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Article

Methodology to Determine the Driving Cycle on Urban Routes in the City of Guayaquil

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Abstract: Due to the lack of representativeness of standardized cycles such as the FTP-75, designed for specific regions and not adapted to cities such as Guayaquil, this study aimed to determine the representative driving cycles for the most congested urban routes of the city, covering the north, south, center and west zones. The methodology used was the direct method, carrying out trips in scenarios with real traffic. An M1 vehicle equipped with the OBDLINK MX+ device was used, which allowed data collection in real time. These data were processed and analyzed with the OBDWIZ program to characterize local driving patterns. With the support of the Minitab tool, the sample size was determined from the data obtained in the pilot tests performed on each route. In addition, normality tests were performed on each route to determine the distribution of the data and apply the most appropriate measure of central tendency. Finally, using the weighting criteria method, the representative cycle for each route was determined. The results obtained showed that, on Route 1, the selected repetition was 7, with an average speed of 65.39 km/h and a maximum speed of 79 km/h. For Route 2, repetition 11 was selected, with an average speed of 21.39 km/h and a maximum speed of 67 km/h. For Route 3, the chosen repetition was 2, with an average speed of 11.05 km/h and a maximum speed of 50 km/h. Finally, for Route 4, the selected repetition was 5, with an average speed of 16.27 km/h and a maximum of 39 km/h.

Keywords: driving cycle; urban routes; traffic congestion

1. Introduction

Traffic congestion in urban areas, such as Guayaquil and its environment, represents a significant problem in terms of mobility and environmental impact. Excessive traffic affects travel efficiency and contributes to polluting gas emissions, deteriorating air quality and posing risks to public health [1]. Internal combustion engines release substances such as carbon monoxide (CO), carbon dioxide (CO₂), nitrogen oxides (NO_x), unburned hydrocarbon (HC) and lead compounds [2]. According to the World Meteorological Organization, between 1990 and 2022 greenhouse gas emissions increased by 49 percent, with CO₂ being responsible for 78 percent of this increase [3,4].

In order to decrease the environmental impact of the transportation sector, numerous studies have been developed, and governments have implemented strict regulations to control emissions, including a representative driving cycle (DC) [5]. China adopts this initiative by replacing the European Driving Cycle (NEDC) with the Driving Cycle (WLTC) [6], which is based on emissions tests under real driving conditions (RDE) [7]. However, although this globally standardized and harmonized cycle works well at altitudes below 2400 masl, it is not suitable for higher altitudes. A detailed study reveals that, at these 35 altitudes, engine efficiency decreases and traffic in high density areas aggravates the problem [8,9].

A study in Mexico oriented to the evaluation of pollutant emissions in freight vehicles highlights a comparison between a DC performed by them and other international reference cycles applied in that country, which results show that, in relation to simulated emissions, problems were observed when adopting international DCs. The results show that, in comparison with the DC determined in

the study area, emissions can be underestimated by 19 percent for NO_x and 25 percent for CO if the EPA Federal Test Procedure (FTP-75) [10] is adopted; this is due to the fact that the DC chosen will not have the same driving patterns or the same topology as the place where the tests would be carried out [11].

In several countries, DCs are developed to reflect local driving conditions [12], whether legislative or not [13], because they want to obtain more accurate data in their studies. In the United States, Japan and the European Community established legislative cycles such as FTP-75, NEDC and JC08, respectively, to meet vehicle emission regulations [3]. Non-legislative cycles have been analyzed in cities such as Vadodara, Bangalore, Hong Kong, Pune, Edinburgh, Athens, Singapore, 11 Chinese cities and Malaysia with its MUDC. These are used for energy, efficiency and emissions studies, as well as in certifications and laboratory tests [14,15].

On the other hand, studies carried out in several cities in Ecuador, such as Esmeraldas, Ambato, Cuenca, among others, detailed the importance of these investigations. This was due to the fact that, by implementing a representative cycle for these specific regions, better results can be obtained in the evaluation of fuel consumption and emissions. The methodology used for data collection was the direct method, which consisted of obtaining information in real time using the ON BOARD technique. For this purpose, the vehicle was equipped with an OBD or GPS device and two or more drivers were involved in order to simulate the best traffic conditions. Finally, the method used to obtain the representative driving cycle was based on the weighting criterion, which assigned a relative weight to each of the selected variables, reflecting their importance in the characterization of the driving cycle. Thus, through the equation of weighted averages, the optimal route was determined, ensuring that it accurately reflected the actual driving conditions in the area. [16–18].

In consideration, this study aims to determine the DC in urban routes in the city of Guayaquil, analyze the traffic behavior of specific routes where a series of data will be collected to obtain the actual driving pattern in the selected routes, using as a tool an OBD LINK MX+ device. These data were implemented for a statistical analysis, where the normality test was determined for each route to determine the distribution of their data. Finally, using the weighting criteria method, the selected repetition was determined for each route, which corresponds to its respective driving cycle.

This study, carried out at the Polytechnic Salesiana University of Ecuador (UPS) Guayaquil, during the period 2024 - 2025, is directed not only to the academic community, providing theoretical foundations for future research, as well as municipalities and other entities interested in the DC. It also represents a novel approach to evaluate various parameters under different conditions, through the implementation of a methodology, taking as references the standardized cycles. The expected results seek to provide valuable information to understand the real dynamics of traffic and its environmental impact in the urban environment of Guayaquil.

The lack of specific DC adapted to local conditions represents a challenge in vehicle design, energy consumption assessment and pollutant emission control in vehicle homologation processes [19]. Although an ideal DC should reflect the common driving style under different traffic conditions, considering key factors such as vehicle technology, traffic 85 characteristics, and climatic and geographical conditions (such as altitude), in many cases an adequate representation is not achieved. In Ecuador, the National Traffic Agency (ANT) and the Ecuadorian Standardization Service (INEN) are responsible for implementing these cycles for vehicle certification [20], where the ideal time for a DC is 25 minutes according to research conducted by Giraldo in 2021 [21].

Previous studies highlight the importance of developing a representative DC that adapts to local characteristics, allowing a more accurate evaluation of vehicle performance under real operating conditions and optimizing its adaptation to the topology and urban traffic of the region. In Guayaquil, the absence of a specific DC represents a major challenge, since foreign cycles, such as the FTP-75 [22,23], are currently used. This generates significant discrepancies, since these cycles do not adequately reflect the driving patterns typical of the geographical environment and the real conditions of the city.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted in the city of Guayaquil, located in the coastal region of Ecuador. It is the most populated city in the country, with more than 2.7 million inhabitants, which represents 16 percent of the national population, according to data from the 2022 census [24]. It has a territory of approximately 380 square kilometers and an average altitude of 4 meters above sea level. Its climate is tropical, with high temperatures throughout the year.

For the reliability of the data obtained, specific routes were selected within the urban area of Guayaquil, covering the northern, southern, western and central areas with the highest traffic congestion. These routes were defined in strategic areas that reflect the real and usual driving conditions, characterized by a high level of traffic, thus establishing a total of four main routes.

For the selection of routes, several criteria must be taken into account:

1. A large flow of vehicles;
2. Linking the main population centers;
3. Numerous squares and crossroads;
4. Access to public transport networks, for the purpose of normal driving [25].

Juan Tanca Marengo Avenue is one of Guayaquil's main thoroughfares, connecting several key sectors of the city. This avenue extends from the north, in areas near Rodrigo Chávez González Avenue, to the Maritime Port sector, and passes through high-density commercial and residential areas. Due to its strategic location, it is a road with a high vehicular flow, used by both public and private transportation, which makes it a neuralgic point for urban mobility. In addition, the avenue is home to a large number of stores, restaurants and services, which reinforces its economic importance [26].

The last accountability report for the year 2023 presented by the Agencias de Tránsito y Movilidad (ATM) [27] streets such as Av Portete located in the southern area of Guayaquil is a busy road that connects several important roads and passes through residential areas with small businesses, markets and public transport stations, and is characterized by high pedestrian and vehicular activity. Machala Street, on the other hand, located in the south-central area of the city, is characterized by its dense commercial and labor activity, houses workshops, retail stores and connects with important streets leading to the city center and surrounding areas. Finally, Via a la Costa is one of the city's main thoroughfares, designed for fast vehicular traffic, connecting Guayaquil with neighboring cities and tourist destinations along this road, where there are private housing developments, shopping centers, schools and housing developments to consolidate as a city.

The main points of vehicular traffic in different streets of the city were identified with the support of the GPS navigation platform Google Maps, a tool that allows analyzing daily traffic in certain places. In addition, Diario El Universo [28] in its study used this platform along with interviews to provide results in the most conflictive areas of the north, west, south and center of the city. This information helped to determine 4 specific routes for the analysis.

Route 1, illustrated in Figure 1 (a), covers a total distance of 14.9 kilometers. The route begins on Via a la Costa, near the crosswalk that connects to the Puerto Azul housing development. From this point, the route continues along Vía a la Costa, characterized by its wide roadway and constant flow of vehicles, until reaching the entrance to the Chongón toll booth, located on the border between urban developments and areas of transition to rural and recreational zones. According to the Escuela Superior Politécnica del Litoral (ESPOL), the Via a la Costa sector is considered an urban area within the city, which concentrates 23.14 percent of the urban land [29,30].

Route 2, shown in Figure 1 (b), has a total length of 5.7 kilometers and covers an urban route that connects several key points in the city. The route begins at the San Marino shopping center. From there, it moves towards Avenida Rodrigo Chávez, a main artery that connects important sectors of the city. Along this avenue, the route continues until reaching Juan Tanca Marengo Avenue, another

important road that crosses the city in an east-west direction. Finally, the route concludes at the Colegio Americano facilities.

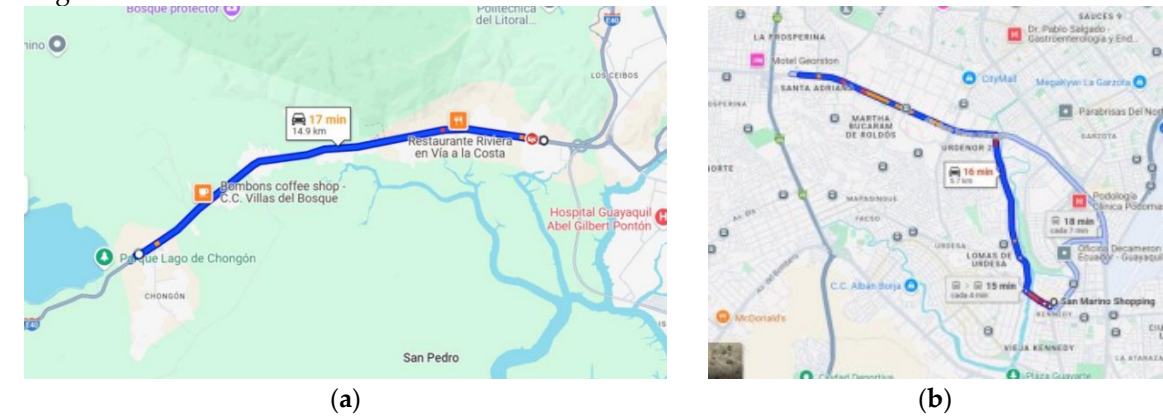


Figure 1. Routes: (a) Route 1, Via a la Costa-Peaje, 14.9 km long. (b) Route 2, San Marino-Colegio Americano with an extension of 5.7 km.

Route 3, shown in Figure 2 (a), is 4.7 kilometers long and covers an urban route that connects strategic points in the city. The route begins at the Centenario campus of the UPS (Universidad Politécnica Salesiana del Ecuador). From there, the route follows a series of streets until it reaches Portete Street and 17th Street, in front of a well-known KFC fast foodrestaurant, an easily recognizable place in the area. This route was selected especially for its relevance in terms of traffic density and flow, making it a key route for urban commuting.

Route 4, shown in Figure 2 (b), has a total distance of 3.9 kilometers and runs through aspecific sector within the city, connecting several main avenues. The route begins at Avenida 9 de Octubre, one of the most important and busiest arteries, known for its commercialactivity and access to several key points in the city. From there, the route continues alongAvenida Francisco Aguirre Abad, a road that also has relevance in urban connectivity and vehicular flow. Subsequently, the route advances along Machala Avenue, a street that crosses different residential and commercial areas, and finally concludes on El Oro Street, another significant point within the city's road network.



Figure 2. Routes: (a) Route 3, UPS Centenario-17th Street and Portete with an extension of 4.7 km. (b) Route 4, Av. 9 de Octubre-El Oro with an extension of 3.9 km.

2.2. Vehicle Selection

For the selection of the vehicle, an Aveo Emotion was chosen because it is one of the most commercial vehicles sold in the country according to the AEADE (Asociación de Empresas Automotrices del Ecuador) [31]. Table 1 below shows the technical specifications.

Table 1. Technical specifications of the study vehicle.

Vehicle Data		
Brand	Chevrolet	
Model	Emotion	
Year	2015	
Fuel	Gasolina	
Displacement	4 cilindros, 1,8L	
Type	DOCH 16V	
Power	103 Hp @ 6000 RPM	
Torque	144.1 Nm @ 3600 RPM	

2.3. Measuring Instruments and Data Collection

The “OBDLINK MX” diagnostic device was used as a tool to collect speed data. It is connected to the vehicle’s OBD II port, which is usually located on the lower part of the dashboard, near the steering wheel. This port allows communication between the device and the different control units of the vehicle, facilitating the diagnosis of problems and the reading of data [32].

It is important to note that the use of this device for data collection involves the application of several protocols, being in this case supported by ISO 15765-4:2016. This standard focuses on diagnostic communication via the controller area network (CAN) in vehicles, which ensures greater reliability and more accurate data collection [33].

The device was operated using the “OBDWiz” program, an application designed for Windows systems. This tool made it possible to interact with the vehicle’s ECM (Engine Control Unit) through an intuitive interface and a firm structure. Thanks to this, real-time data can be obtained and key parameters related to the vehicle’s performance and general condition can be analyzed, thus extending its capabilities for automotive diagnostics. In addition, it was necessary to use a voltage converter to ensure that the computer with the installed software remained charged during data collection.

Finally, the application used for traffic analysis was Google Maps, an effective tool for mobility and traffic analysis. It provides real-time data on congestion, travel times and traffic patterns. Thanks to its detailed information and up-to-date databases, it facilitates road efficiency analysis, optimal route planning and customization of studies through Google My Maps and its traffic management APIs [34].

2.4. Data Collection Methodology

The methodology used in this study is the so-called direct method, which consists in the acquisition of data of speed values with respect to the time of the real conditions of urban traffic in the city, a clear example is the American cycle FTP 75, which is used in the homologation and consumption tests in Ecuadorian vehicles. By means of this method, data collection can be obtained by different techniques, of which the ON BOARD technique was used, which consists of the instrumentation of the vehicle, in which a category M1 vehicle was used. At the same time, 3 drivers were required, alternating on each route, to simulate the real conditions on the routes [16,17].

The Chevrolet Aveo Emotion 1.6 4P 4X2 TM, which was instrumented with an OBD device, was used as the test vehicle. The OBDLINK MX+ was used to collect data in real time, along with the OBDWiz program for processing and storing data on each of the runs. The input variables recorded

in the program are: speed, time, distance, as the main parameters for the elaboration of the characteristic curves.

Pilot tests were conducted for the selection of the routes established in various areas of the city of Guayaquil, comprising the North, South, Center and West; in which the total number of repetitions was established for each route. Next, in Figure 3 (a), a flow chart was made that explains in detail the process used to acquire data and obtain the representative DC for each route: first, the vehicle was turned on and the presence of any warning indicator on the dashboard was verified. If any anomaly was detected, the vehicle was taken to a workshop for diagnosis. In the absence of warnings, the fuel, oil and coolant levels were checked to ensure that the vehicle was in optimum condition.

Then, the route was chosen and, in turn, the vehicle was instrumented using the OBD LINK MX+ device. Then, the OBDWiz program was opened to record the input variables, and the software started to collect the information during the trip. Once finished, the data recording was stopped, and the data was imported in “.csv” format in Microsoft Excel. Finally, the data was collected, and, through statistical analysis, normality tests were determined for each route using Minitab software, in order to analyze the distribution of the data and obtain DC for each one. For the correct instrumentation and monitoring of data in the vehicle, it was essential to follow a specific procedure for each established route, as shown in Figure 3, item (b).

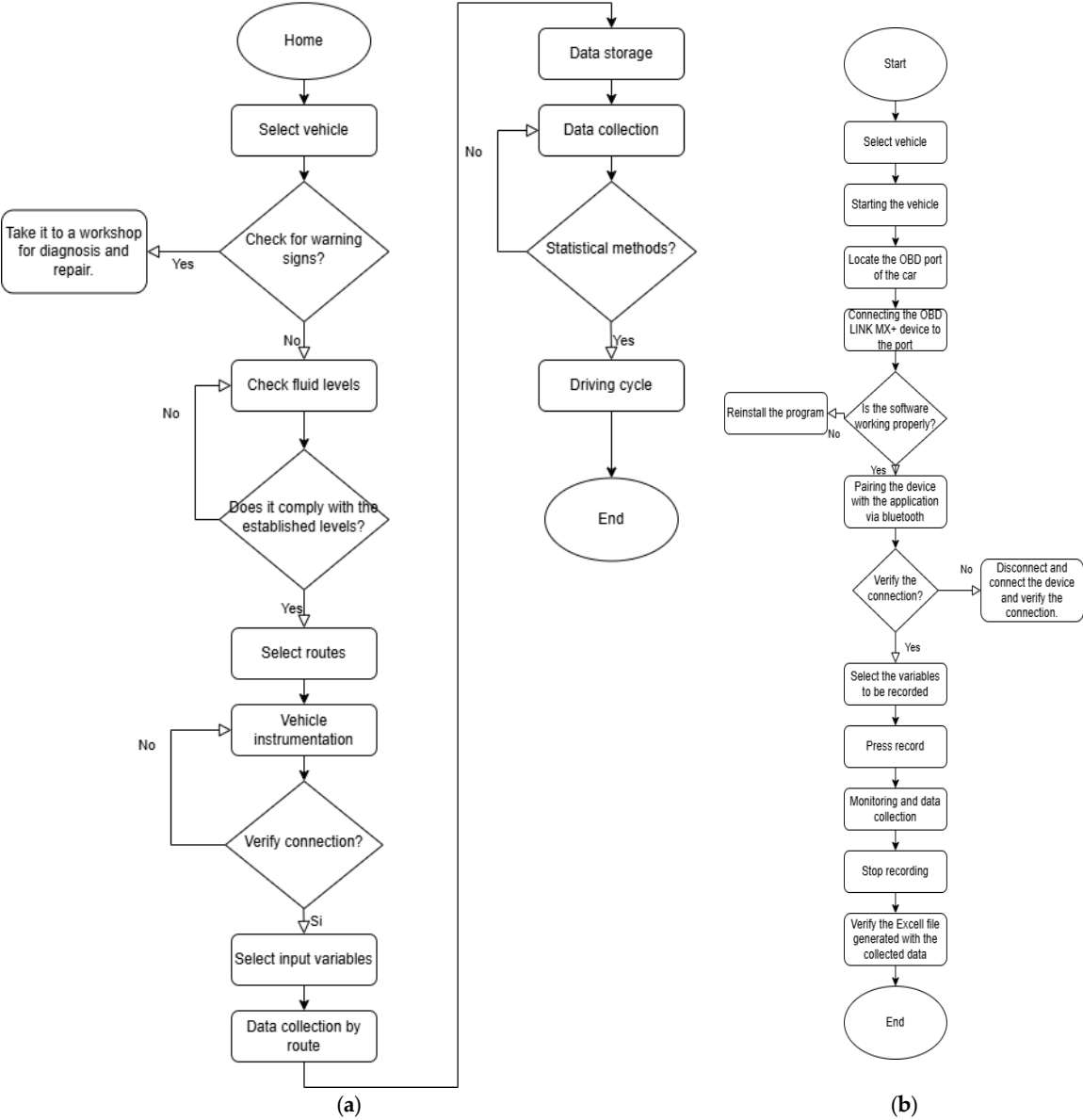


Figure 3. Flow diagrams: (a) Process flow chart for data acquisition and driving cycle acquisition. (b) On-board instrumentation and device control.

2.5. Data Analysis Methods and Techniques

2.5.1. Data Analysis Tools

The specialized statistical analysis software Minitab was used, which is a tool recognized for its ability to investigate and analyze data in different areas. It provides a platform that allows users to perform exploratory data analysis, hypothesis testing, statistical modeling and quality control with high scientific accuracy. Its user-friendly interface and diverse statistical functionalities facilitate the conduct of studies and drive data-driven decision making in both academia and industry [35,36].

2.5.2. Data Analysis Methodology

The following variables were collected and used in different studies to obtain a representative driving cycle [16,18]:

Table 2. Variables of analysis.

Variables of analysis
Controllable variables
Distance (km)
Time (s)
Non-controllable variables
Ambient temperature (Celsius) Altitude (m.s.n.m.)
Wind speed (m/s) Fuel quality (Octane)
Route conditions (Regular)
Response variable
Maximum speed (km/h) Average speed (km/h) Number of stops (N) Idle time (s)
Positive acceleration time (s)
% of driving time
% of time accelerating

2.5.3. Data Processing Methodology

The methodology implemented for the analysis of the data obtained was based on previous studies carried out in different countries, such as the United States, Colombia, among others [37]. Likewise, it was used in the determination of driving cycles in various cities of Ecuador, such as Quito, Esmeraldas, Cuenca and Riobamba [16–18,38], applying the weighting criterion. This method consisted of selecting, within a set of data, the most relevant one. To this end, each variable was assigned a value according to its degree of importance, using a scale from 0 to 1, where 0 represented the least importance and 1 the greatest. These values were established in multiples of 0.25. Table 3 shows the weighting weights assigned to each variable previously defined, according to its relevance.

Table 3. Variables and their respective weightings in the study.

Variables	Weightings (Wi)
Maximum speed (km/h)	1
Average speed (km/h)	0.25
Number of stops	1
Driving time (s)	0.25
Idle time (s)	0.75
Distance traveled (m)	1

Positive acceleration time (s)	0.25
% of driving time	1
% of time accelerating	1

Next, the lowest value of “Y” is selected because it represents the smallest deviation from the mean/median. This is determined as follows:

$$\gamma = \frac{W_i * \frac{|X_{ij} - \tilde{X}|}{\tilde{X}}}{Total\ Weightings}, \tag{1}$$

- Y : Weighted mean/median of the deviations of all parameters from the arithmetic mean.
- W_i : Weighting coefficient.
- $X_{(i,j)}$: Value of the variable.
- $\tilde{X}$: Mean / median of the variable.
- $\frac{|X_{ij}-\tilde{X}|}{\tilde{X}}$: Deviation from the mean/median with absolute value.

It is worth mentioning that, before performing this analysis, it is necessary to carry out a normality test to determine the distribution of the data. From there, the centra tendency measure is calculated, which can be the mean or the median. Then, the weighted mean/median of the deviations of all variables from the arithmetic mean “Y” is calculated for each of the cases, as in Equation 1. Finally, the minimum value of the total obtained is selected. This value represents the smallest deviation from the mean/median, which indicates that the driving cycle among the analyzed repetitions corresponds to the one with the smallest value of “Y”.

3. Results

3.1. Pilot Test

Pilot tests were carried out to determine the routes in different areas of the city of Guayaquil, establishing a total of four routes as shown in Table 4. To calculate the sample size, Minitab software was used to determine the total number of repetitions for each route. Prior to this calculation, a descriptive analysis was carried out in Minitab, through which the deviation and standard error of the mean were obtained, fundamental elements for establishing the sample size. The variable that was analyzed was speed, given that, since we are dealing with driving cycles, the main parameters of this study were speed and time.

Table 4. Average per route traveled.

Tours	Routes	Distance (km)	Time (s)	Average Speed (km/h)
Vía a la Costa-Peaje	1	14.9	777.139	63.94
San Marino-Colegio Americano	2	5.7	839.934	22.22
Av. 9 de Octubre-El Oro	3	3.9	1111.917	11.93
UPS Centenario-17th Street and Portete	4	4.7	681.925	22.96

From the data collected in each pilot test, the standard deviation and standard error were calculated to estimate the appropriate sample size for each route. This analysis was performed using Minitab software, which allowed determining a total of 12 replicates for Route 1 and 11 replicates for the other routes, as detailed in Table 5. In total, 45 replicates were obtained.

Table 5. Sample size.

Routes	Tours	Standard deviation	Standard error	Sample Size	Total number of repetitions
1	Vía a la Costa-Peaje	18.45	0.617	1836	12
2	San Marino-Colegio Americano	17.87	0.643	1594	11
3	Av. 9 de Octubre-El Oro	13.527	0.402	2308	11
4	UPS Centenario-17th Street and Portete	15.48	0.585	1450	11

3.2. Data Collection

After completing all the repetitions, the processing of the data stored in the Microsoft Excel program was started, in which the data from each of the repetitions were grouped in their respective route, including the pilot tests. Once the data were collected and organized, filtering began with a resolution of 1 second. This is because the results obtained for each repetition were recorded at 0.1 second intervals, generating a total of 10,000 data per repetition.

The reduction in resolution was essential to eliminate visual noise and highlight major trends, allowing for a less dense graphical representation while maintaining meaningful patterns. This adjustment simplified the plots, preserving the overall trends more clearly [39–41]. In addition, this process reduced the data for each repetition from 10,000 to a range of 700 to 1000 data per repetition, making it easier to manipulate and analyze. Once the data were pooled and filtered, normality tests (N.P.) were performed for each of the routes to determine the distribution of the data and select the appropriate measure of central tendency [42].

3.3. Analysis of Data Obtained

The data obtained for Route 1 (Via a la Costa-Peaje), which included 12 repetitions, are presented below. In each repetition, the OBD LINK MX+ device was used to record the variables detailed in Table 6. These variables reflect traffic behavior and are fundamental for obtaining and analyzing the driving cycle.

Table 6. Data obtained from Route 1 (Via a la Costa-Peaje).

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	64,38	79	0	750,54	5	14890	623	99,33	83,01
2	67,32	89	0	714,05	9	14899	565	98,74	79,13
3	65,80	83	0	730,50	11	14902	592	98,49	81,04
4	65,50	77	0	762,14	13	14911	588	98,29	77,15
5	67,58	87	0	713,81	12	14898	500	98,32	70,05
6	66,02	81	0	730,53	19	14904	553	97,40	75,70
7	65,39	79	0	735,62	10	14901	556	98,64	75,58
8	59,83	77	0	830,76	8	14897	667	99,04	80,29
9	61,87	73	0	781,19	7	14907	581	99,10	74,37

10	63,99	79	0	750,64	6	14888	566	99,20	75,40
11	66,30	84	0	725,00	13	14893	653	98,21	90,07
12	59,87	74	0	829,14	12	14896	665	98,55	80,20

For Route 2 (San Marino - Colegio Americano), which included 11 replicates, the variables listed in Table 7 were recorded.

Table 7. Data obtained from Route 2 (San Marino-Colegio Americano).

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	24,32	64	5	756,034	200	5691	277	73,55	36,64
2	24,20	58	6	751,015	149	5707	316	80,16	42,08
3	21,79	62	7	845,622	281	5699	317	66,77	37,49
4	20,70	54	5	882,628	262	5698	285	70,32	32,29
5	18,37	66	7	997,481	425	5710	313	57,39	31,38
6	21,29	69	7	855,873	305	5700	297	64,36	34,70
7	25,69	66	4	714,186	212	5711	247	70,32	34,58
8	20,40	66	8	898,316	331	5697	313	63,15	34,84
9	19,10	61	8	944,384	379	5690	301	59,87	31,87
10	22,03	62	4	819,683	249	5695	319	69,62	38,92
11	21,39	67	4	850,091	243	5712	306	71,41	36,00

Likewise, for Route 3 (Av. 9 de Octubre - El Oro), which included 11 repetitions, the variables listed Table 8 were recorded.

Table 8. Data obtained from Route 3 (Av. 9 de Octubre-El Oro).

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	12,03	41	14	1118,043	417	3899	330	62,70	29,52
2	11,05	50	18	1223,416	613	3900	332	49,89	27,14
3	9,86	53	24	1349,582	676	3898	367	49,91	27,19
4	9,48	53	20	1407,603	758	3880	373	46,15	26,50
5	9,57	49	22	1391,487	701	3901	363	49,62	26,09

6	10,93	54	17	1229,422	638	3904	319	48,11	25,95
7	10,63	57	22	1260,551	607	3896	384	51,85	30,46
8	10,50	44	19	1265,836	558	3910	320	55,92	25,28
9	9,41	48	20	1380,757	689	3892	327	50,10	23,68
10	17,43	58	10	762,672	233	3895	290	69,45	38,02
11	11,24	47	16	1187,074	534	3901	311	55,02	26,20

Finally, for Route 4, comprising UPS Centenario - 17th Street and Portete, data were 300 collected for its 11 repetitions, on various variables, which were recorded directly by the 301 OBD device, as shown in Table 9.

Table 9. Data obtained from Route 4 (UPS Centenario-17th Street and Portete).

R	Average speed (km/h)	Maximum speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	15,76	43	13	988,19	345	4701	338	65,09	34,20
2	16,65	36	7	943,40	192	4700	566	79,65	60,00
3	17,71	44	10	873,02	217	4698	355	75,14	40,66
4	16,01	47	13	977,14	295	4692	352	69,81	36,02
5	16,27	39	11	961,22	247	4689	374	74,30	38,91
6	16,52	58	12	955,73	313	4711	287	67,25	30,03
7	14,17	41	16	1099,16	402	4694	371	63,43	33,75
8	17,50	45	8	886,64	229	4707	265	74,17	29,89
9	19,42	50	7	802,86	196	4699	253	75,59	31,51
10	17,03	46	10	918,60	249	4698	284	72,89	30,92
11	15,04	42	13	1040,42	331	4703	364	68,19	34,99

3.4. Normality Test

Once all the routes had been compiled, the statistical analysis of this study was carried out. As part of the analysis, it was necessary to examine the distribution of the data obtained. Appendix B presents the Anderson-Darling normality test, which was applied to each of the routes evaluated in the experiment. On the other hand, to carry out this analysis, the data corresponding to the repetitions performed for each route were grouped in order to obtain the specific normality test in each case.

Using Minitab software, the Anderson-Darling normality test was run on the four routes analyzed, since this test allows one to verify whether the data follow a normal distribution. Figure 4 (a) shows the test applied to route 1 (Via a la Costa-Peaje). The results indicate that the data are not

normally distributed, as the obtained value of p is less than 0.05, which leads to the rejection of the null hypothesis. Therefore, the median is used as a representative measure for this route.

Similarly, the tests applied to the other routes, shown in Figures 4 (b), (c) and (d), also reveal that the data do not follow a normal distribution. Consequently, the same median-based method was used for the remaining routes.

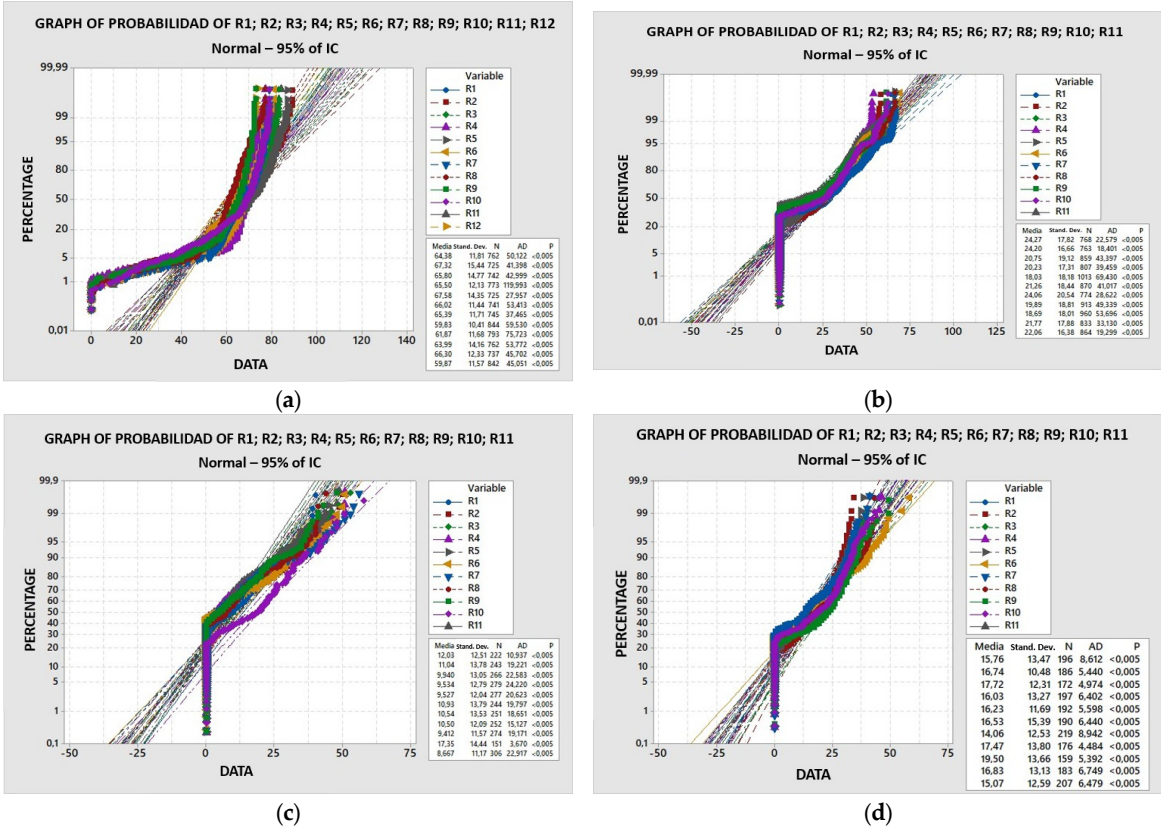


Figure 4. Normality Test: (a) Route 1 does not follow a normal distribution in its data. (b) Route 2 does not follow a normal distribution in its data. (c) Route 3 does not follow a normal distribution in its data. (d) Route 4 does not follow a normal distribution in its data.

3.5. Weighting Criteria

After performing the normality test, it was determined that the data did not follow a normal distribution. For this reason, the median (X) was calculated from the 12 repetitions. With these values, the “Y” value was obtained for each of the variables analyzed in each of the repetitions of Route 1 (Via a la Costa - Toll). Subsequently, these values were added in each repetition to obtain the total “Y” in each case. Finally, the value with the smallest deviation with respect to the median was selected, thus identifying that the corresponding driving cycle among the selected repetitions is number 7, as shown in Table 10.

Table 10. Statistical results of the data obtained in Route 1: Selected repetition number 7.

	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating	Total
W	1	0,25	0,25	1	0,75	1	0,25	1	1	6,5
$\bar{X}$	65,45	79,00	0	743,08	10,50	14899	584,50	98,60	78,14	
1 X_{ij}	64,38	79	0	750,54	5	14890	623	99,33	83,01	

	Y	0,00250 37	0,00000 00	0	0,00154 41	0,06043 96	0,00008 78	0,0025334	0,00115 02	0,0095851	0,07784 38
	$X_{i,j}$	67,32	89	0	714,05	9	14899	565	98,74	79,13	
2	Y	0,00439 32	0,00486 85	0	0,00601 01	0,01648 35	0,00000 52	0,0012831	0,00022 30	0,0019436	0,03521 03
	$X_{i,j}$	65,80	83	0	730,50	11	14902	592	98,49	81,04	
3	Y	0,00083 11	0,00194 74	0	0,00260 60	0,00549 45	0,00003 61	0,0004935	0,00015 99	0,0057143	0,01728 29
	$X_{i,j}$	65,50	77	0	762,14	13	14911	588	98,29	77,15	
4	Y	0,00012 62	0,00097 37	0	0,00394 51	0,02747 25	0,00012 91	0,0002303	0,00047 18	0,0019436	0,03529 23
	$X_{i,j}$	67,58	87	0	713,81	12	14898	500	98,32	70,05	
5	Y	0,00500 60	0,00389 48	0	0,00606 00	0,01648 35	0,00000 52	0,0055603	0,00043 34	0,0159326	0,05337 59
	$X_{i,j}$	66,02	81	0	730,53	19	14904	553	97,40	75,70	
6	Y	0,00134 44	0,00452 49	0	0,00259 83	0,09340 66	0,00005 68	0,0020728	0,00186 85	0,0048048	0,11067 72
	$X_{i,j}$	65,39	79	0	735,62	10	14901	556	98,64	75,58	
7	Y	0,00012 62	0,00000 00	0	0,00154 41	0,00549 45	0,00002 58	0,0018754	0,00006 86	0,0050335	0,01416 81
	$X_{i,j}$	59,83	77	0	830,76	8	14897	667	99,04	80,29	
8	Y	0,01321 36	0,00097 37	0	0,01815 29	0,02747 25	0,00001 55	0,0054287	0,00068 71	0,0042315	0,07017 56
	$X_{i,j}$	61,87	73	0	781,19	7	14907	581	99,10	74,37	
9	Y	0,00840 51	0,00292 11	0	0,00788 88	0,03846 15	0,00008 78	0,0002303	0,00079 15	0,0074118	0,06619 79
	$X_{i,j}$	63,99	79	0	750,64	6	14888	566	99,20	75,40	
10	Y	0,00342 30	0,00000 00	0	0,00156 42	0,04945 05	0,00010 84	0,0012173	0,00094 25	0,0053869	0,06209 28
	$X_{i,j}$	66,30	84	0	725,00	13	14893	653	98,21	90,07	
11	Y	0,00201 13	0,00243 43	0	0,00374 37	0,02747 25	0,00005 68	0,0045075	0,00060 82	0,0234895	0,06432 37
	$X_{i,j}$	59,87	74	0	829,14	12	14896	665	98,55	80,20	
12	Y	0,01310 29	0,00243 43	0	0,01781 66	0,01648 35	0,00002 58	0,0052971	0,00006 86	0,0040662	0,05929 51

Next, the value of “Y” was calculated for each of the variables in the 11 repetitions and the one with the lowest value was chosen. Thus, it was concluded that the driving cycle associated with Route 2 (San Marino Shopping - Colegio Americano), among the 11 repetitions, corresponds to repetition number 11, as shown in Table 11.

Table 11. Statistical results of the data obtained in Route 2: Selected repetition number 11.

	Avera ge speed (km/h)	Max. speed (km/h)	N	Drivin g time (s)	Idle time (s)	Distan ce (m)	Positive accelerat ion time (s)	% of drivin g time	% of time accelerat ing	Total
W	1	0,25	0,25	1	0,75	1	0,25	1	1	6,5
$\tilde{X}$	21,39	64,00	6	850,09	262,00	5699	306,00	69,62	34,84	
1 $X_{i,j}$	24,32	64	5	756,03 4	200	5691	277	73,55	36,64	

	Y	0,0210 822	0,0000 000	0,0064 10	0,0170 221	0,0273 048	0,0002 160	0,003645 0	0,0086 704	0,007928 3	0,0922 790
	$X_{i,j}$	24,20	58	6	751,01 5	149	5707	316	80,16	42,08	
2	Y	0,0202 616	0,0036 058	0,0000 00	0,0179 304	0,0497 651	0,0002 160	0,001256 9	0,0232 856	0,031938 5	0,1482 599
	$X_{i,j}$	21,79	62	7	845,62 2	281	5699	317	66,77	37,49	
3	Y	0,0028 959	0,0012 019	0,0064 10	0,0008 088	0,0083 676	0,0000 000	0,001382 6	0,0063 030	0,011675 4	0,0390 453
	$X_{i,j}$	20,70	54	5	882,62 8	262	5698	285	70,32	32,29	
4	Y	0,0049 146	0,0060 096	0,0064 10	0,0058 884	0,0000 000	0,0000 270	0,002639 5	0,0015 325	0,011272 7	0,0386 946
	$X_{i,j}$	18,37	66	7	997,48 1	425	5710	313	57,39	31,38	
5	Y	0,0216 879	0,0012 019	0,0064 10	0,0266 741	0,0717 851	0,0002 969	0,000879 8	0,0270 243	0,015294 7	0,1712 550
	$X_{i,j}$	21,29	69	7	855,87 3	305	5700	297	64,36	34,70	
6	Y	0,0007 106	0,0113 122	0,0064 10	0,0010 464	0,0189 372	0,0000 270	0,001131 2	0,0116 199	0,000625 1	0,0518 198
	$X_{i,j}$	25,69	66	4	714,18 6	212	5711	247	70,32	34,58	
7	Y	0,0309 813	0,0012 019	0,0128 21	0,0245 956	0,0220 200	0,0003 239	0,007415 8	0,0015 323	0,001139 8	0,1020 311
	$X_{i,j}$	20,40	66	8	898,31 6	331	5697	313	63,15	34,84	
8	Y	0,0070 766	0,0012 019	0,0128 21	0,0087 276	0,0303 876	0,0000 540	0,000879 8	0,0142 950	0,000000 0	0,0754 430
	$X_{i,j}$	19,10	61	8	944,38 4	379	5690	301	59,87	31,87	
9	Y	0,0164 608	0,0018 029	0,0128 21	0,0170 648	0,0515 267	0,0002 430	0,000628 5	0,0215 545	0,013115 3	0,1352 169
	$X_{i,j}$	22,03	62	4	819,68 3	249	5695	319	69,62	38,92	
0	Y	0,0046 427	0,0012 019	0,0128 21	0,0055 031	0,0057 252	0,0001 080	0,001634 0	0,0000 000	0,017990 7	0,0496 261
1	$X_{i,j}$	21,39	67	4	850,09 1	243	5712	306	71,41	36,00	
1	Y	0,0000 000	0,0018 029	0,0128 21	0,0000 000	0,0083 676	0,0003 509	0,000000 0	0,0039 608	0,005091 7	0,0323 944

Then, the value of “Y” was calculated for each of the variables in the 11 repetitions and the one with the lowest value was chosen. Thus, it was concluded that the driving cycle associated with Route 3 (Av. 9 de Octubre - El Oro), among the 11 repetitions, corresponds to repetition number 2, as shown in Table 12.

Table 12. Statistical results of the data obtained in Route 3: Selected repetition number 2.

Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating	Total
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	W	1	0,25	0,25	1	0,75	1	0,25	1	1	6,5
	$\bar{X}$	10,63	50,00	19	1260,55	613,00	3899	330,00	50,10	26,50	
1	$X_{i,j}$	12,03	41	14	1118,04 3	417	3899	330	62,70	29,52	
	Y	0,02017 71	0,00692 31	0,0101 21	0,01739 26	0,03689 30	0,00000 00	0,0000000 0	0,03870 07	0,0175154 0	0,14772 33
2	$X_{i,j}$	11,05	50	18	1223,41 6	613	3900	332	49,89	27,14	
	Y	0,00597 18	0,00000 00	0,0020 24	0,00453 22	0,00000 00	0,00003 95	0,0002331 0	0,00063 09	0,0037051 0	0,01713 68
3	$X_{i,j}$	9,86	53	24	1349,58 2	676	3898	367	49,91	27,19	
	Y	0,01126 47	0,00230 77	0,0101 21	0,01086 59	0,01185 85	0,00003 95	0,0043124 0	0,00058 17	0,0040330 0	0,05538 47
4	$X_{i,j}$	9,48	53	20	1407,60 3	758	3880	373	46,15	26,50	
	Y	0,01664 30	0,00230 77	0,0020 24	0,01794 72	0,02729 33	0,00074 97	0,0050117 0	0,01213 04	0,0000000 0	0,08410 72
5	$X_{i,j}$	9,57	49	22	1391,48 7	701	3901	363	49,62	26,09	
	Y	0,01537 88	0,00076 92	0,0060 73	0,01598 03	0,01656 42	0,00007 89	0,0038462 0	0,00146 66	0,0023905 0	0,06254 76
6	$X_{i,j}$	10,93	54	17	1229,42 2	638	3904	319	48,11	25,95	
	Y	0,00432 24	0,00904 98	0,0040 49	0,00379 92	0,00470 57	0,00019 73	0,0012821 0	0,00612 36	0,0032036 0	0,03673 22
7	$X_{i,j}$	10,63	57	22	1260,55 1	607	3896	384	51,85	30,46	
	Y	0,00000 00	0,00538 46	0,0060 73	0,00000 00	0,00112 94	0,00011 84	0,0062937 0	0,00536 35	0,0230135 0	0,04737 60
8	$X_{i,j}$	10,50	44	19	1265,83 6	558	3910	320	55,92	25,28	
	Y	0,00189 49	0,00461 54	0,0000 00	0,00064 50	0,01035 26	0,00043 40	0,0011655 0	0,01786 78	0,0070784 0	0,04405 37
9	$X_{i,j}$	9,41	48	20	1380,75 7	689	3892	327	50,10	23,68	
	Y	0,01768 12	0,00153 85	0,0020 24	0,01467 08	0,01430 54	0,00027 62	0,0003497 0	0,00000 00	0,0163507 0	0,06719 66
10	$X_{i,j}$	17,43	58	10	762,672	233	3895	290	69,45	38,02	
	Y	0,09831 64	0,00615 38	0,0182 19	0,06076 45	0,07152 72	0,00015 78	0,0046620 0	0,05941 88	0,0669127 0	0,38613 19
11	$X_{i,j}$	11,24	47	16	1187,07 4	534	3901	311	55,02	26,20	
	Y	0,00876 57	0,00230 77	0,0060 73	0,00896 76	0,01487 01	0,00007 89	0,0022145 0	0,01509 48	0,0017422 0	0,06011 43

Finally, the value of “Y” was calculated for each of the variables in the 11 repetitions and the one with the lowest value was chosen. Thus, it was concluded that the driving cycle associated with Route 4 (UPS Centenario - 17th Street and Portete), among the 11 repetitions, corresponds to repetition number 5, as shown in Table 13.

Table 13. Statistical results of the data obtained in Route 4: Selected repetition number 5.

	Avera ge speed (km/h)	Max. speed (km/h)	N	Drivin g time (s)	Idle time (s)	Distan ce (m)	Positive accelerat ion time (s)	% of drivin g time	% of time accelerat ing	Total	
	W	1	0,25	0,25	1	0,75	1	0,25	1	6,5	
	$\tilde{X}$	16,52	44,00	11	955,73	249,00	4699	352,00	72,89	34,20	
	$X_{i,j}$	15,76	43	13	988,19	345	4701	338	65,09	34,20	
1	Y	0,0070	0,0008	0,0069	0,0052	0,0444	0,0000	0,001529	0,0164	0,000000	0,0826
		430	741	93	255	856	655	7	744	0	908
	$X_{i,j}$	16,65	36	7	943,40	192	4700	566	79,65	60,00	
2	Y	0,0012	0,0069	0,0139	0,0019	0,0264	0,0000	0,023382	0,0142	0,116009	0,2042
		391	930	86	846	133	327	9	561	4	973
	$X_{i,j}$	17,71	44	10	873,02	217	4698	355	75,14	40,66	
3	Y	0,0110	0,0000	0,0034	0,0133	0,0148	0,0000	0,000327	0,0047	0,029054	0,0768
		917	000	97	139	285	327	8	495	4	950
	$X_{i,j}$	16,01	47	13	977,14	295	4692	352	69,81	36,02	
4	Y	0,0046	0,0026	0,0069	0,0034	0,0213	0,0002	0,000000	0,0065	0,008184	0,0539
		737	224	93	461	160	292	0	082	8	734
	$X_{i,j}$	16,27	39	11	961,22	247	4689	374	74,30	38,91	
5	Y	0,0022	0,0043	0,0000	0,0008	0,0009	0,0003	0,002403	0,0029	0,021162	0,0353
		776	706	00	844	268	274	8	762	0	288
	$X_{i,j}$	16,52	58	12	955,73	313	4711	287	67,25	30,03	
6	Y	0,0000	0,0316	0,0034	0,0000	0,0296	0,0003	0,007102	0,0119	0,018776	0,1030
		000	742	97	000	571	929	3	105	4	099
	$X_{i,j}$	14,17	41	16	1099,16	402	4694	371	63,43	33,75	
7	Y	0,0218	0,0026	0,0174	0,0230	0,0708	0,0001	0,002076	0,0199	0,002027	0,1601
		351	224	83	881	990	637	0	804	7	750
	$X_{i,j}$	17,50	45	8	886,64	229	4707	265	74,17	29,89	
8	Y	0,0091	0,0008	0,0104	0,0111	0,0092	0,0002	0,009506	0,0026	0,019412	0,0728
		915	741	90	210	678	619	1	990	5	235
	$X_{i,j}$	19,42	50	7	802,86	196	4699	253	75,59	31,51	
9	Y	0,0270	0,0052	0,0139	0,0246	0,0245	0,0000	0,010817	0,0056	0,012107	0,1240
		389	448	86	071	598	000	3	858	2	468
	$X_{i,j}$	17,03	46	10	918,60	249	4698	284	72,89	30,92	
10	Y	0,0048	0,0017	0,0034	0,0059	0,0000	0,0000	0,007430	0,0000	0,014785	0,0382
		295	483	97	774	000	327	1	000	4	999
	$X_{i,j}$	15,04	42	13	1040,42	331	4703	364	68,19	34,99	
11	Y	0,0137	0,0017	0,0069	0,0136	0,0379	0,0001	0,001311	0,0099	0,003517	0,0890
		399	483	93	328	981	310	2	355	3	070

3.6. Characteristic Curves

3.6.1. Route 1 (Via a la Costa - Peaje)

Figure 5 below shows the driving cycle representative of Route 1 corresponding to repetition number 7, which covers the route from the Via a la Costa to the Chongon Toll. Table 14 also shows the characteristic variables associated with this cycle.

Table 14. Driving cycle parameters Route 1.

Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
65,39	79	0	735,62	10	14901	556	98,64	75,58

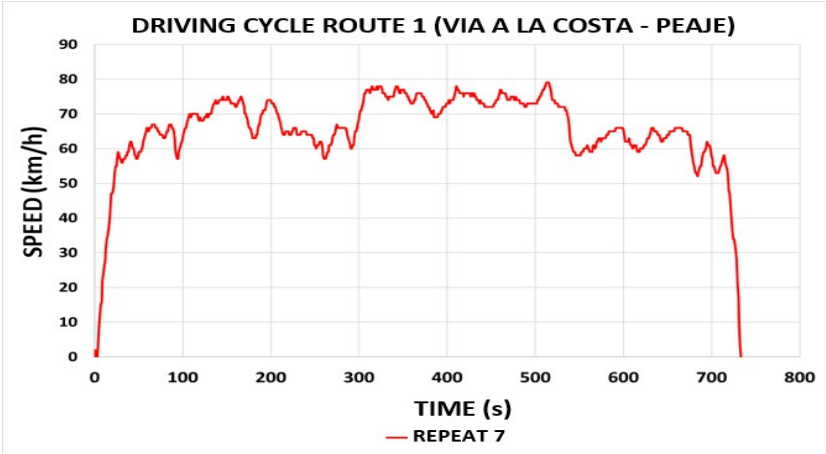


Figure 5. Speed vs. Time Graph (Via a la Costa-Peaje).

3.6.2. Route 2 (San Marino - Colegio Americano)

Figure 6 shows the driving cycle representative of Route 2 corresponding to repetition number 11, which covers the route from San Marino to Colegio Americano. Table 15 also shows the characteristic variables associated with this cycle.

Table 15. Driving cycle parameters Route 2.

Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
21,39	67	4	850,091	243	5712	306	71,41	36,00

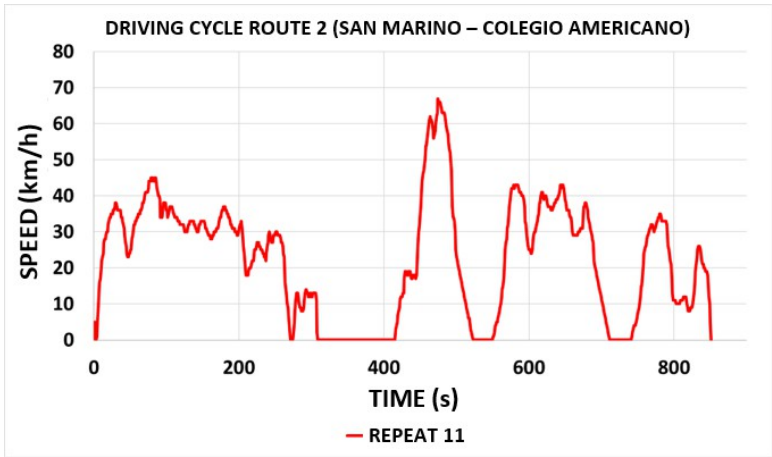


Figure 6. Speed vs. Time Graph (San Marino-Colegio Americano).

3.6.3. Route 3 (Av. 9 de Octubre - El Oro)

Figure 7 below shows the driving cycle representative of Route 3 corresponding to repetition number 2, which covers the route from Av. 9 de Octubre to El Oro. Table 16 also shows the characteristic variables associated with this cycle.

Table 16. Driving cycle parameters Route 3.

Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
11,05	50	18	1223,416	613	3900	332	49,89	27,14

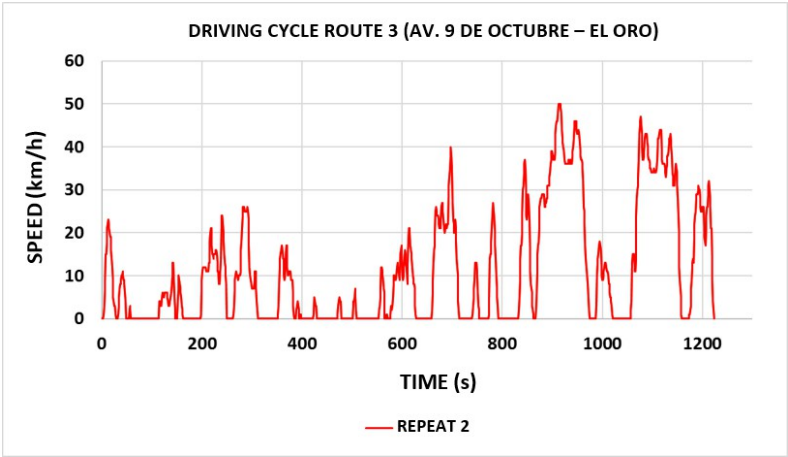


Figure 7. Speed vs. Time Graph (Av. 9 de Octubre-El Oro).

3.6.4. Route 4 (UPS Centenario - Calle 17 y Portete)

Figure 8 below shows the representative driving cycle for Route 4 corresponding to repetition number 5, which covers the route from UPS Centenario to 17th Street and Portete. Table 17 also shows the characteristic parameters associated with this cycle.

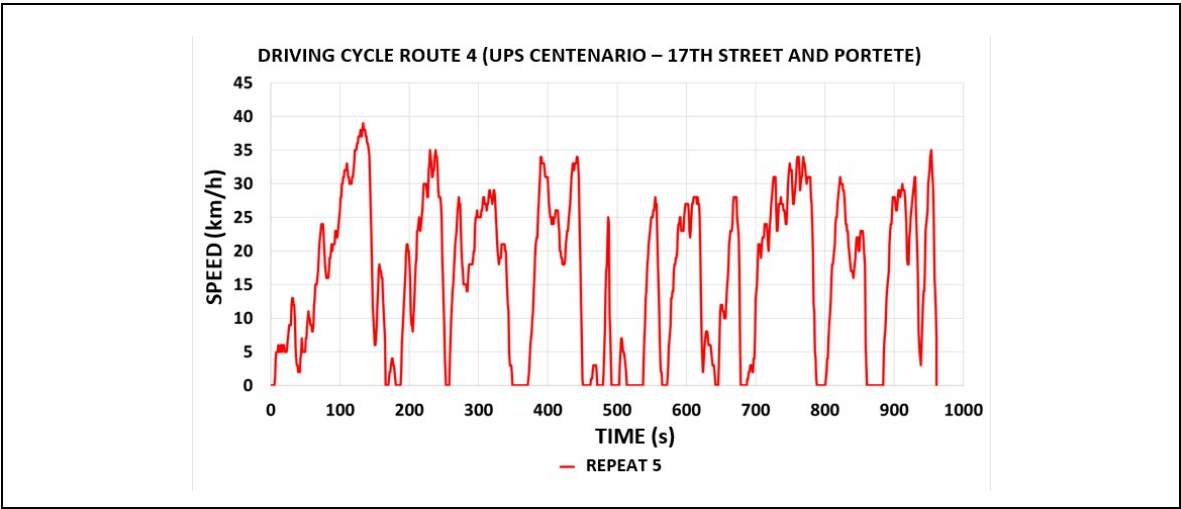


Figure 8. Speed vs. Time Graph (UPS Centenario-17th Street and Portete).

Table 17. Driving cycle parameters Route 4.

Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
16,27	39	11	961,22	247	4689	374	74,30	38,91

3.7. Comparisons with other Driving Cycles

The driving cycles in Guayaquil show significant differences compared to standardized cycles (FTP-75, HWFET, and NEDC). Vía a la Costa has the highest average speed (65.39 km/h), similar to HWFET (77.7 km/h), while Route 3 and WSL have the lowest speeds (11.05 km/h and 6.7 km/h, respectively), indicating more congested traffic. In terms of maximum speed, NEDC leads with 120.09 km/h, far exceeding the values recorded in Guayaquil. Route 3 has the highest number of stops (18), similar to FTP-75 (16), reflecting more stop-and-go traffic conditions. Regarding driving time, NEDC is the longest (1633 s), followed by Route 3 (1223 s). Idling time is significantly high in Route 3 (613 s) and in FTP-75 and NEDC cycles (241 s), showing prolonged traffic standstills.

In terms of distance traveled, NEDC has the highest value (17,786 m), while Route 3 records the lowest (3,900 m), confirming its heavy congestion. For the proportion of driving time, HWFET and Vía a la Costa stand out with values close to 100 percent, indicating smooth traffic flow, whereas Route 3 (49.89 percent) and NEDC (79.58 percent) show lower efficiency. Finally, acceleration time is highest in Vía a la Costa (75.58 percent), surpassing the standardized cycles, suggesting more dynamic driving conditions in this area. As shown in Table 18.

Table 18. Comparison with other driving cycles.

Variables	Guayaqui 1/ Vía a la Costa	Guayaqui 1/ San Marino	Guayaqui 1/ Centro	Guayaqui 1/ Portete	WSL Congeste d traffic cycle	FTP-75	HWFE T	NEDC
Average speed (km/h)	65,39	21,39	11,05	16,27	6,7	34,20	77,7	33,60
Max. speed (km/h)	79	67	50	39	43,65	91,09	96,32	120,09
N	0	4	18	11	22	16	0	14
Time (s)	735,624	850,091	1223,416	961,223	838	1633,00	764	939,00
Idle Time (s)	10	243	613	247	191	241	1	241
Distance (m)	14901	5712	3900	4689	1920,59	17786,5 9	16503,1 3	11016,6 3
Positive acceleration time (s)	556	306	332	374	314	683	264	278
% of driving time	98,64	71,41	49,89	74,3	81,44	87,14	99,87	79,58
% of time accelerating	75,58	36	27,14	38,91	30,52	36,45	34,51	23,56

The driving conditions in Guayaquil, Cuenca, and Quito vary significantly. Vía a la Costa and Quito / Highway have the highest average speeds (65.39 km/h and 65.98 km/h, respectively), while Guayaquil / Route 3 (11.05 km/h) and Quito / City (13.26 km/h) show the lowest speeds, indicating heavy congestion. In terms of maximum speed, Quito / Highway leads with 89.91 km/h, followed by Vía a la Costa (79 km/h), while Guayaquil / Route 3 (50 km/h) and Quito / City (45.77 km/h) have the lowest values, reflecting urban traffic conditions. Quito / Combined and Quito / City experience the highest number of stops (63 and 58, respectively), suggesting frequent traffic interruptions, whereas Vía a la Costa and Quito / Highway have the fewest stops (0 and 2, respectively), indicating smoother driving.

Guayaquil / Route 3 has the longest idling time (613 s), similar to Quito / Cobined (960 s) and Quito / City (1060 s), reinforcing their high congestion levels. Regarding distance traveled, Quito / Highway leads (27,463 m), followed by Quito / Combined (15,673 m) and Vía a la Costa (14,901 m), while Guayaquil / Route 3 records the shortest distance (3,900 m). Quito / Highway and Vía a la Costa also have the longest acceleration times (791 s and 556 s, respectively), suggesting dynamic driving conditions. The proportion of driving time and acceleration mode is highest in Vía a la Costa (98.64 percent and 75.58 percent, respectively), indicating efficient traffic flow, while urban areas such as Guayaquil / Route 3 and Quito / City exhibit lower values, reflecting stop-and-go conditions. As shown in Table 19.

Table 19. Comparison with other driving cycles.

Variables	Guayaquil / Vía a la Costa	Guayaquil / San Marino	Guayaquil / Centro	Guayaquil / Portete	Cuenca	Quito / Ciudad	Quito / Autopista	Quito / Combined
Average speed (km/h)	65,39	21,39	11,05	16,27	26,09	13,26	65,98	19,18
Max. speed (km/h)	79	67	50	39	61	45,77	89,91	78,32
N	0	4	18	11	12	58	2	63
Time (s)	735,624	850,091	1223,416	961,223	1168	3169,00	1493,00	2889,00
Idle Time (s)	10	243	613	247	280	1060	10	960
Distance (m)	14901	5712	3900	4689	10494	11914	27463	15673
Positive acceleration time (s)	556	306	332	374	530	1266	791	1036
% of driving time	98,64	71,41	49,89	74,3	81	-	-	-
% of time accelerating	75,58	36	27,14	38,91	36,6	-	-	-

The driving conditions across Guayaquil, Esmeraldas, and the Ambato-Riobamba route show notable differences. Vía a la Costa and Ambato-Riobamba / Highway have the highest average speeds (65.39 km/h and 60.95 km/h, respectively), indicating smooth traffic flow, while Guayaquil /

Route 3 (11.05 km/h) has the lowest, reflecting heavy congestion. In terms of maximum speed, Ambato-Riobamba / Highway leads with 120.4 km/h, far exceeding values recorded in Guayaquil. The number of stops is highest in Guayaquil / Route 3 (18), similar to Ambato-Riobamba / Urban (13), suggesting frequent interruptions, while Vía a la Costa and Ambato-Riobamba / Highway (0 and 2 stops, respectively) experience the most continuous traffic. Guayaquil / Route 3 also has the longest idling time (613 s), reinforcing its congested conditions.

Regarding driving time, Esmeraldas records 1,750 s, longer than any Guayaquil area but shorter than Ambato-Riobamba / Highway (2,500 s), which is expected for a highway route. The longest distance traveled is in Esmeraldas (15,420 m), surpassing Vía a la Costa (14,901 m), while Guayaquil / Route 3 has the shortest (3,900 m). The proportion of driving time is highest in Ambato-Riobamba / Highway (96.06 percent), similar to Vía a la Costa (98.64 percent), confirming smoother traffic conditions, while Guayaquil / Route 3 (49.89 percent) has the lowest value, indicating frequent stops and idling. Overall, highway routes such as Ambato-Riobamba / Highway and Vía a la Costa show the best driving efficiency, whereas urban areas like Guayaquil / Route 3 experience heavy congestion and frequent traffic interruptions. As shown in Table 20.

Table 20. Comparison with other driving cycles.

Variables	Guayaquil / Via a la Costa	Guayaquil / San Marino	Guayaquil / Centro	Guayaquil / Portete	Esmeraldas	Ambato – Riobamba / Carretera	Ambato – Riobamba / Urban
Average speed (km/h)	65,39	21,39	11,05	16,27	36,20	60,95	26,52
Max. speed (km/h)	79	67	50	39	-	120,40	63,40
N	0	4	18	11	-	2	13
Time (s)	735,624	850,091	1223,416	961,223	1750	2500	1300
Idle Time (s)	10	243	613	247	-	-	-
Distance (m)	14901	5712	3900	4689	15420	-	-
Positive acceleration time (s)	556	306	332	374	-	-	-
% of driving time	98,64	71,41	49,89	74,3	-	96,06	81,28
% of time accelerating	75,58	36	27,14	38,91	-	-	-

4. Discussion

The analysis of the driving conditions on the different routes evaluated reveals significant differences in terms of efficiency and fluidity, as shown in Table A1 of Appendix A. Route 1, which corresponds to the Via a la Costa - Peaje (VC) is the fastest route, with an average speed of 65.39 km/h and a maximum speed of 79 km/h, without stops and with only 10 seconds in idling. In contrast, Route 3 comprising the Downtown sector (C) is the most congested, with an average speed of just 11.05 km/h and a high idling time of 613 seconds, reflecting dense traffic and numerous interruptions.

The intermediate routes, Route 2 starting at the San Marino Shopping Center to the American School (SM) and Route 4, comprising UPS Centenario and, 17th Street and Portete (P), present mixed characteristics. San Marino has an average speed of 21.39 km/h and a maximum speed of 67 km/h, with an idling time of 243 seconds, while Portete shows an average speed of 16.27 km/h and a maximum speed of 39 km/h, with 247 seconds at idle. Both routes maintain relatively high active driving (71.41 percent and 74.30 percent, respectively), although with greater fluctuations in speed due to multiple stops and frequent accelerations.

In terms of stability and efficiency, the Via a la Costa (VC) stands out as the best option, with a continuous and uninterrupted route. On the other hand, the Downtown sector (C) is the least efficient route due to high congestion and long stopping times. San Marino (SM) and Portete (P) fall somewhere in between, with variable traffic conditions, but less critical than Downtown (C). These results underscore the importance of effective road planning to improve mobility in the most congested areas.

According to Table 18, when comparing Guayaquil's driving cycles with foreign cycles, key differences in speed, stops and vehicle flow are observed. The Via a la Costa (VC), similar to the HWFET (Highway Fuel Economy Test), has high speeds (65.39 km/h vs. 77.7 km/h), no stops and a driving time of over 98 percent. On the other hand, the Downtown (C) cycle, with a top speed of 50 km/h and a driving time of 1,223.4 seconds, shows a performance close to the WSL, although with a higher acceleration ratio (27.14 percent) compared to the WSL (30.52 percent). Finally, the NEDC (with a top speed of 120.09 km/h and 23.56 percent acceleration) has a different behavior, with higher top speed and less acceleration. However, the Downtown (C), San Marino (SM) and Portete (P) routes show similar trends to those of the ECE-15, an urban section of the NEDC. In summary, the Guayaquil cycles, especially the one on Via a la Costa, are more dynamic, while the Downtown (C) cycle is more similar to the WSL due to its low speed and long driving time [18,43].

On the other hand, according to Table 19, the comparison of driving cycles in Guayaquil, Quito and Cuenca shows that Via a la Costa (VC) and Quito/Carretera have the best flow conditions, with high speeds (65 km/h), few stops and minimal idling time. In contrast, Guayaquil Route 3 (C) and Quito/Ciudad have dense traffic, with low speeds (11-13 km/h) and multiple stops. San Marino (SM), Portete (P) and Cuenca reflect intermediate conditions, with moderate speeds and frequent interruptions. In addition, Via a la Costa (VC) had the longest time in acceleration (75.58 percent), while Route 3 (C) and Cuenca showed lower fluidity (27-36 percent), highlighting key differences in urban mobility [18].

Finally, according to Table 20, the comparison of driving cycles in Guayaquil, Esmeraldas and Ambato-Riobamba shows that Via a la Costa and the Ambato-Riobamba highway have the best flow conditions, with high speeds (60-65 km/h), few stops and a high proportion of driving time (>96 percent). In contrast, downtown Guayaquil has the densest traffic, with low speeds (11.05 km/h), multiple stops (18) and long idling times. San Marino, Portete and the Ambato-Riobamba urban area reflect intermediate conditions, with moderate speeds (16-26 km/h) and frequent interruptions. These results show differences in mobility and traffic efficiency between cities and road types [16,17].

5. Conclusions

In this study, driving cycles were determined for the four selected routes in the city of Guayaquil. It was concluded that it was not possible to develop a general driving cycle that would represent the entire city due to its large geographic extension, which made it difficult to cover all the zones. However, it was possible to characterize the cycle of each of the selected zones, obtaining a total of four cycles. For this purpose, the direct method was used, based on the collection of real traffic data. The ON BOARD technique was implemented, in which an M1 category vehicle was instrumented, and three drivers were assigned to simulate real traffic conditions, following an approach similar to the American FTP-75 cycle. Speed, time and distance data were collected using the OBDLINK MX+ device and processed in the OBDWiz software, whose outputs were imported into Microsoft Excel. Through a descriptive analysis performed in Minitab, the sample size was

determined, which consisted of a total of 45 repetitions distributed among all routes. Likewise, in the data processing, weighting criteria were applied, which made it possible to select the representative cycle for each of the routes analyzed.

The traffic analysis carried out in this study made it possible to identify the characteristics and differences in the vehicular behavior of the main routes selected in Guayaquil. The results show a marked variability in traffic conditions, with highly congested areas, such as in the downtown sector, and others with fluid traffic, such as the route comprising Via a la Costa. Each of the routes was characterized with the help of a GPS application such as Google Maps, which indicated the routes with the most traffic, since it shows the traffic conditions in real time, indicating areas with congestion, accidents and other obstacles.

The analysis showed notable differences between the routes in Guayaquil. Via a la Costa (VC) stood out for its high efficiency, with an average speed of 65.39 km/h, no stops and only 10 seconds idling, reflecting smooth and constant traffic. In contrast, San Marino (SM) presented an average speed of 21.39 km/h, with 4 stops and 243 seconds idling, showing intermediate conditions. Route 3 (C), with an average speed of 11.05 km/h, had the worst conditions, with 18 stops and 613 seconds idling, showing high congestion. Finally, the Portete (P) route, with an average speed of 16.27 km/h, showed similar conditions to San Marino, with 11 stops and 247 seconds idling, indicating moderate traffic flow but with some interruptions. In summary, Via a la Costa showed the best driving conditions, while Downtown experienced more congestion.

Compared to other driving cycles in Ecuador, Guayaquil presents a mix of characteristics. Via a la Costa shows similarities to Quito’s interurban roads, noted for smoother traffic and higher speeds. In contrast, the Route 3 and San Marino routes are more similar to those of Quito/City and Cuenca, where dense traffic and reduced speeds predominate. These results underscore the need to improve road infrastructure in the most congested areas to reduce travel times, emissions and fuel consumption.

Abbreviations

The following abbreviations are used in this manuscript:

CO	Carbon monoxide
CO2	Carbon dioxide
NOx	Nitrogen oxides
UHC	Unburned hydrocarbons
DC	Driving Cycle
UPS	Universidad Politecnica Salesiana del Ecuador
N	Number of stops
N.P.	Normality test
VC	Via a la Costa-Peaje, Route 1
SM	San Marino-Colegio Americano, Route 2
C	Av. 9 de Octubre-El Oro, Route 3
P	UPS Centenario-Calle 17 y Portete, Route 4
m	Meters
s	Second
R	Repetitions

Appendix A

Table A1. Final results corresponding to each Route.

Routes	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
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VC	65,39	79	0	735,624	10	14901	556	98,64	75,58
SM	21,39	67	4	850,091	243	5712	306	71,41	36,00
C	11,05	50	18	1223,416	613	3900	332	49,89	27,14
P	16,27	39	11	961,223	247	4689	374	74,30	38,91

Table A2. Calculation of the deviation from the median of Route 1.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	0.016274	0	0	0.010037	0.523810	0.000571	0.065868	0.007476	0.062303
2	0.028556	0.126582	0	0.039066	0.142857	0.000034	0.033362	0.001450	0.012633
3	0.005402	0.050633	0	0.016939	0.047619	0.000235	0.012831	0.001039	0.037143
4	0.000820	0.025316	0	0.025643	0.238095	0.000839	0.005988	0.003067	0.012633
5	0.032539	0.101266	0	0.039390	0.142857	0.000034	0.144568	0.002817	0.103562
6	0.008739	0.117647	0	0.016889	0.809524	0.000369	0.053892	0.012145	0.031231
7	0.000820	0	0	0.010037	0.047619	0.000168	0.048760	0.000446	0.032718
8	0.085888	0.025316	0	0.117994	0.238095	0.000101	0.141146	0.004466	0.027505
9	0.054633	0.075949	0	0.051277	0.333333	0.000571	0.005988	0.005145	0.048176
10	0.022249	0	0	0.010167	0.428571	0.000705	0.031651	0.006126	0.035015
11	0.013073	0.063291	0	0.024334	0.238095	0.000369	0.117194	0.003953	0.152682
12	0.085169	0.063291	0	0.115808	0.142857	0.000168	0.137725	0.000446	0.026431

Table A3. Determination of the “Y” value for each repetition of Route 1.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating	Weighted Median (Y)
1	0,002504	0,000000	0	0,001544	0,060440	0,000088	0,002533	0,001150	0,009585	0,077843793
2	0,004393	0,004869	0	0,006010	0,016484	0,000000	0,001283	0,000223	0,001944	0,035210292
3	0,000831	0,001947	0	0,002606	0,005495	0,000003	0,000494	0,000160	0,005714	0,017282947
4	0,000126	0,000974	0	0,003945	0,027473	0,000129	0,000230	0,000472	0,001944	0,035292337
5	0,005006	0,003895	0	0,006060	0,016484	0,000000	0,005560	0,000433	0,015933	0,053375852
6	0,001344	0,004525	0	0,002598	0,093407	0,000005	0,002073	0,001869	0,004805	0,110677161
7	0,000126	0,000000	0	0,001544	0,005495	0,000002	0,001875	0,000006	0,005034	0,014168079
8	0,013214	0,000974	0	0,018153	0,027473	0,000001	0,005429	0,000687	0,004232	0,07017558

9	0,00840	0,00292	0	0,00788	0,03846	0,00008	0,000230	0,00079	0,007412	0,0661979
	5	1		9	2	8		2		4
1	0,00342	0,00000	0	0,00156	0,04945	0,00010	0,001217	0,00094	0,005387	0,0620928
0	3	0		4	1	8		2		46
1	0,00201	0,00243	0	0,00374	0,02747	0,00005	0,004507	0,00060	0,023489	0,0643236
1	1	4		4	3	7		8		63
1	0,01310	0,00243	0	0,01781	0,01648	0,00002	0,005297	0,00006	0,004066	0,0592950
2	3	4		7	4	6		9		68

Table A4. Calculation of the deviation from the median of Route 2.

R	Averag e speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distanc e (m)	Positive acceleratio n time (s)	% of driving time	% of time acceleratin g
1	0,13703	0	0,16666	0,11064	0,23664	0,001404	0,094771	0,05635	0,051534
	5	0	7	3	1			8	
2	0,13170	0,09375	0,00000	0,11654	0,43129	0,001404	0,032680	0,15135	0,207600
	1	0	0	8	8			6	
3	0,01882	0,03125	0,16666	0,00525	0,07251	0,000000	0,035948	0,04096	0,075890
	3	0	7	7	9			9	
4	0,03194	0,15625	0,16666	0,03827	0,00000	0,000175	0,068627	0,00996	0,073273
	5	0	7	5	0			1	
5	0,14097	0,03125	0,16666	0,17338	0,62213	0,001930	0,022876	0,17565	0,099415
	1	0	7	1	7			8	
6	0,00461	0,29411	0,16666	0,00680	0,16412	0,000175	0,029412	0,07552	0,004063
	9	8	7	2	2			9	
7	0,20137	0,03125	0,33333	0,15987	0,19084	0,002106	0,192810	0,00996	0,007409
	8	0	3	1	0			0	
8	0,04599	0,03125	0,33333	0,05672	0,26335	0,000351	0,022876	0,09291	0,000000
	8	0	3	9	9			7	
9	0,10699	0,04687	0,33333	0,11092	0,44656	0,001579	0,016340	0,14010	0,085249
	5	5	3	1	5			4	
1	0,03017	0,03125	0,33333	0,03577	0,04961	0,000702	0,042484	0,00000	0,116939
0	7	0	3	0	8			0	
1	0,00000	0,046875	0,333	0,00000	0,07251	0,002281	0,000000	0,02574	0,033096
1	0		333	0	9			5	

Table A5. Determination of the “Y” value for each repetition of Route 2.

R	Avera ge speed (km/h)	Max. speed (km/h)	N	Drivin g time (s)	Idle time (s)	Distanc e (m)	Positive accelerati on time (s)	% of drivin g time	% of time accelerati ng	Weight ed Median (Y)
1	0,0210	0,0000	0,0064	0,0170	0,0273	0,00021	0,003645	0,0086	0,007928	0,09229
	82	00	10	22	05	6		70		0
2	0,0202	0,0036	0,0000	0,0179	0,0497	0,00021	0,001257	0,0232	0,031939	0,14825
	62	06	00	30	65	6		86		99
3	0,0028	0,0012	0,0064	0,0008	0,0083	0,00000	0,001383	0,0063	0,011675	0,03904
	96	02	10	09	68	0		03		53
4	0,0049	0,0060	0,0064	0,0058	0,0000	0,00002	0,002640	0,0015	0,011273	0,03869
	15	10	10	88	00	7		32		46
5	0,0216	0,0012	0,0064	0,0266	0,0717	0,00029	0,000880	0,0270	0,015295	0,17125
	88	02	10	74	85	7		24		50
6	0,0007	0,0113	0,0064	0,0010	0,0189	0,00002	0,001131	0,0116	0,000625	0,05181
	11	12	10	46	37	7		20		98

7	0,0309 81	0,0012 02	0,0128 21	0,0245 96	0,0220 20	0,00032 4	0,007416	0,0015 32	0,001140	0,10203 11
8	0,0070 77	0,0012 02	0,0128 21	0,0087 28	0,0303 88	0,00005 4	0,000880	0,0142 95	0,000000	0,07544 30
9	0,0164 61	0,0018 03	0,0128 21	0,0170 65	0,0515 27	0,00024 3	0,000628	0,0215 54	0,013115	0,13521 69
10	0,0046 43	0,0012 02	0,0128 21	0,0055 03	0,0057 25	0,00010 8	0,001634	0,0000 00	0,017991	0,04962 61
11	0,0000 00	0,0018 03	0,0128 21	0,0000 00	0,0083 68	0,00035 1	0,000000	0,0039 61	0,005092	0,03239 44

Table A6. Calculation of the deviation from the median of Route 3.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	0.13115	0.18000	0.26316	0.11305	0.31974	0.00000	0.00000	0.25155	0.11385
2	0.03882	0.00000	0.05263	0.02946	0.00000	0.00026	0.00606	0.00410	0.02408
3	0.07322	0.06000	0.26316	0.07063	0.10277	0.00026	0.11212	0.00378	0.02621
4	0.10818	0.06000	0.05263	0.11666	0.23654	0.00487	0.13030	0.07885	0.00000
5	0.09996	0.02000	0.15789	0.10387	0.14356	0.00051	0.10000	0.00953	0.01554
6	0.02810	0.23529	0.10526	0.02469	0.04078	0.00128	0.03333	0.03980	0.02082
7	0.00000	0.14000	0.15789	0.00000	0.00979	0.00077	0.16364	0.03486	0.14959
8	0.01232	0.12000	0.00000	0.00419	0.08972	0.00282	0.03030	0.11614	0.04601
9	0.11493	0.04000	0.05263	0.09536	0.12398	0.00180	0.00909	0.00000	0.10628
10	0.63906	0.16000	0.47368	0.39497	0.61990	0.00103	0.12121	0.38622	0.43493
11	0.05698	0.06000	0.15789	0.05829	0.12887	0.00051	0.05758	0.09812	0.01132

Table A7. Determination of the “Y” value for each repetition of Route 3.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating	Weighted Median (Y)
1	0,0201 77	0,0069 23	0,0101 21	0,0173 93	0,0368 93	0,00000 0	0,000000	0,0387 01	0,017515	0,147723 33
2	0,0059 72	0,0000 00	0,0020 24	0,0045 32	0,0000 00	0,00003 9	0,000233	0,0006 31	0,003705	0,017136 82
3	0,0112 65	0,0023 08	0,0101 21	0,0108 66	0,0118 58	0,00003 9	0,004312	0,0005 82	0,004033	0,055384 75
4	0,0166 43	0,0023 08	0,0020 24	0,0179 47	0,0272 93	0,00075 0	0,005012	0,0121 30	0,000000	0,084107 24
5	0,0153 79	0,0007 69	0,0060 73	0,0159 80	0,0165 64	0,00007 9	0,003846	0,0014 67	0,002391	0,062547 57
6	0,0043 22	0,0090 50	0,0040 49	0,0037 99	0,0047 06	0,00019 7	0,001282	0,0061 24	0,003204	0,036732 17
7	0,0000 00	0,0053 85	0,0060 73	0,0000 00	0,0011 29	0,00011 8	0,006294	0,0053 63	0,023014	0,047375 96

8	0,0018 95	0,0046 15	0,0000 00	0,0006 45	0,0103 53	0,00043 4	0,001166	0,0178 68	0,007078	0,044053 65
9	0,0176 81	0,0015 38	0,0020 24	0,0146 71	0,0143 05	0,00027 6	0,000350	0,0000 00	0,016351	0,067196 62
10	0,0983 16	0,0061 54	0,0182 19	0,0607 65	0,0715 27	0,00015 8	0,004662	0,0594 19	0,066913	0,386131 93
11	0,0087 66	0,0023 08	0,0060 73	0,0089 68	0,0148 70	0,00007 9	0,002214	0,0150 95	0,001742	0,060114 34

Table A8. Calculation of the deviation from the median of Route 4.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating
1	0.045779	0.022727	0.181818	0.033966	0.385542	0.000426	0.039773	0.107084	0.000000
2	0.008054	0.181818	0.363636	0.012900	0.228916	0.000213	0.607955	0.092665	0.754061
3	0.072096	0.000000	0.090909	0.086540	0.128514	0.000213	0.008523	0.030872	0.188854
4	0.030379	0.068182	0.181818	0.022400	0.184739	0.001490	0.000000	0.042304	0.053201
5	0.014804	0.113636	0.000000	0.005748	0.008032	0.002128	0.062500	0.019345	0.137553
6	0.000000	0.823529	0.090909	0.000000	0.257028	0.002554	0.184659	0.077418	0.122047
7	0.141928	0.068182	0.454545	0.150073	0.614458	0.001064	0.053977	0.129873	0.013180
8	0.059744	0.022727	0.272727	0.072286	0.080321	0.001702	0.247159	0.017544	0.126181
9	0.175753	0.136364	0.363636	0.159946	0.212851	0.000000	0.281250	0.036958	0.078696
10	0.031392	0.045455	0.090909	0.038853	0.000000	0.000213	0.193182	0.000000	0.096105
11	0.089309	0.045455	0.181818	0.088613	0.329317	0.000851	0.034091	0.064581	0.022863

Table A9. Determination of the “Y” value for each repetition of Route 4.

R	Average speed (km/h)	Max. speed (km/h)	N	Driving time (s)	Idle time (s)	Distance (m)	Positive acceleration time (s)	% of driving time	% of time accelerating	Weighted Median (Y)
1	0,0070 43	0,0008 74	0,0069 93	0,0052 25	0,0444 86	0,00006 5	0,001530	0,0164 74	0,000000	0,082690 84
2	0,0012 39	0,0069 93	0,0139 86	0,0019 85	0,0264 13	0,00003 3	0,023383	0,0142 56	0,116009	0,204297 29
3	0,0110 92	0,0000 00	0,0034 97	0,0133 14	0,0148 29	0,00003 3	0,000328	0,0047 49	0,029054	0,076895 03
4	0,0046 74	0,0026 22	0,0069 93	0,0034 46	0,0213 16	0,00022 9	0,000000	0,0065 08	0,008185	0,053973 43
5	0,0022 78	0,0043 71	0,0000 00	0,0008 84	0,0009 27	0,00032 7	0,002404	0,0029 76	0,021162	0,035328 83
6	0,0000 00	0,0316 74	0,0034 97	0,0000 00	0,0296 57	0,00039 3	0,007102	0,0119 11	0,018776	0,103009 91
7	0,0218 35	0,0026 22	0,0174 83	0,0230 88	0,0708 99	0,00016 4	0,002076	0,0199 80	0,002028	0,160174 98
8	0,0091 91	0,0008 74	0,0104 90	0,0111 21	0,0092 68	0,00026 2	0,009506	0,0026 99	0,019413	0,072823 50
9	0,0270 39	0,0052 45	0,0139 86	0,0246 07	0,0245 60	0,00000 0	0,010817	0,0056 86	0,012107	0,124046 82

1	0,0048	0,0017	0,0034	0,0059	0,0000	0,00003		0,0000		0,038299
0	30	48	97	77	00	3	0,007430	00	0,014785	88
1	0,0137	0,0017	0,0069	0,0136	0,0379	0,00013		0,0099		0,089007
1	40	48	93	33	98	1	0,001311	36	0,003517	04

Appendix B

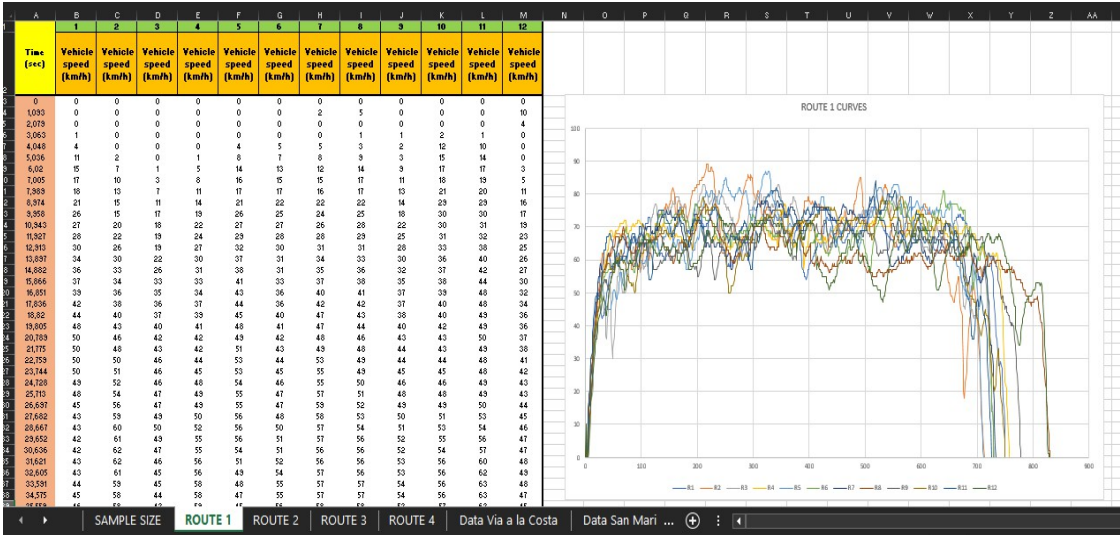


Figure A1. Data obtained from the 12 repetitions of Route 1.

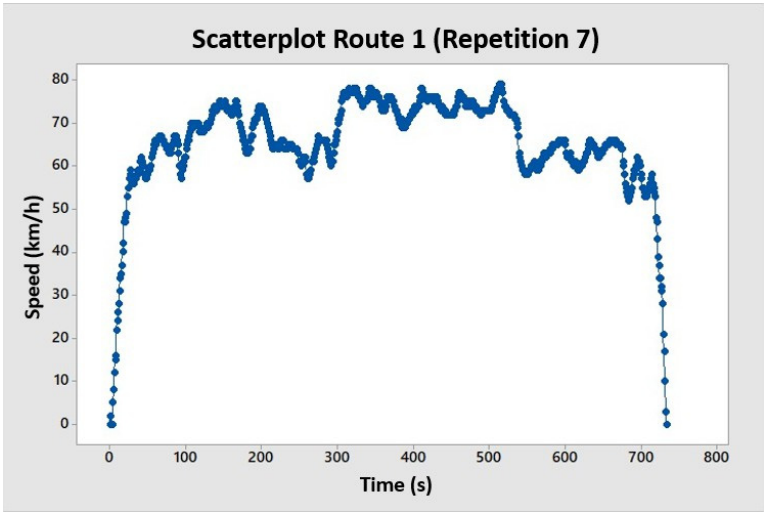


Figure A2. Scatter plot of Route 1.

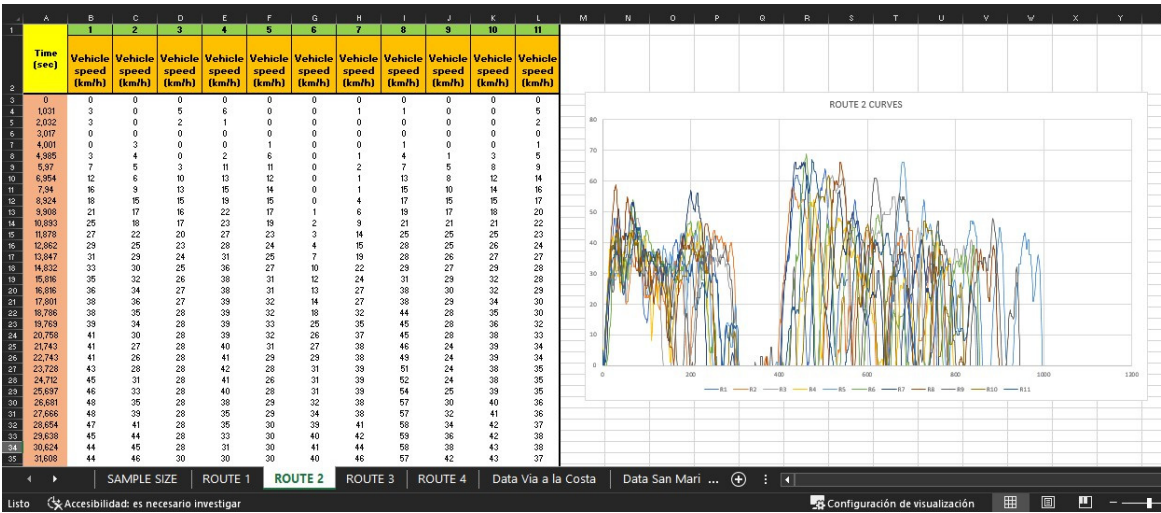


Figure A3. Data obtained from the 11 repetitions of Route 2.

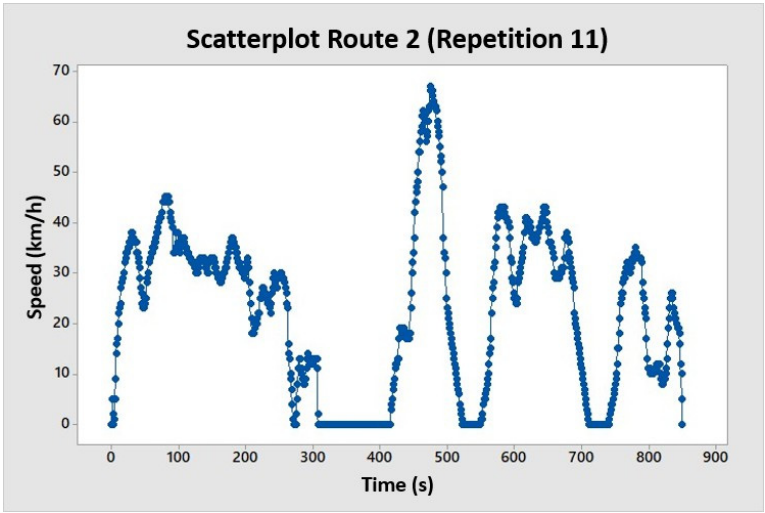


Figure A4. Scatter plot of Route 2.

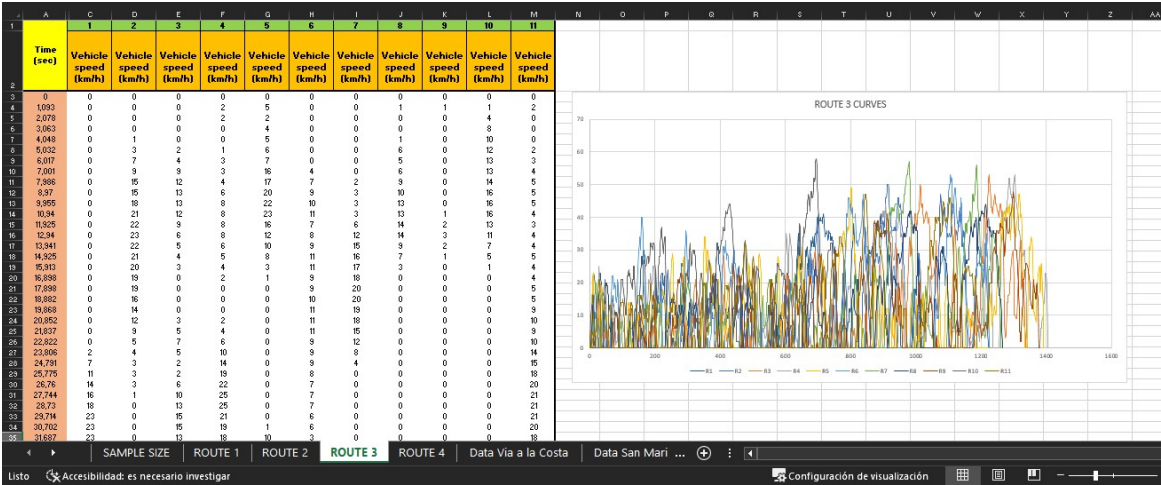


Figure A5. Data obtained from the 11 repetitions of Route 3.

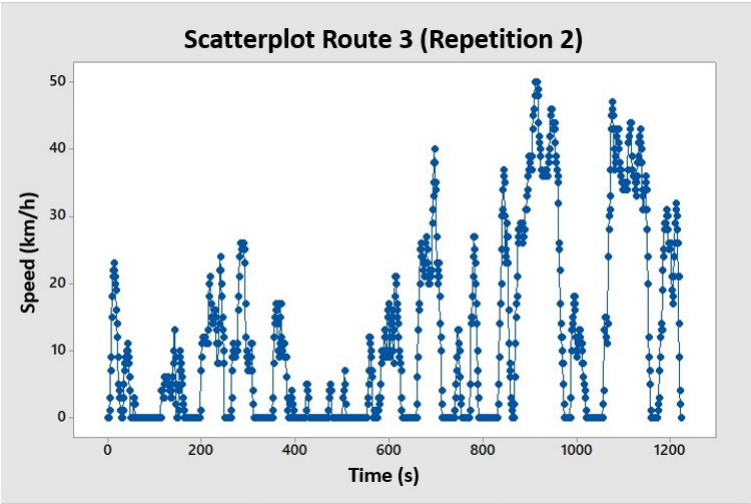


Figure A6. Scatter plot of Route 3.

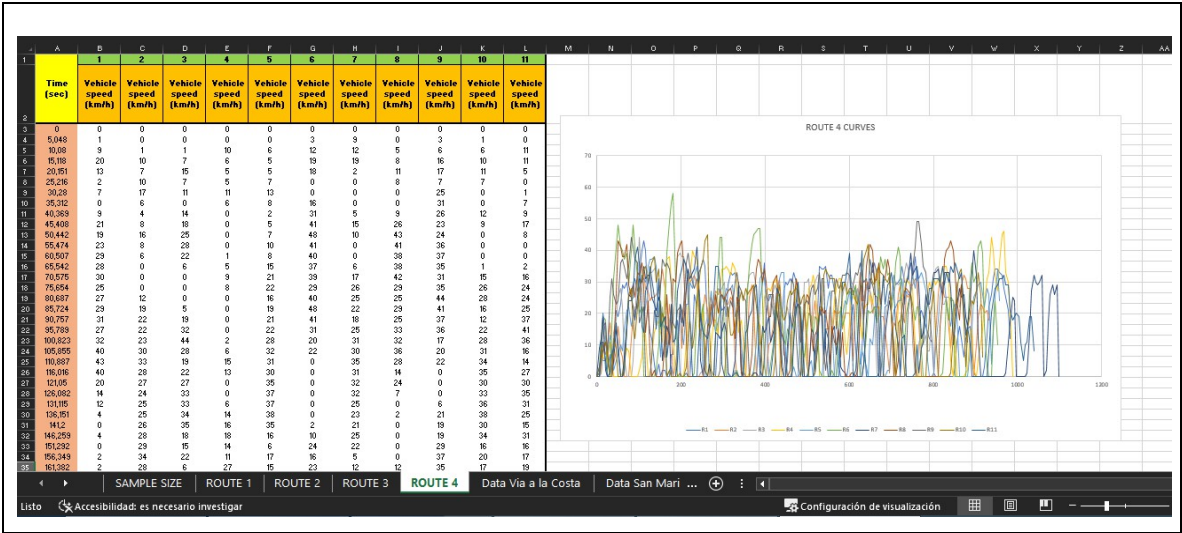


Figure A7. Data obtained from the 11 repetitions of Route 4.

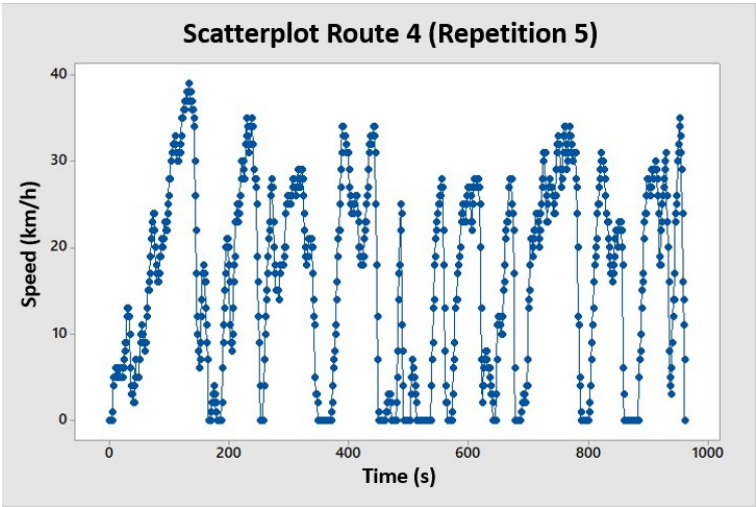


Figure A8. Scatter plot of Route 4.

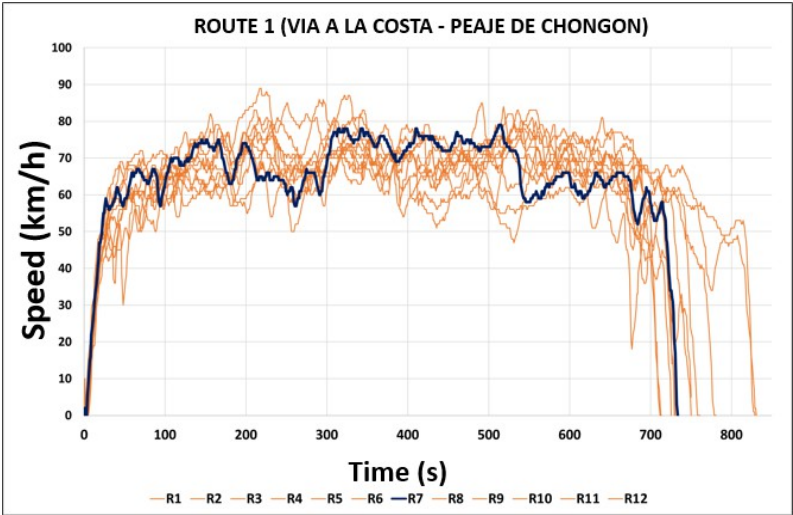


Figure A9. Repetitions corresponding to Route 1 and its respective cycle.

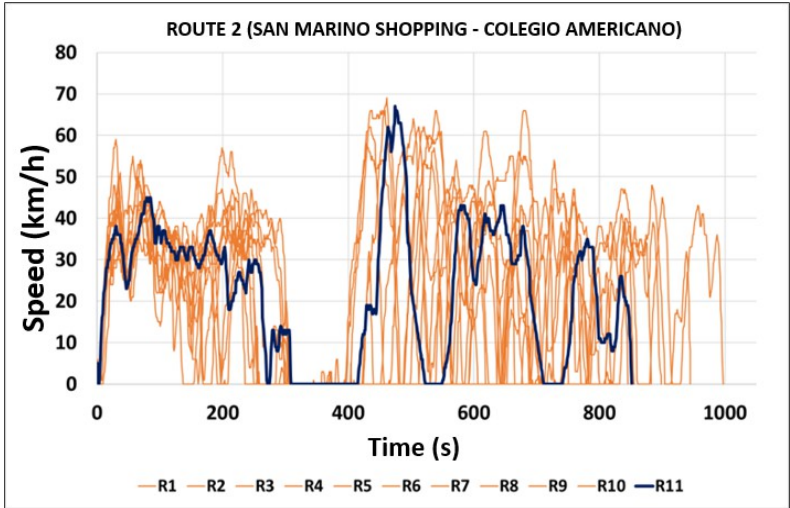


Figure A10. Repetitions corresponding to Route 2 and its respective cycle.

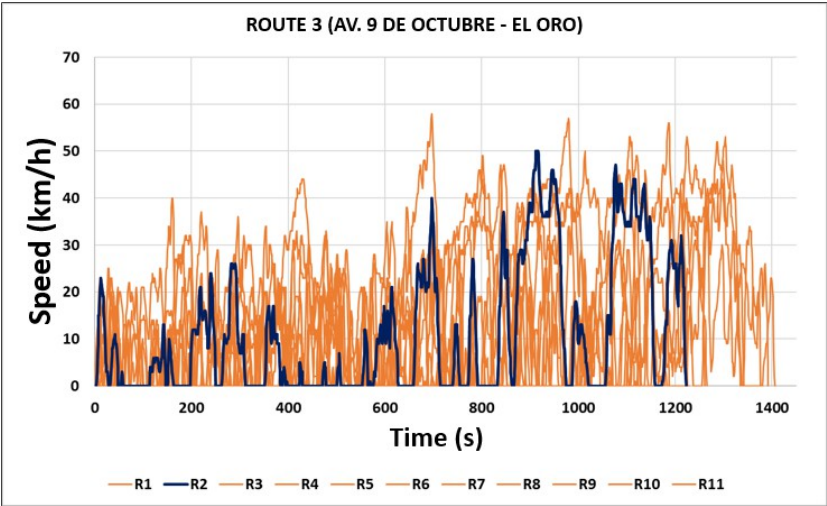


Figure A11. Repetitions corresponding to Route 3 and its respective cycle.

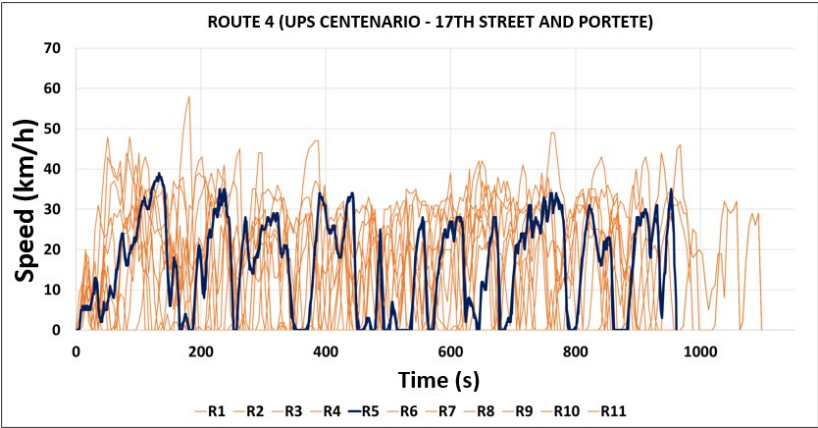


Figure A12. Repetitions corresponding to Route 4 and its respective cycle.

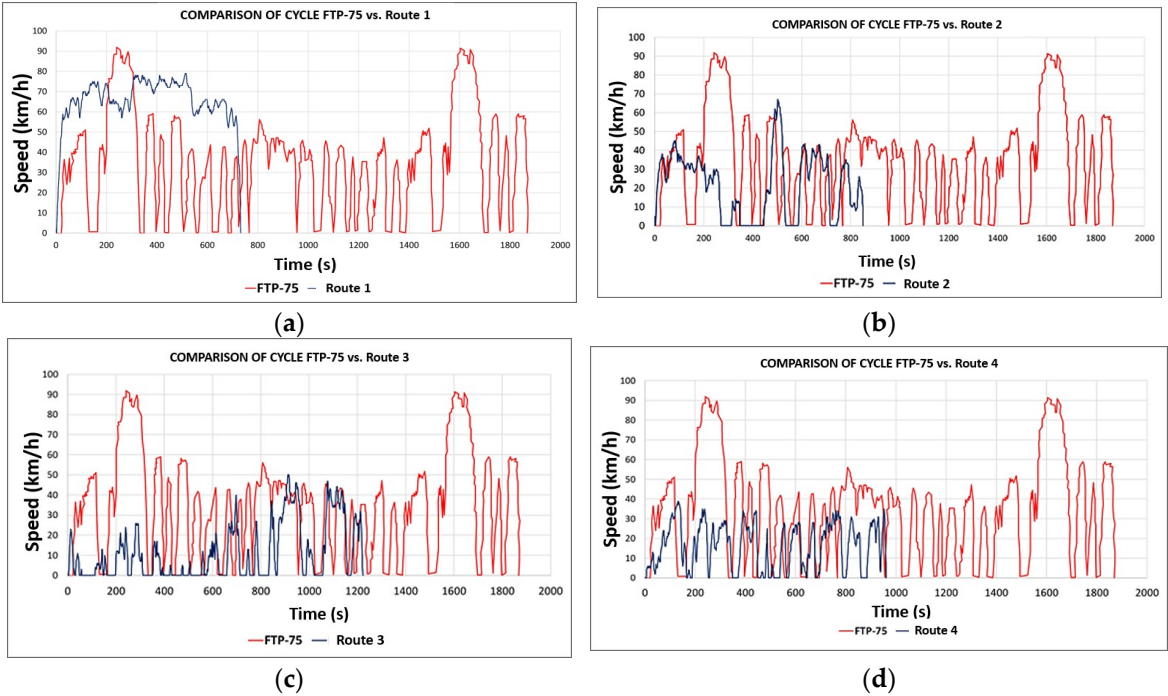
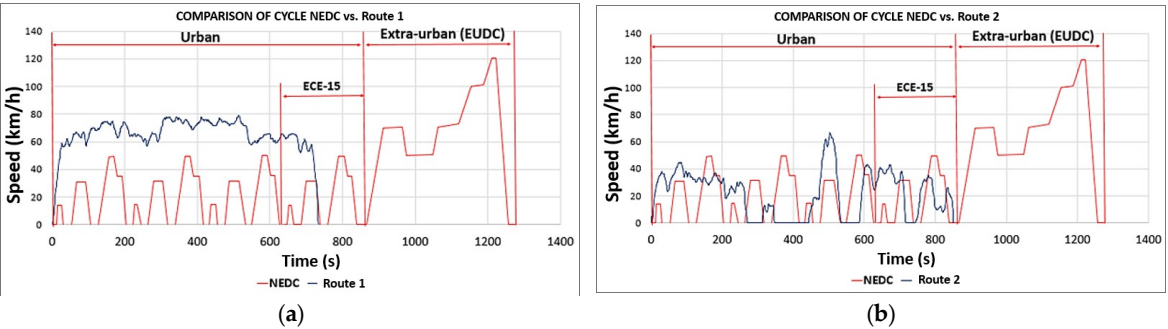


Figure A13. Comparison: (a) Comparison of the FTP-75 cycle with Route 1 (Repetition n. 7). (b) Comparison of the FTP-75 cycle with Route 2 (Repetition n. 11). (c) Comparison of the FTP-75 cycle with Route 3 (Repetition n. 2). (d) Comparison of the FTP-75 cycle with Route 4 (Repetition n. 5).



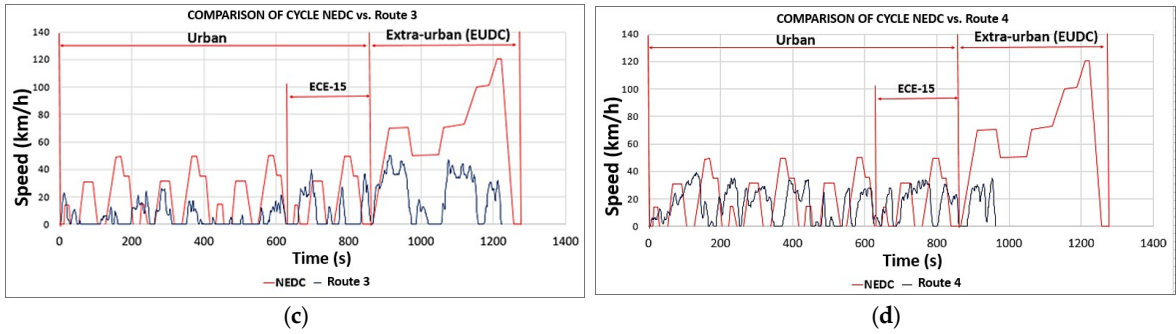


Figure A14. Comparison: (a) Comparison of the NEDC cycle with Route 1 (Repetition n. 7). (b) Comparison of the NEDC cycle with Route 2 (Repetition n. 11). (c) Comparison of the NEDC cycle with Route 3 (Repetition n. 2). (d) Comparison of the NEDC cycle with Route 4 (Repetition n. 5).

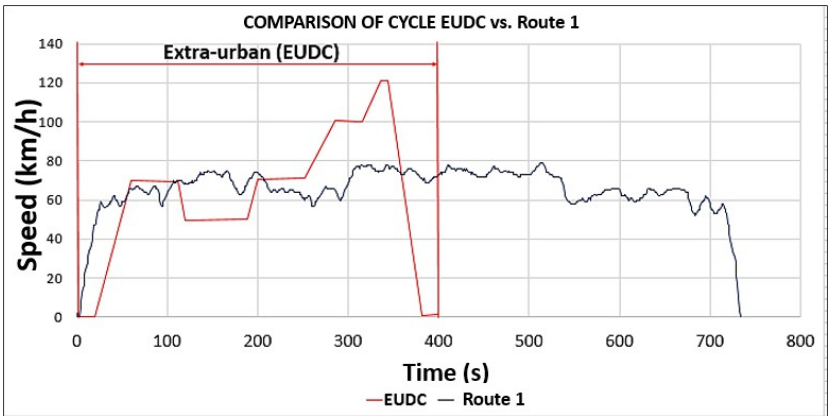


Figure A15. Comparison of the EUDC cycle with Route 1 (Repetition n. 7).

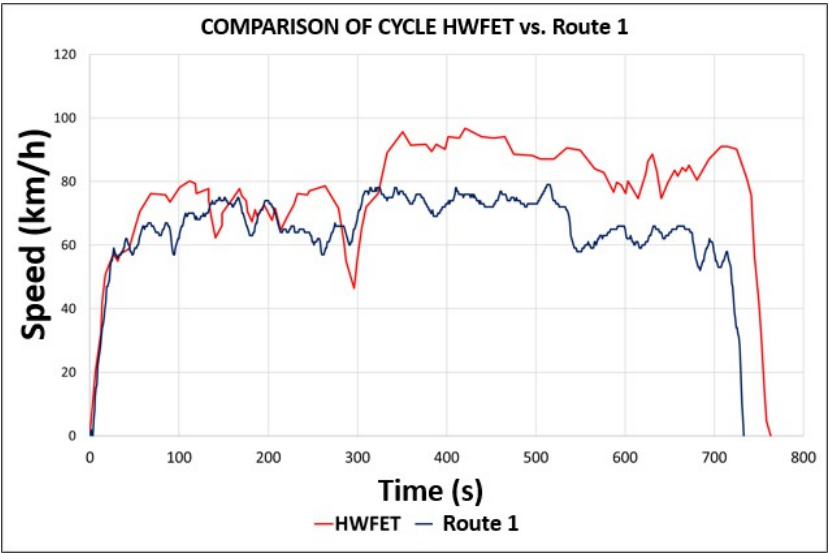


Figure A16. Comparison of the HWFET cycle with Route 1 (Repetition n. 7).

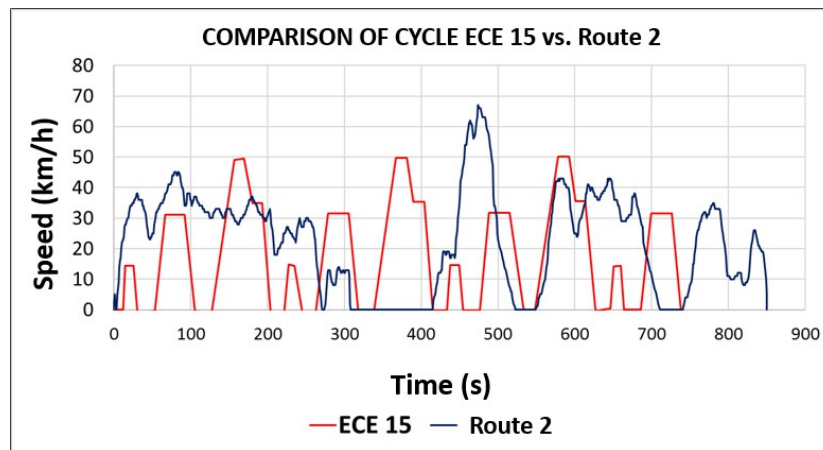


Figure A17. Comparison of the ECE-15 cycle with Route 2 (Repetition n. 11).

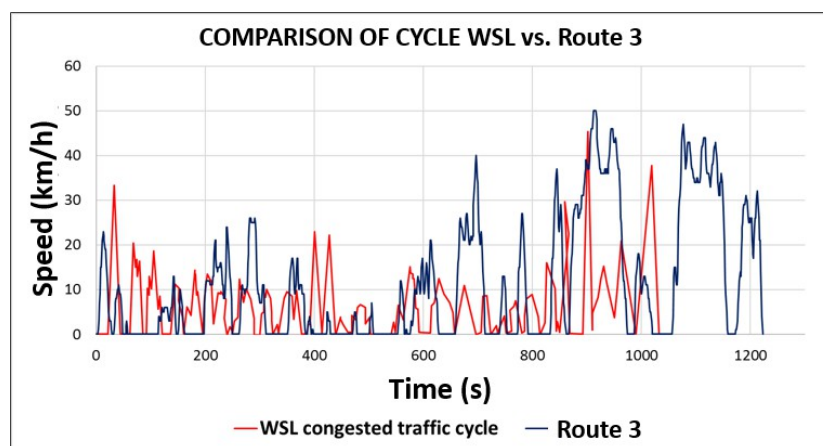


Figure A18. Comparison of the WSL congested traffic cycle with Route 3 (Repetition n. 2).

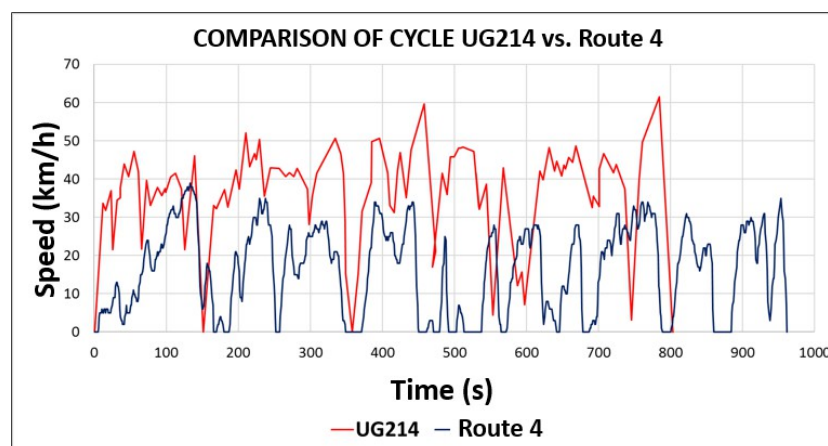


Figure A19. Comparison of cycle UG214 with Route 4 (Repetition n. 5).

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