving cycles that reflect the characteristics of the city of Quito, Ecuador, during peak hours using electronic means to gather driving parameters. To achieve this, the OBD2 ELM327 module and its corresponding mobile application, Car Scanner ELM OBD2, were utilized to record, store, and export real-time data for variables such as vehicle speed, fuel consumption, distance traveled, and travel time, among others, in three zones: urban, highway, and combined. This information enables a comprehensive understanding of the level of vehicle mobility and fuel consumption during peak hours in each zone. The resulting speed vs. time graphs for the selected routes demonstrate the lowest mobility and highest consumption in the urban zone in comparison to the highway and combined zones in terms of kilometers traveled.

Keywords: Driving Cycle, Fuel Consumption, Driving Parameters, OBD2 Module, Speed, Distance.

1. INTRODUCTION

The city of Quito, the capital of Ecuador, is one of the most populous in the country, as indicated in the yearbook of the Association of Automotive Companies of Ecuador (AEADE). In 2019, the largest sale of cars in the country took place within the province of Pichincha, with a total of 49,718 units, representing 37.61 % of the national total. SUV type vehicles experienced the highest increase in sales compared to 2018, with a growth rate of 1.4 %, totaling 45,266 units and accounting for 34.2 % of the market share [1]. This has led to mobility issues, particularly during rush hours, when vehicular congestion affects the air quality index in Quito.

One of the most widely utilized methods for evaluating fuel consumption and pollutant emissions in urban areas, highways, and combined roads is the driving cycle, which involves the study of speeds versus time to determine the standardized behavior of vehicles traveling these routes. According to Quinchimbla and Solís [2], driving cycles can be classified as modal and transitory. The first variant, the modal type, is the least accurate as it integrates prolonged sequences of constant speeds and linear accelerations, which does not accurately represent the real behavior of the driver. The modal type includes the European cycle New European Driving Cycle (NEDC) and Japanese Mode 10-15. The second type is more complex, characterized by variable speeds and accelerations over time, allowing for driving conditions to be much more realistic than the modal type. The transient type includes cycles such as FTP-75 (Federal Test Procedure) and ARTEMIS (Assessment and Reliability of Transport Emission Model and Inventory System) [3].

The development of driving cycles for certain places is a complex task, as it is influenced by several parameters such as the driving styles of individuals, traffic conditions, and the topography of cities [4]. As a result, standardized cycles have been established globally, such as those addressed by Calva and Flores [5], which focus on a road driving cycle for the conditions of the city of Riobamba in Ecuador. González-Oropeza [3] reviewed the specialized literature on driving cycles developed in various countries, including the United States of America, European Union, England, and Mexico. Additionally, Romain [6] compares various modal driving cycles, such as the European standard NEDC or Japanese Mode 10-15, with transient cycles like the FTP-75 or Artemis cycle. According to Calva and Flores [5], the Ecuadorian Standardization Institute, through its NTE INEN 2205 [7] and NTE INEN 2477 [8] Standard, recommends the utilization of the FTP-75 transient cycle, as well as the European ECE EUDC (NEDC) mode, for the evaluation and control of pollutant emissions. However, they do not consider the development of speed profiles or fuel consumption.

Given the aforementioned background, the primary aim of this research was to acquire updated driving patterns specific to the city of Quito, Ecuador, during rush hour utilizing electronic means in order to establish the defining driving parameters of the city.

2. MATERIEL AND METHODS

In order to establish adequate driving cycles, it is necessary to understand the areas with the highest vehicular flow, including their peak hours, and to determine how they will be utilized for various daily activities such as work/study trips, shopping, and leisure [9]. Previous studies, such as those conducted by Quinchimbla and Solís [2] in Quito-Ecuador, have identified the main areas of vehicular flow and highlighted that the Center-North of Quito has the highest concentration with 31 %, followed by the North with 27 %, the Center with 14 %, and the remaining percentages distributed among the Historic Center, South Center, South, and Periphery. Vega and Parra [10] found that the vehicular flow in the North zone on weekdays was 10% higher than on Saturdays and 60% higher than on Sundays, while in the South zone, it was also higher on weekdays. In the Periphery, it increased from 11% to 47% on holidays due to trips made outside and inside the Metropolitan District of Quito (DMQ). Additionally, the timetable for vehicular flow was identified to have congestion predominantly between 7:00 and 9:00 a.m. on working days due to commuting to work or educational centers, followed by 1:00 p.m. for lunch and ending with the return home between 6:00 and 8:00 p.m.

2.1. Route Selection

Three routes were established, comprising an urban area, a highway, and a combined urban-highway stretch. These routes were traversed three times each at 8:00 am, 1:00 pm, and 5:00 pm on working days, and the readings were taken according to the recommendations of the NTE INEN 2205 [7] and NTE INEN 2477 [8] standards, which stipulate that at least three readings per test be recorded and averaged. To select the routes, Quinchimbla and Solís [2] suggest relating the distances of the most common driving cycles and establishing a range, which resulted in distances between 2.1 km and 11.9 km for the urban zone, 8.8 km and 27.5 km for the highway zone, and 6.2 km and 25.6 km for the combined zone. The selected routes are as follows:

2.1.1. Urban Zone

Starting at the intersection of Eloy Alfaro Avenue and Mortiños Avenue, the route proceeds along Granados Avenue, passing through 6 de Diciembre Avenue and Naciones Unidas Street, concluding at Mariana de Jesús Avenue, as depicted in Figure 1. Along the way, there are several points of interest, including Universidad de Las Américas, Quicentro Shopping, and Centro Comercial Iñaquito (CCI), among others. The journey spans approximately 5.6 kilometers and takes place on Mondays. Notably, the road and combined traffic zones are restricted on Tuesdays and Wednesdays due to vehicle restrictions in the city.

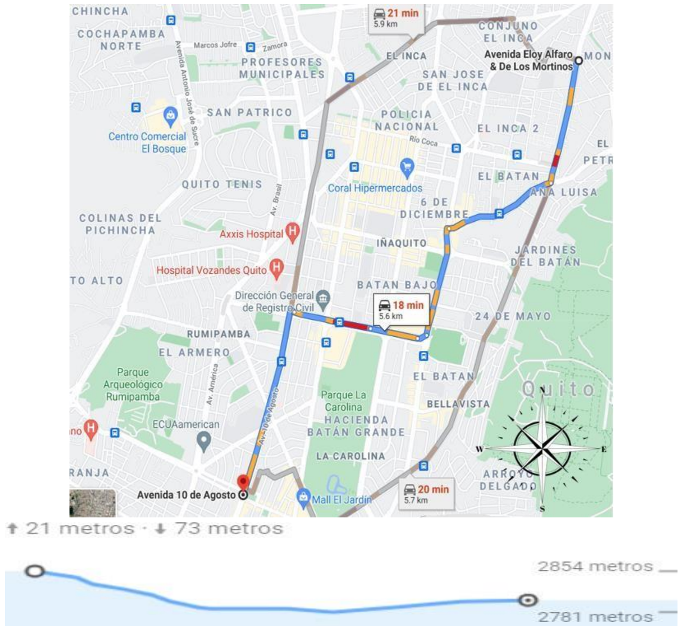

Figure 1. Eloy Alfaro Avenue–10 de Agosto Avenue urban route with its elevation profile. Source: Google Maps, by Google [11].

2.1.2. Highway Zone

The route commences at the Ciclista traffic circle located at the beginning of Simon Bolivar Avenue and concludes at the entrance to San Rafael on the General Rumiñahui Highway (as shown in Figure 2). This stretch spans a distance of 25.9 km and traverses several areas of interest such as the International University of Ecuador, the Johannes Kepler school, residential complexes, and the toll booth on the General Rumiñahui Highway, among others. This route is the quickest means of connecting Quito with the Los Chillos Valley.

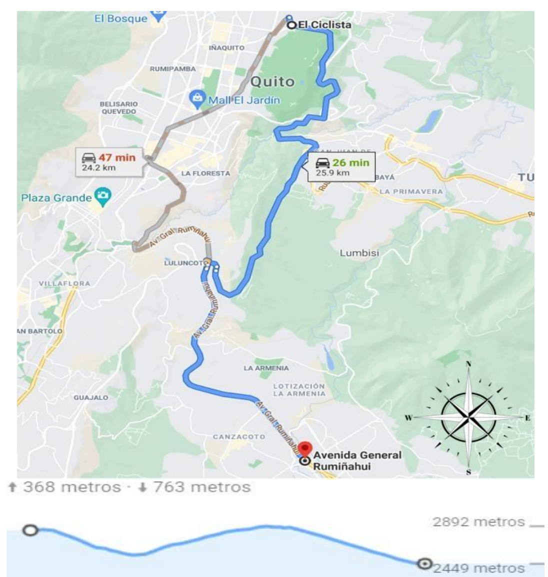

Figure 2. Simón Bolívar Avenue - General Rumiñahui Avenue road route with its elevation profile. Source: Google Maps, by Google [11].

2.1.3. Combined Zone

The section of interest commences at La "Y" Park, situated on Av. 10 de Agosto, and concludes at the Padre Luis

Vaccari Street Park in Carapungo (refer to Figure 3); this route traverses streets such as El Inca, Simón Bolívar, Las Palmeras, and Panamericana Norte. The total distance spans 12.2 km, with 5.65 km distributed within urban areas and 6.55 km dedicated to roadways. Along this route, numerous businesses, restaurants, banks, and residential complexes are found to be of interest.

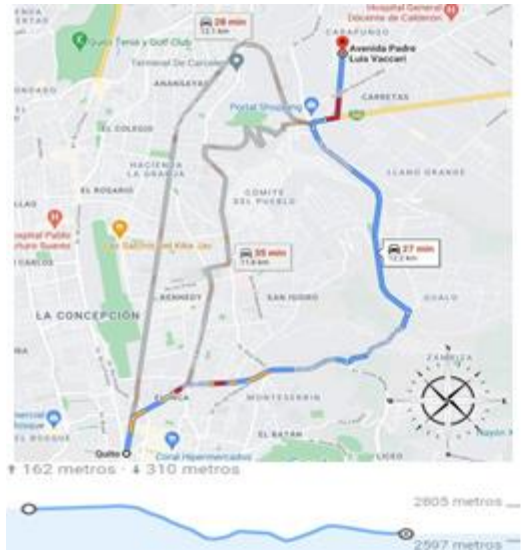

Figure 3. Combined route Av.10 de Agosto - Carapungo with its elevation profile. Source: Google [11]. Images obtained from Google Maps.

2.2. Data Collection Techniques

Cedillo [12] put forth three possibilities: expert drivers, daily drivers, and pursuit cars. Additionally, Esteves-Booth, Muneer, Kubie, and Kirby [13] present two classifications: ON-BOARD (encompassing both driver variants) and Vehicle Pursuit (following car). The ON-BOARD system was chosen due to its more straightforward data collection process, enhanced accuracy in recording, and simplified and more cost-effective instrumentation.

2.2.1. Test Vehicle

The test vehicle utilized for this study was a Great Wall SUV model Haval H5 4X2, which is equipped with a 2.4-liter gasoline engine (see Figure 4). This particular vehicle conforms to the INEN denotation as a type M1 vehicle.

Figure 4. Great Wall Haval H5 test vehicle.

2.2.2. Sampling Devices

In previous studies such as Quinchimbla and Solís [2], Hurtado [14], Astudillo [15], Peréz and Quito [16] and Dávalos [17], researchers have utilized GPS systems that collect data on speed, time, and distance, and then export this information to software for analysis. In the present study, an ELM327 Mini type Bluetooth OBD2 device was employed (see Figure 5), which is capable of performing the same functions as GPS systems while also determining fuel consumption and maintaining a stable connection even when traveling through areas with low coverage. This device consists of an interface that communicates with the vehicle's ECU, requiring software to perform the scanning function [18]. The application chosen for data collection was a Car Scanner (Figure 5) that is capable of storing the desired information in real time and exporting it to Excel or other programs for analysis.

Figure 5. ELM 327 Mini OBD2 module and Car Scanner application.

2.2.3. Fuel Consumption Measurement

Figure 6 depicts the fuel storage unit, which operates under pressure to provide fuel to the vehicle's combustion system at a pressure equal to that of the vehicle's fuel pump. The unit has a storage capacity of 5 liters and the pressure is adjusted manually using a pump. At the end of the test, the amount of fuel consumed can be determined.

Figure 6. Pressure tank hand pump LIQUI MOLY

A 5-liter Erlenmeyer flask was utilized to gauge the quantity of fuel stored in the tank, as depicted in Figure 7. The fuel remaining after the test was measured using a 1000 mL test tube, as depicted in Figure 8.

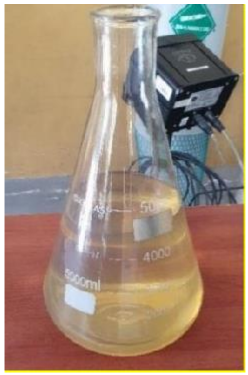

Figure 7. 5L Erlenmeyer flask

Figure 8. 1000mL test tube

2.2.4. Study Variables and their Analysis

The work of Restrepo Victoria et al. [19] and adapted by Quinchimbla Pisuña and Solís Santamaría [2] and Hurtado Gómez [14] has noted that the fundamental parameters for the development of the driving cycles are the average speed, maximum speed, idle time, number of stops, total travel time, distance traveled, average positive acceleration, maximum positive acceleration, and time with positive acceleration, which were obtained through a comparison of previously established driving cycles and additional cycles. The Weighted Average Analysis is a commonly used technique for data analysis, and its application has been recorded in various countries including Mexico, Australia, France, and the United States [19] and more recently adopted in Ecuador by Quinchimbla Pisuña & Solís Santamaría [2], Peréz & Quito [16], and Dávalos Figueroa [17]. This technique involves selecting the path closest to the mean of all paths by comparing all the aforementioned variables with the mean values of all experimental curves. The first step is to rank the importance of each variable by relating it to a multiple of 0.25 (minimum 0.25, maximum 1), which are called Weighting Weights (W). Once the variables have been defined, their respective weighting weights are assigned as shown in Table 1.

Table 1. Weighting of the weights W with respect to the parameters i.

Parameter i	Weighting weight W
Average speed	1
Maximum positive acceleration	1
Distance traveled	1
Travel time	1
Fuel consumption	1
Positive acceleration time	1
Idle time	0,75
Maximum positive acceleration	0,75
Maximum speed	0,25
Total stops	0,25
Total	8

Note: *The weight of each parameter was taken from "Design and application of a methodology to determine vehicular driving cycles in the city of Pereira", by Restrepo, Carranza, and Tibaquirá [19]. Fuel consumption was added with a weighting of 1 due to its significance ingreenhouse gas concentrations.*

Next, we use Equation 1 from the weighted averages presented by Quinchimbla and Solís [2] and Restrepo, Carranza, and Tibaquirá [19], which is as follows:

$$Y = \frac{\sum_i W_i * \frac{|P_{ij} - \bar{P}|}{\bar{P}}}{Total\ de\ las\ ponderaciones} \quad (1)$$

Where:

Y: Weighted average value

Wi: Weighting weight of parameter i

Pij: Value of parameter i for cycle j

$\bar{P}$: Average of parameter i

$\frac{|P_{ij} - \bar{P}|}{\bar{P}}$: Deviation from the mean in dimensionless terms.

Lastly, a spreadsheet is constructed to calculate a weighted mean for each excursion, and the minimum value is selected for each study area because it represents the smallest deviation from the average of all parameters/variables.

3. RESULTS AND DISCUSSIONS

The following sections will present the most representative driving cycles of each zone, which were obtained utilizing the ELM 327 OBD2 Module, its accompanying Car Scanner application, and the subsequent data tabulation in Excel. These cycles were constructed by selecting the most relevant parameters from the previously discussed main driving cycles (average speed, maximum speed, travel time, travel distance, maximum acceleration, etc.).

3.1. Representative Graphs of the Cycles in the D.M.Q.

A total of 27 trips were undertaken between the morning, midday, and afternoon hours on the three defined routes. For the sake of brevity, only three graphs (zone: urban, highway, and combined) are presented here, which were obtained based on the minimum deviations of the weightings determined using Equation 1 and the respective parameters listed in Table 1.

3.1.1. Urban Cycle

Figure 9 depicts the representative cycle observed during midday hours (13h00) with a weighted mean value of Y = 0.04133. Comparing this value to the lowest weighted mean obtained by Quinchimbla and Solis [2] in their urban route (Y = 0.1342), a smaller deviation is evident, with the present results exhibiting a deviation of only 31 %. These findings suggest a lower variability in the results obtained in this study compared to the aforementioned research.

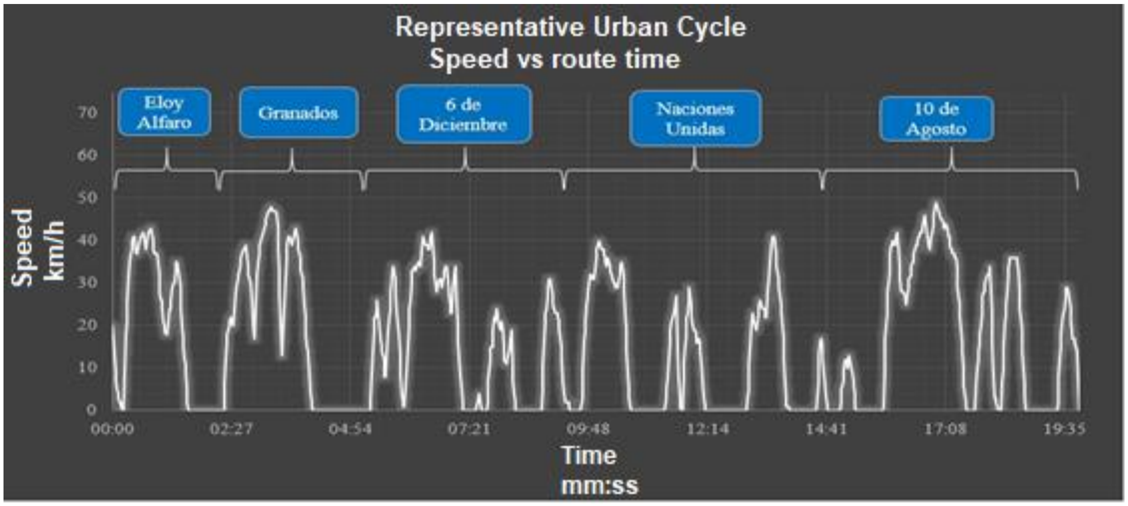

Figure 9. Representative graph of the urban cycle for the selected route.

The most common travel time and speed on each of the streets comprising the route have been recorded: on Eloy Alfaro Avenue, the route takes approximately 2 minutes with a maximum speed of 43 km/h; De Los Granados Avenue averages 3 minutes with a maximum speed of 49 km/h; 6 de diciembre Avenue takes around 4 minutes with peaks of 41 km/h; Naciones Unidas Avenue takes 5 minutes with a maximum speed of 40 km/h, and finally, 10 de Agosto Avenue takes between 4 and 5 minutes with a maximum speed of 49 km/h. It should be noted that the United Nations Avenue was found to be the most congested area based on the comparison in Figure 1, due to its longer stop times and the high concentration of buses, as it is also the most commercial area. Table 2 provides a comparison of the cycle variables, including their mean, maximum, and minimum values.

Table 2. Data obtained from the representative cycle and average, maximum and minimum values of the total urban cycles.

	Max. speed (km/h)	Average speed (km/h)	Positive Acceleration. Max. (m/s^2)	Average Positive Acceleration (m/s^2)	Distance traveled (km)	Total Stoppages	Travel time (s)	Fuel Consumed (L)	Idle time (s)	Positive Acceleration Time (s)
Cycle	49	15,17	1,41	0,54	5,58	16	1193	0,73	474	372
Prom.	51	15,98	1,62	0,52	5,56	15	1200	0,74	432	379
Max.	56	22,61	2,44	0,63	-	21	1606	0,88	876	444
Min.	48	5,53	1,41	0,43	-	8	887	0,61	220	323

The duration of the trips ranged from 14 to 27 minutes, with the afternoon recording the highest concentration of vehicles and peak speeds reaching 48-56 km/h. The fuel consumption for the entire trip was between 0.6125 L and 0.8873 L, with an average of 0.7476 L, which is associated with maximum positive accelerations between 1.4107 m/s2 and 2.4437 m/s2, lasting between 5 and 7 minutes, and a varying number of stops between 8 and 21.

3.1.2. Road Cycling

Figure 10, which corresponds to the midday trip (13h00), exhibited the lowest weighted mean of Y= 0.16626.

When compared to the minimum value of Quinchimbla and Solís [2] in their road route, which was Y = 0.2932, a reduced deviation in the results is evident, with a 57% decrease in variability.

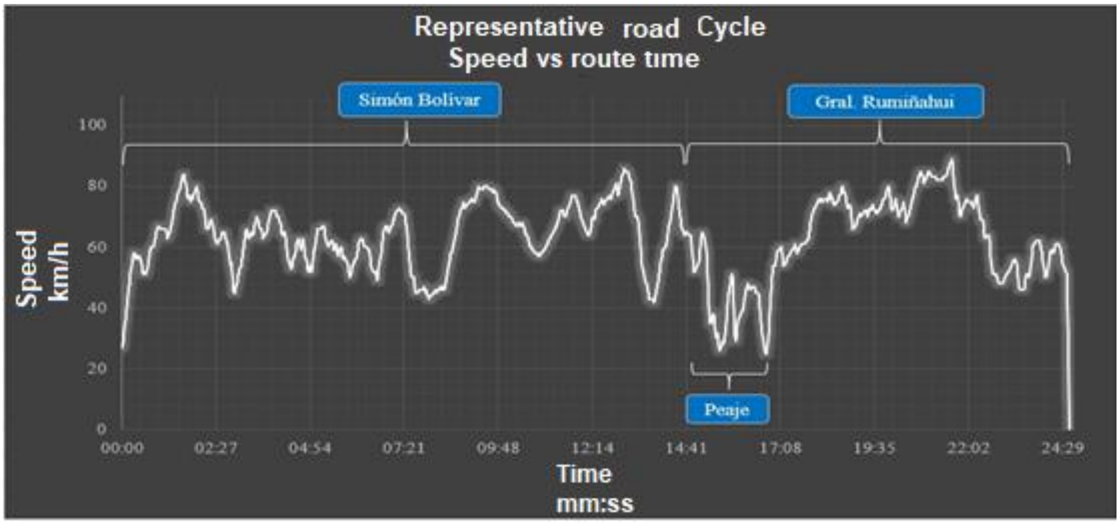

Figure 10. Representative graph of the road cycle of the chosen route.

Figure 10 illustrates that the travel time along Simón Bolívar Avenue typically ranges between 14 and 15 minutes, with a maximum speed of 85 km/h. Conversely, the General Rumiñahui Highway takes approximately 10 minutes and reaches a maximum speed of 88 km/h. Simón Bolívar Avenue is the busiest thoroughfare, as it connects with various surrounding areas, including Guápulo, Llano Grande, Llano Chico, Nayón, and Zámbiza. Meanwhile, the General Rumiñahui Highway connects with Conocoto, San Rafael, and Capelo. Table 3 presents a comparison of the cycle variables, including their mean, maximum, and minimum values.

Table 3. Data obtained from the representative cycle and average, maximum and minimum values of the total road cycles.

	Max. speed (km/h)	Average speed (km/h)	Positive Acceleration. Max. (m/s^2)	Average Positive Acceleration (m/s^2)	Distance traveled (km)	Total Stoppages	Travel time (s)	Fuel Consumed (L)	Idle time (s)	Positive Acceleration Time (s)
Cycle	89	63,14	0,92	0,20	25,94	0	1479	1,74	0	732
Prom.	87	63,07	1,20	0,24	25,94	0	1486	1,72	0	737
Max.	89	69,31	1,58	0,28	-	1	1600	1,83	1	874
Min.	82	58,32	0,90	0,20	-	0	1348	1,57	0	580

The duration of trips can range from 22 to 27 minutes, with peak speeds varying between 82 and 89 km/h. At the conclusion of the trip, fuel consumption can be expected to fall within a range of 1.575 L to 1.837 L, with an average of 1.722 L. This consumption is directly proportional to the maximum positive accelerations recorded during the trip, which range from 0.9035 m/s2 to 1.5833 m/s2, as well as the trip's duration time, which can vary from 9 to 15 minutes, and the distance traveled, which is approximately 25.9 km.

3.1.3. Combined Cycle

Figure 11 depicts the typical cycle associated with the morning commute at 8:00 a.m., with an average value of Y equal to 0.03960. Quinchimba and Solis [2] recorded the minimum average of Y at 0.1098, which demonstrates a lower deviation in the results and a 36% decrease in variability compared to the current study.

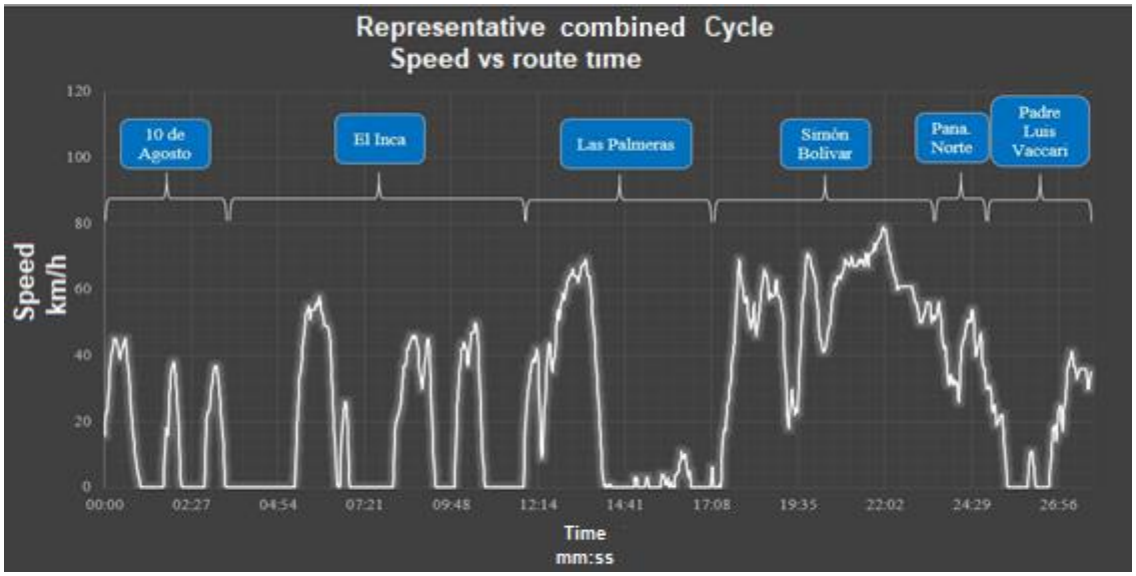

Figure 11. Representative graph of the combined cycle of the chosen route.

Figure 11 depicts the travel time and maximum speed for each avenue. Travelling Av. 10 de Agosto takes approximately 3 minutes and 30 seconds with a maximum speed of 44 km/h. Av. El Inca requires a travel time of between 8 and 9 minutes and has a maximum speed of 57 km/h. Av. De Las Palmeras takes 6 minutes with a maximum speed of 68 km/h after crossing the Zámbiza bridge. Av. Simón Bolívar takes 6 minutes and has a maximum speed of 79 km/h. The Panamericana Norte has a travel time of between 1 and 2 minutes with a maximum speed of 56 km/h. Finally, Av. Padre Luis Vaccari takes slightly over 3 minutes with a maximum speed of 41 km/h. The table below (Table 4) displays the comparison of cycle variables with their mean, maximum, and minimum values. The congestion is most prominent on Av. El Inca, where the longest stops and highest number of vehicles are observed.

Table 4. Data obtained from the representative cycle and average, maximum and minimum values of the total combined cycles.

	Max. speed (km/h)	Average speed (km/h)	Positive Acceleration. Max. (m/s^2)	Average Positive Acceleration (m/s^2)	Distance traveled (km)	Total Stoppages	Travel time (s)	Fuel Consumed (L)	Idle time (s)	Positive Acceleration Time (s)
Cycle	79	26,32	1,53	0,38	12,21	19	1670	1,22	551	602
Prom.	84	27,68	1,55	0,41	12,25	21	1664	1,22	459	604
Max.	91	38,91	1,75	0,45	-	33	2173	1,39	733	764
Min.	79	20,30	1,32	0,36	-	7	1135	0,96	14	497

									5	

The duration of trips ranges between 19 and 36 minutes, with afternoons experiencing the most congestion. Peak speeds of 79-91 km/h were recorded, and fuel consumption from the departure point to the arrival destination can vary between 0.968 L and 1.397 L, with an average of 1.2244 L. The maximum positive acceleration recorded was between 1.3244 m/s2 and 1.7570 m/s2, lasting for a duration between 8 and 13 minutes. The distance of the trip was 12.2 km, and the number of stops varied from 7 to 33, with most or the longest stops located on El Inca Avenue. These factors significantly impact fuel consumption.

3.2. Comparison of Representative Cycles

To gain a more comprehensive understanding of the behavior of vehicles in the areas studied, it was determined necessary to compare the travel time and fuel consumption of the three cycles previously observed, against the studies conducted within the country. The primary objective of this analysis is to differentiate travel time from the speed profile and travel distance.

3.2.1. Velocity vs Time Profile

Figure 12 illustrates the three cycles superimposed, with a clear distinction in the velocities achieved in the urban zone (light blue), the highway zone (orange), and the combined zone (green). As can be observed, the urban zone was the shortest in terms of distance (5.58 km), yet it lasted only 5 minutes less than the road zone, which covered a significantly greater distance of 25.94 km and 7 minutes less than the combined zone of 12.21 km. This information suggests that the urban zone has the highest level of vehicular congestion, followed by the combined zone, and finally the highway zone.

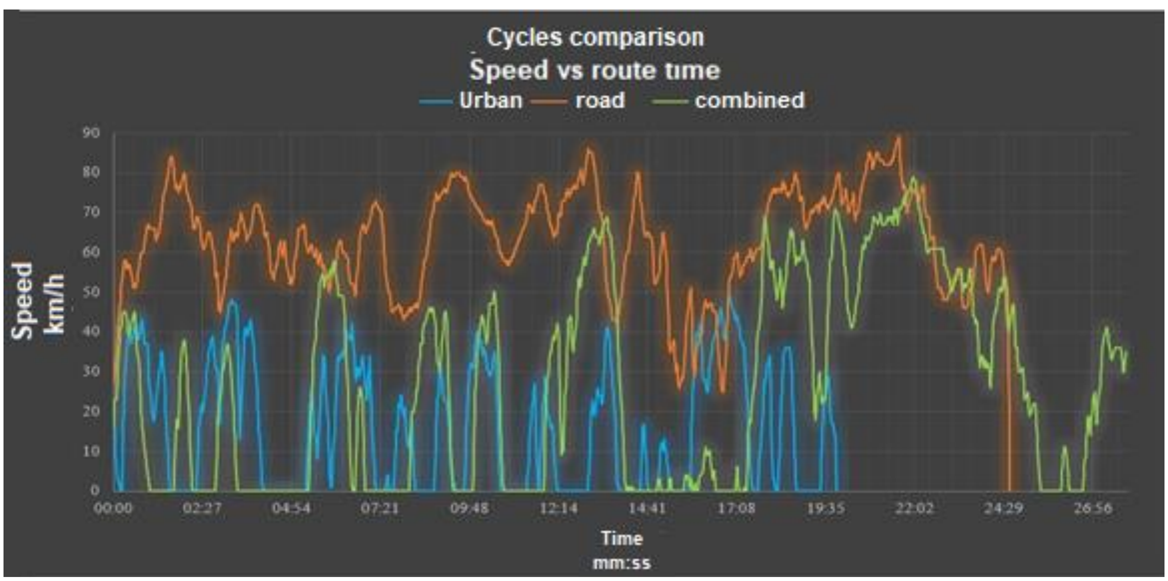

Figure 12. Comparative graph of representative driving cycles.

In the study conducted by Quinchimbra and Solis [2], the urban zone was assigned a distance of 11.9 km, with a duration of 52 minutes and 49 seconds. The road zone had a distance of 27.5 km and a duration of 24 minutes and 53 seconds. Finally, the combined zone had a distance of 15.7 km and a duration of 48 minutes and 10 seconds. Analysis of the results indicates that despite the urban route being the shortest distance, it took longer than both the road and combined cycle routes. Furthermore, the duration of the combined cycle was likely slower in its urban zone. Similarly, Calva and Flores [5] found that when choosing routes between 2.53 km and 3.56 km in urban areas, the duration time ranged from 12 minutes and 24 seconds to 13 minutes and 44 seconds. Therefore, the 13 minutes and 44 seconds of the urban cycle in Figure 9 can be considered proportionally equivalent to the study itself, since it covered a distance of 3.74 km.

3.2.2. Fuel Consumption

Figure 13 illustrates the comparative consumption of the three cycles during the urban cycle segment (5.58 km), to identify the behavior of the three representative stages. As depicted, the road route marginally leads in the initial 500 meters, but after the first kilometer, the road route stabilizes until it consumes 0.258 L at 5.58 km, while the combined zone exhibits an increase in consumption between the first and fourth kilometers and reaches 0.654 L at 5.58 km. Additionally, prior to the beginning of the fourth kilometer, the urban zone commences to surpass the two cycles and concludes its final stretch with 0.737 L consumed, representing the zone that expends the most fuel per kilometer of travel. The combined zone is also noteworthy as it consumes 0.68 L of the total 1.2293 L in the urban sections, underscoring that the urban zone accounts for the most fuel consumption within the urban zone.

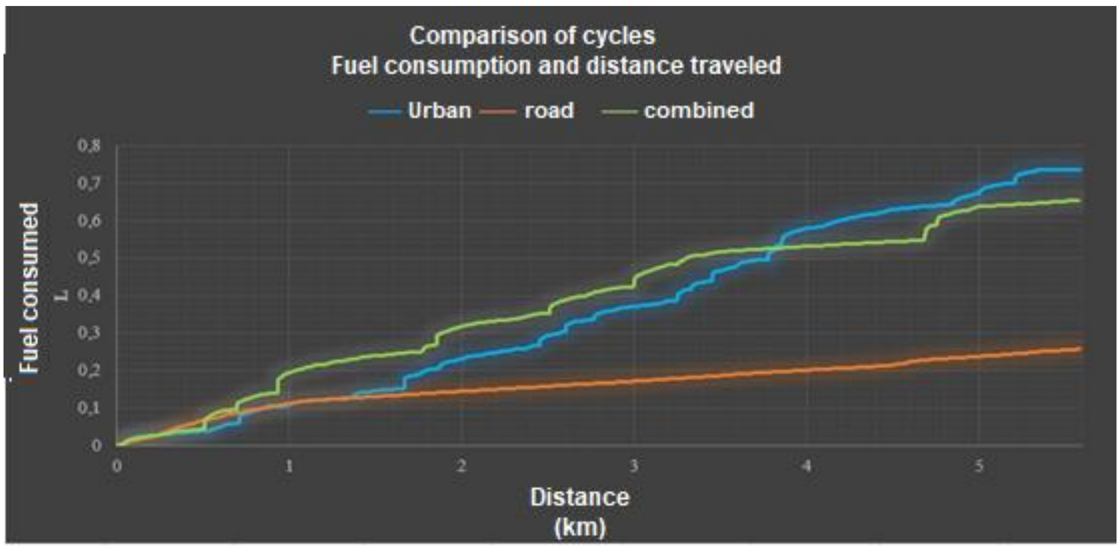

Figure 13. Comparative graph of fuel consumption in the first 5.58 km.

The consumption profiles obtained by Quinchimbra and Solis [2] indicate that, for the urban area within the same parameters covered in the previous paragraph, a yield of 8.859 km/L (consuming 1.343 L) was obtained. On the highway, a yield of 10.236 km/L (consuming 2.687 L) was obtained, and in the combined area, a yield of 13.29 km/L (consuming 1.181 L) was obtained. These values are higher because the distances chosen are greater and a different vehicle is used. However, if the km/L ratio were used for the study itself, the values would be 0.629 L for the urban zone, 2.534 L for the highway, and 0.918 L for the combined zone. These values are very close to those obtained in Tables 2-4 with a clear difference in the highway variant.

In the urban test conducted by Calva and Flores [5], an average performance of 11.53 km/L was obtained in the variant closest to the displacement of the Great Wall Haval H5 (2,000 cc), meaning that it would consume 0.484 L, a value 264 mL lower than the average consumption obtained from the present project. However, it should be noted that their study was conducted in the city of Riobamba, outside the proposed study area, and, as also mentioned, the km/L value of their practice was for 2,000 cc vehicles, while the Great Wall Haval H5 had a displacement of 2,400 cc, meaning that it would probably consume more fuel.

Given the aforementioned uncertainties, it was deemed necessary to evaluate the fuel consumption of each of the aforementioned cycles in comparison to the data provided by the Great Wall Haval H5 data sheet, obtained from reputable sources such as AutoData24 [20], Tate [21], and Fallah [22]. A table (Table 5) and bar chart (Figure 14) have been included to display this information.

Table 5. Fuel consumption data obtained versus technical data sheet.

Cycle	Consumption obtained in tests		Theoretical Consumption (Technical Data)	
	L/100 km	km/L	L/100 km	km/L
Urban	13,4	7,7	14	7,1
Road	6,6	15,2	8,5	11,8
Combined	10	10	10,3	9,7

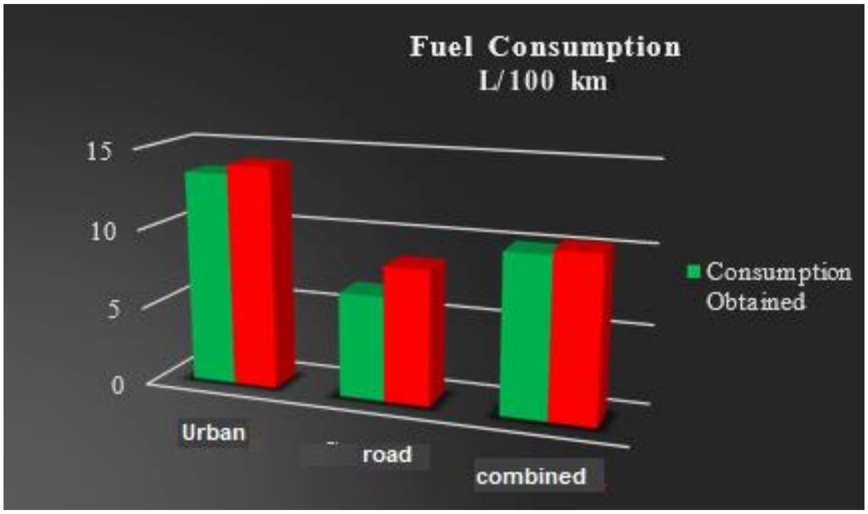

Figure 14. Comparative graph of the fuel consumption obtained with respect to the theoretical consumption.

Table 5 indicates that there is minimal discrepancy between the theoretical data and the practical results obtained, with an 8.5% urban cycle, 28.8% highway, and 3.1% combined variation. The highest consumption of fuel was observed to occur in the urban area, followed by a decrease in consumption on the combined route, and the lowest consumption on the highway. After examining studies conducted in Ecuador and comparing the results in Table 5, Figure 9, and Figure 1, it was determined that the highway and combined zones exhibited the greatest mobility in the D.M.Q., while the urban zone had the highest fuel consumption and elapsed time per kilometer traveled.

CONCLUSIONS

The driving cycles selected were based on the roads with the highest vehicular flow and were approached during peak hours (8h00, 13h00 and 17h00). The cycles were constructed using the most important parameters of the FTP 75, NEDC, and ARTEMIS cycles, among others. It was found that the most representative trips in the city and highway were at midday (13h00) and morning (8h00). A weighted mean analysis was conducted to identify the most characteristic trips based on the minimum deviations with respect to the average values of the cycles. The urban area obtained a value of 0.04133, the highway had a value of 0.16626, and the combined cycle had a value of 0.03960. These values were compared with the national literature and it was observed that the results obtained were 31%, 57%, and 36% lower, respectively, indicating a lower error in practice. The urban cycle recorded the lowest average speeds of 15.98 km/h, the highway cycle had average speeds of 63.07 km/h, and the combined cycle had average speeds of 27.68 km/h. The urban section of Av. El Inca had the longest stops, greater congestion, and longest duration, mainly in the afternoon hours. The highest fuel consumption was recorded in the urban cycle with a ratio of 7.7 km/L, followed by the combined cycle with 10 km/L, and finally the highway cycle with the best performance of 15.2 km/L with the highest speeds and practically no stops.

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