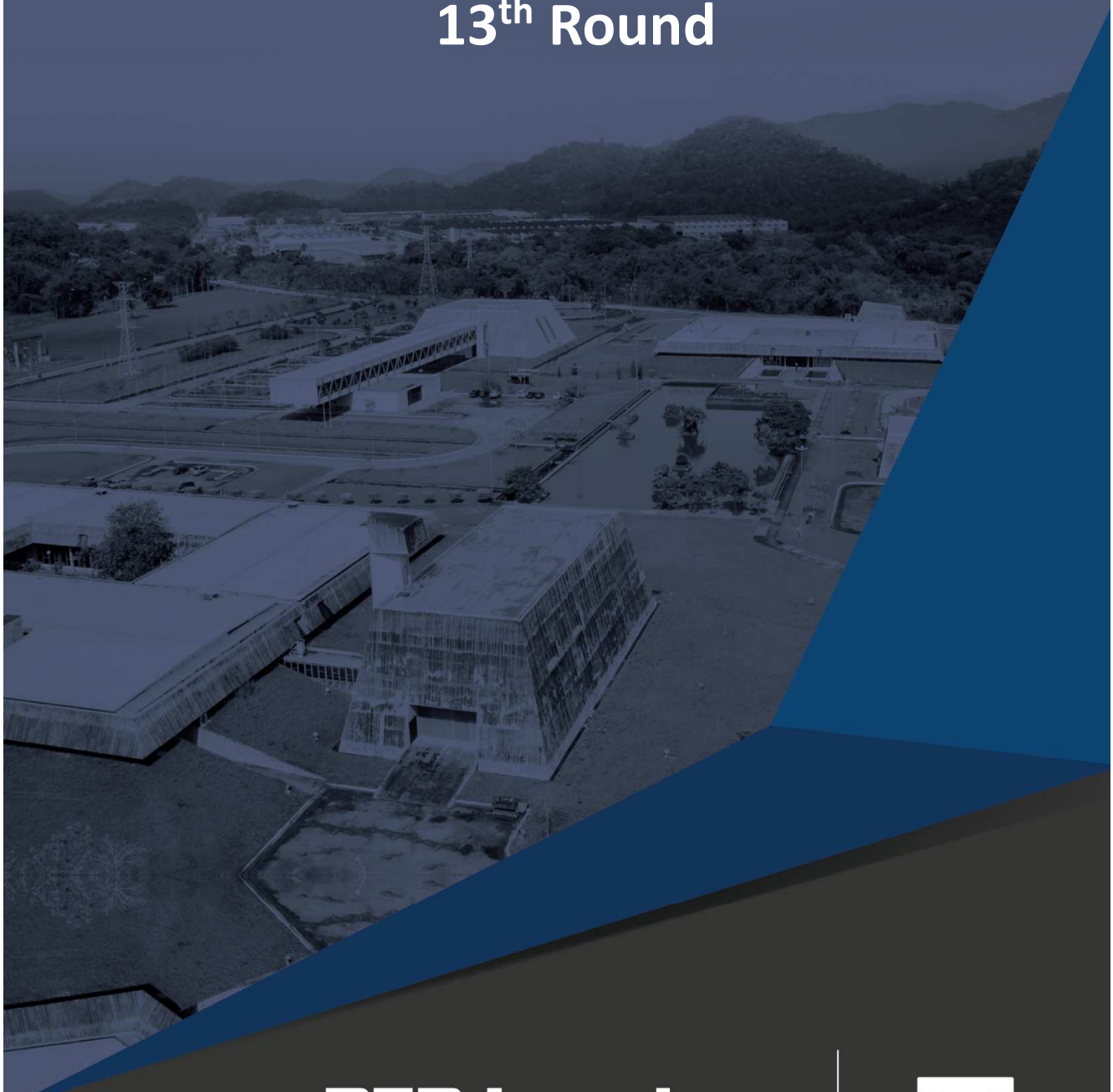
Final Report of the Proficiency Testing in Vehicles Emissions 13th Round



PEP-Inmetro

PROGRAMA DE ENSAIOS DE PROFICIÊNCIA DO INMETRO

INMETRO

PROFICIENCY TESTING IN VEHICLES EMISSIONS

13th ROUND

Period of completion: from 19/05/2021 to 26/06/2023

FINAL REPORT – Nº 001/2023

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SUMMARY

1. Introduction

The automotive industry is in continuous development, being of fundamental importance the incessant quest for the insurance of the validity of results, especially vehicular emissions, which have an impact on the environment. One of the tools for this assurance of the validity of results are the proficiency testing (PT). Carrying out this PT has the purpose of evaluating the performance of laboratories in determining the amount of compounds present in vehicular emissions, providing subsidies for identifying and proposing solution for analytical problems and contributing for the harmonization of measurement results for the performance evaluation, besides being a tool for data generation, which can support the preparation of new insertion in the most diverse markets.

The general objectives of this PT Scheme were:

- To determine the performance of laboratories for the proposed tests;
- To monitor the ongoing performance of the analytical vehicle emissions laboratories;
- To increase the confidence of the measuring emission process of the vehicle emission laboratories;
- To improve continuously the measurement techniques of vehicle emissions laboratories.

1. Materials and Methods

2.1. Test Item

The test item was a vehicle provided by Hyundai Motor Brasil with the following characteristics: Hyundai HB20X model, silver color, Chassis 9BHBG51DAFP421760, 1.6 liters motor and 6 speed manual transmission.

Each participating laboratory used as fuel Gasool A22H0, as defined in the protocol.

2.2. Metodology

In this round, the following tests were analyzed, according to the current versions of the respective documents:

Parameters		Documents
Mandatory	**Urban Cycle**	ABNT NBR 6601:2021 Standard THC, CH_4, NMHC, CO, CO_2, NO_x; ABNT NBR 7024:2017 Standard Urban Autonomy IBAMA Nº 22, 24/09/2020 Normative Instruction: NMOG 1 and NMOG 2
	Road Cycle	ABNT NBR 7024:2017 THC, CO, CO_2, Road autonomy and combined autonomy Standard
	Aldehydes	ABNT NBR 12026:2021 Standard

Parameters		Documents
	Idling Speed CO	ABNT NBR 10972:2010 Standard
Optional	**Evaporative Emissions**	ABNT NBR 11481:2010 Standard or ABNT NBR 16927:2021 Standard

Comments:

1- NMOG 1: parameter calculated according to Normative Instruction IBAMA Nº 22, 24/09/2020, using unburned etanol and aldeydes parameters values;

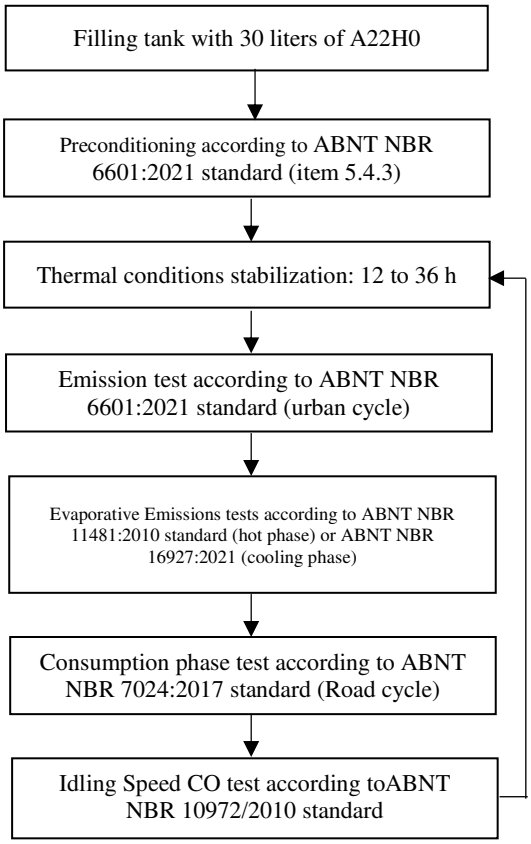
2- NMOG 2: parameter calculated according to Normative Instruction IBAMA Nº 22, 24/09/2020, applying 1.1864 factor to NMHC result;

3- For NMOG 1 parameter calculation the protocol instruction was to measure the Unburned Ethanol (UBE) parameter according to ABNT NBR 15598:2016 standard. However, UBE would not be reported.

The deceleration curve data were provided in tabular form by CETESB after carrying out the first tests in its own laboratory.

Laboratories drained the fuel of the tank to refuel with 30 L at minimum and to perform all the tests planned in this PT. Participants should follow the test flow chart presented below and to start tests preferably at 25 °C, aiming minimizing cold start effects in results.

Figure 1- Flow chart of PT measurement activities.



Source: Dimci/Dquim/Lanag

Participants sent, obligatorily, **3 (three)** measurements for each parameter, with exception to the parameters the protocol consider optional, otherwise, their results would not be evaluated. The results of Hyundai Motor Brasil to be considered were those referred to the tests performed in the beginning of the cycle (Y_1).

3. Test Item Integrity

Hyundai Motor Brasil laboratory performed stability tests in the beginning, in the middle and at the end of the cycle – first analysis (Y_1), and second analysis (Y_2) and third analysis (Y_3). It was verified if there were significant statistical differences between measurements of the 17 components:
Urban Cycle, with ten (10) measured components: CO (mg/km), CO_2 (g/km), THC (mg/km), NO_x (mg/km), NMHC (mg/km), CH_4 (mg/km), Total Aldehydes (mg/km), NMOG 1 (mg/km), NMOG 2 (mg/km) and Urbana autonomy (km/L);
Road Cycle, with five (5) measured components: CO (mg/km), CO_2 (g/km), THC (mg/km), Road Autonomy (km/L) and Combined Autonomy (km/L);
Idling Speed, with one (1) measured component: CO (% vol);
SHED, with one (1) measured component: Evaporative Emissions (g/phase).

The Wilcoxon test was used to verify the hypothesis that two dependent data sets were extracted from the same population. This test should be used to the detriment of the paired t-test, when it is not possible to assume the normality of both data sets or in cases where there are small samples. In the Wilcoxon test, the original values are replaced by posts as follows:

Table 1 - Statistics and p-values

Before	x_1	x_2	...	x_N
After	y_1	y_2	...	y_N
d_i	d_1	d_2	...	d_N
$\|d_i\|$	$\|d_1\|$	$\|d_2\|$	...	$\|d_N\|$
post	N	2	...	1

Source: Dimci/Dquim/Lanag

In which $d_i = y_i - x_i$. The posts are obtained from absolute values of d_i. The hypotheses to be tested are:

$$\begin{cases} H_0) \text{ no difference between the both sets of data} \\ H_1) \text{ there are differences between both sets of data} \end{cases}$$

The test statistic is defined below:

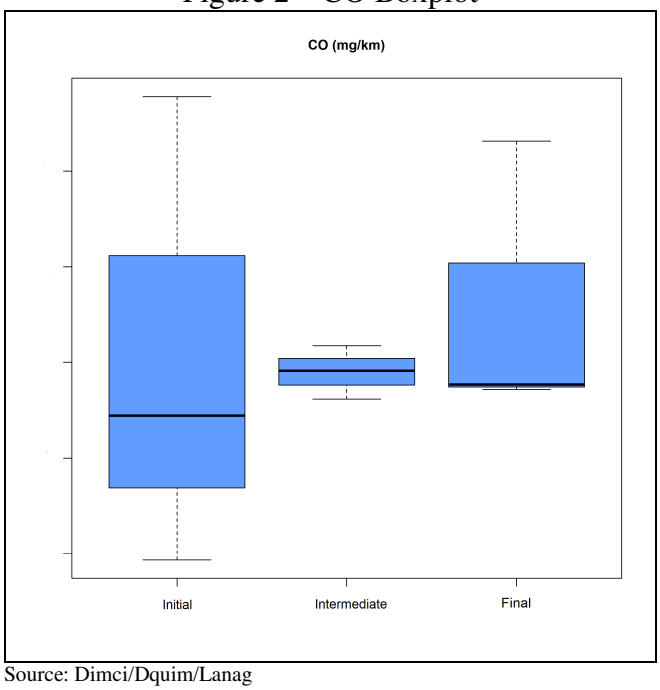
V_s = *sum of the positively signaled posts*

If $V_S \leq c_1$ or $V_S \geq c_2$, H_0 is rejected, in which c_1 and c_2 are such that $P(V_S \leq c_1 \mid H_0) = \alpha/2$ and $P(V_S \geq c_2 \mid H_0) = \alpha/2$.

3.2 Boxplot for test item evaluation – urban cycle

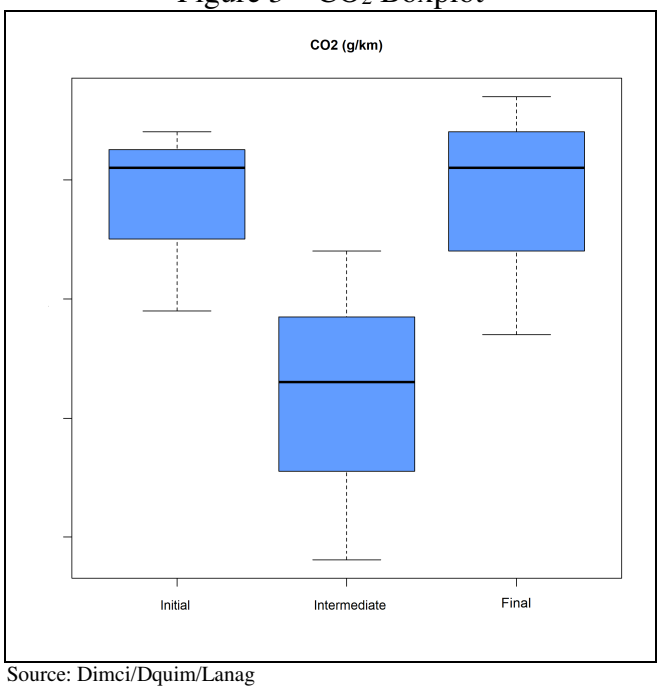
Figures 2 to 11 refer to boxplot for test item evaluation for urban cycle.

Figure 2 – CO Boxplot



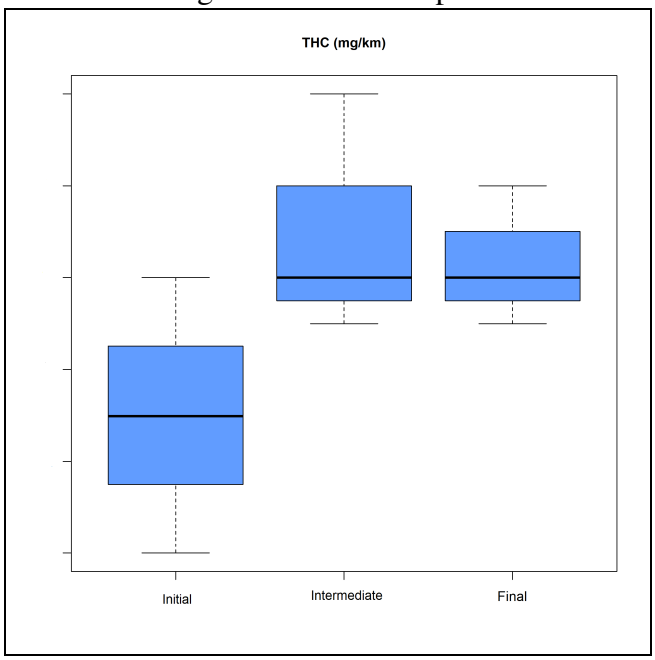
Source: Dimci/Dquim/Lanag

Figure 3 – CO_2 Boxplot



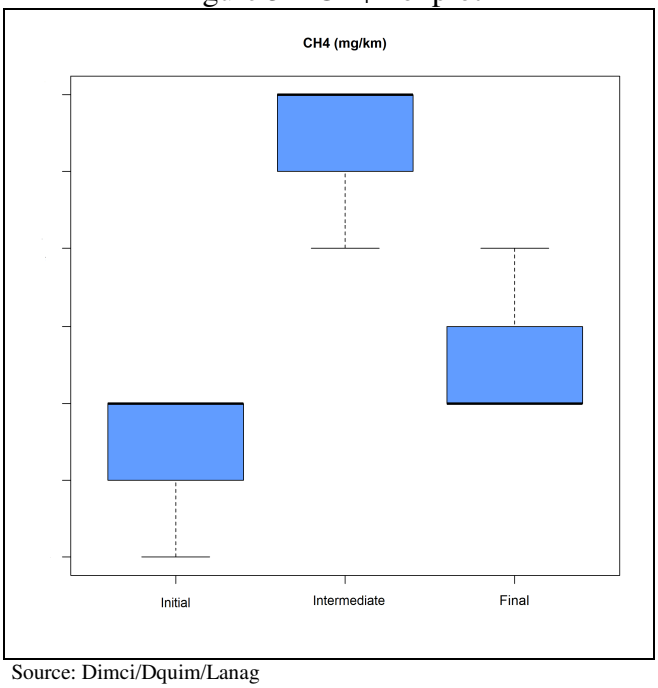
Source: Dimci/Dquim/Lanag

Figure 4 – THC Boxplot



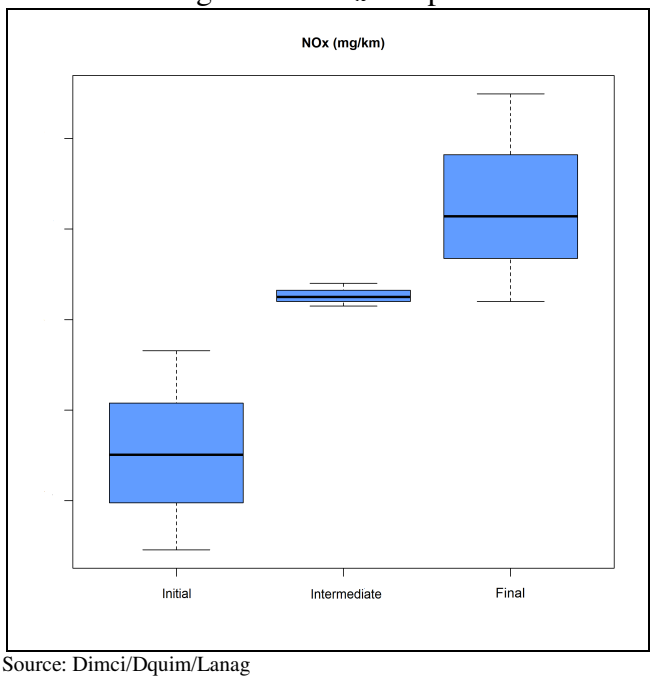
Source: Dimci/Dquim/Lanag

Figure 5 – CH_4 Boxplot



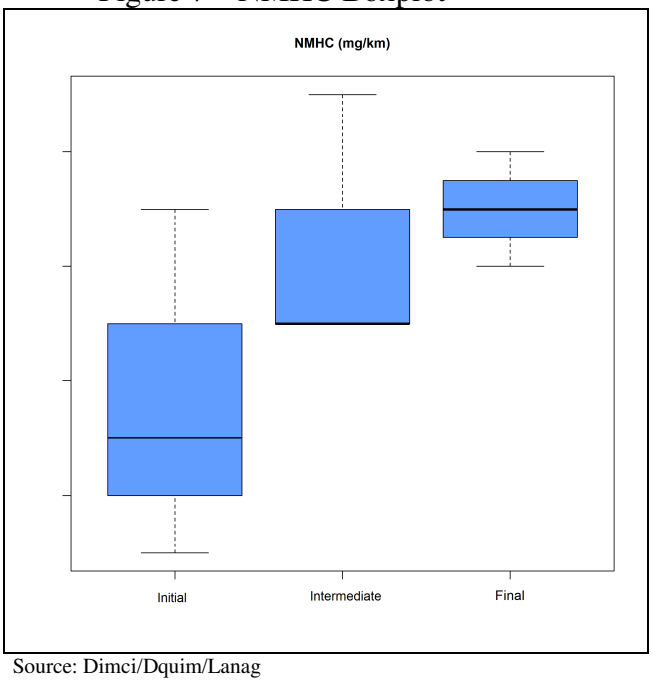
Source: Dimci/Dquim/Lanag

Figure 6 – NO_x Boxplot



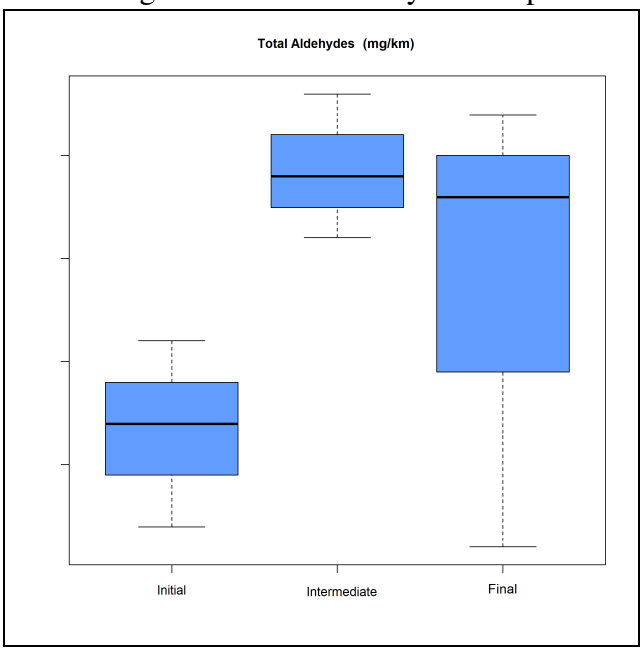
Source: Dimci/Dquim/Lanag

Figure 7 – NMHC Boxplot



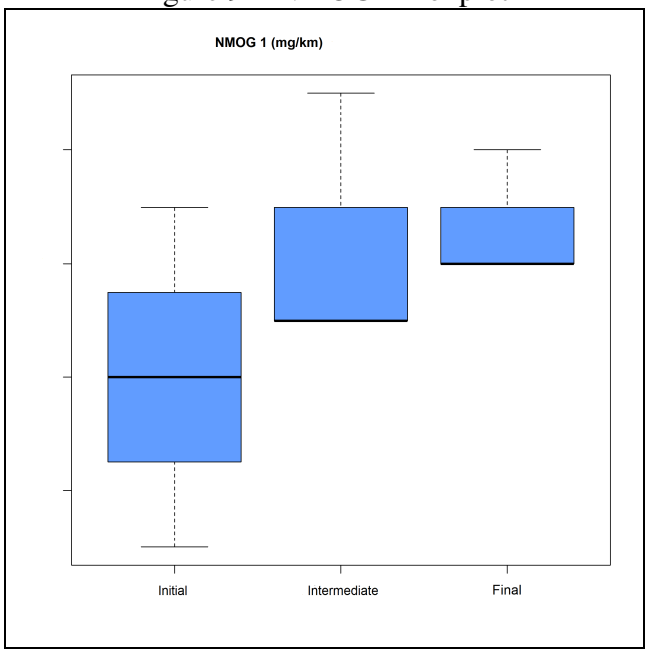
Source: Dimci/Dquim/Lanag

Figure 8 – Total Aldehydes Boxplot



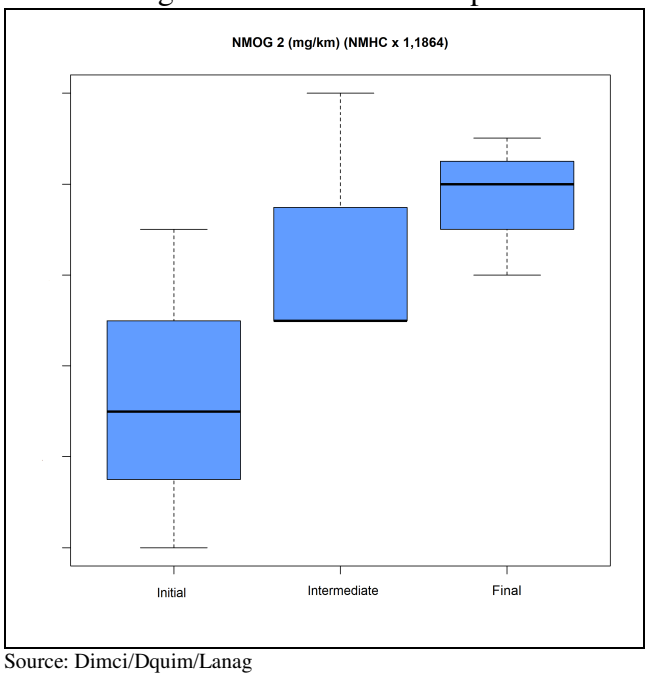
Source: Dimci/Dquim/Lanag

Figure 9 – NMOG 1 Boxplot



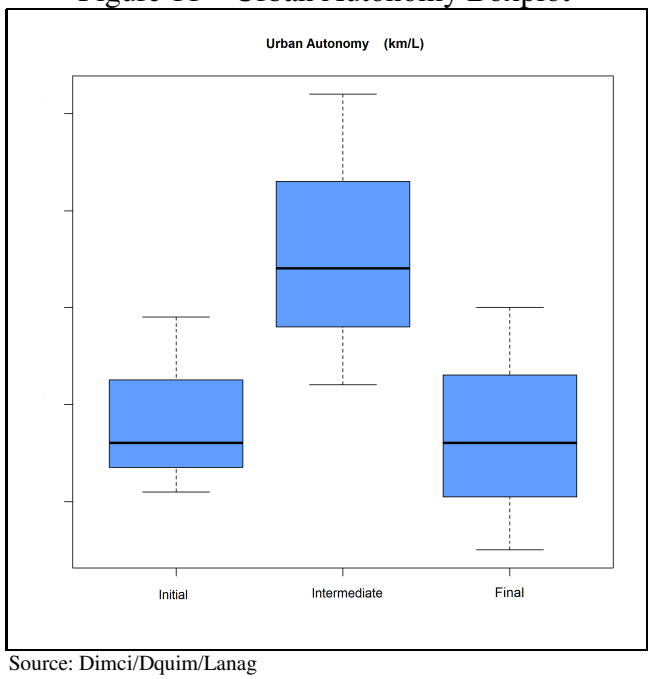
Source: Dimci/Dquim/Lanag

Figure 10 – NMOG 2 Boxplot



Source: Dimci/Dquim/Lanag

Figure 11 – Urban Autonomy Boxplot

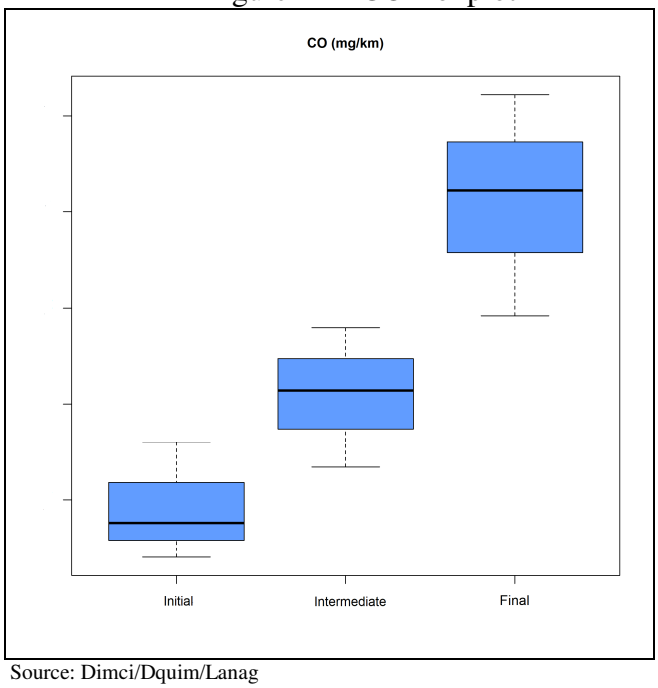


Source: Dimci/Dquim/Lanag

3.2 Boxplot for test item evaluation – Road cycle

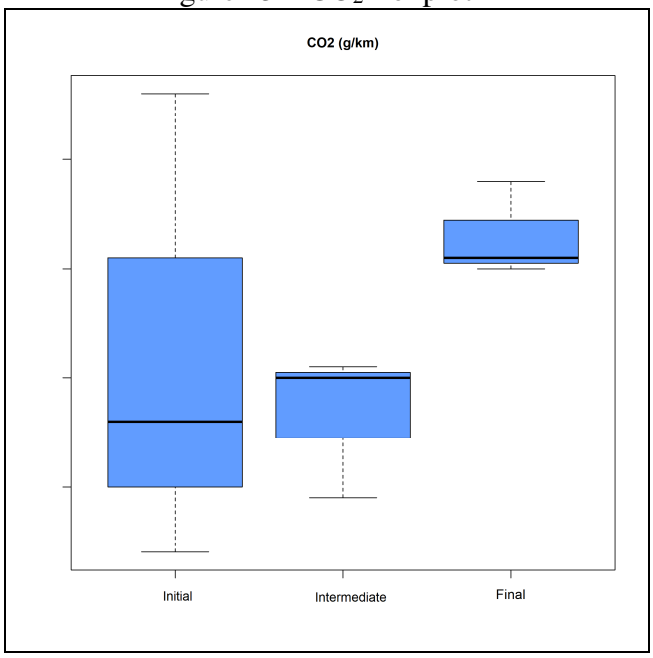
Figures 12 to 16 refer to boxplot for test item evaluation for Road cycle.

Figure 12 – CO Boxplot



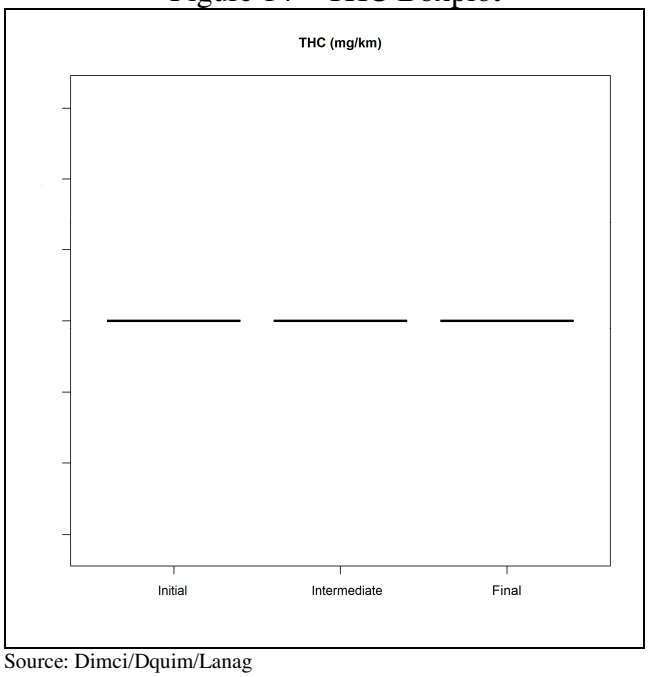
Source: Dimci/Dquim/Lanag

Figure 13 – CO_2 Boxplot



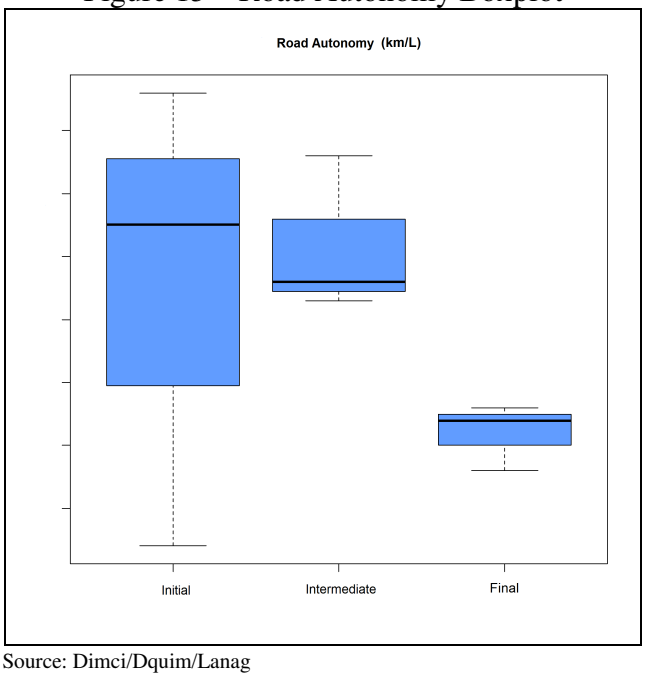
Source: Dimci/Dquim/Lanag

Figure 14 – THC Boxplot



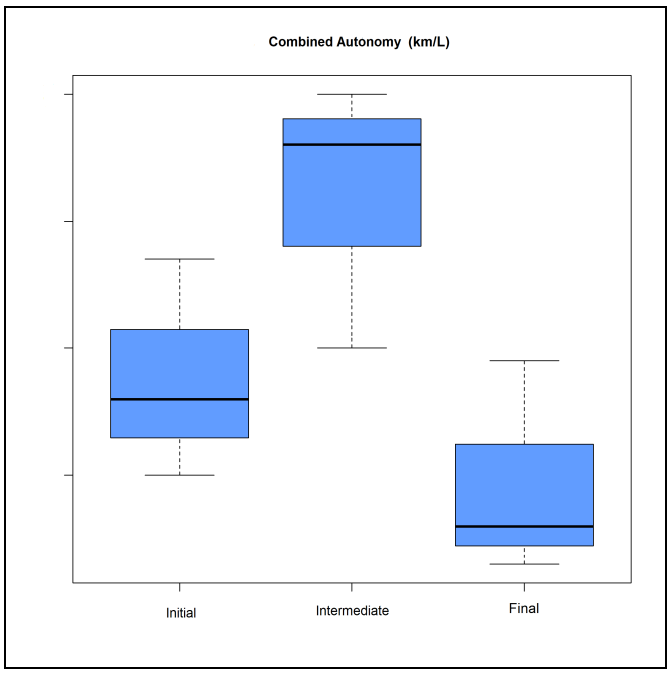
Source: Dimci/Dquim/Lanag

Figure 15 – Road Autonomy Boxplot



Source: Dimci/Dquim/Lanag

Figure 16 – Combined Autonomy Boxplot

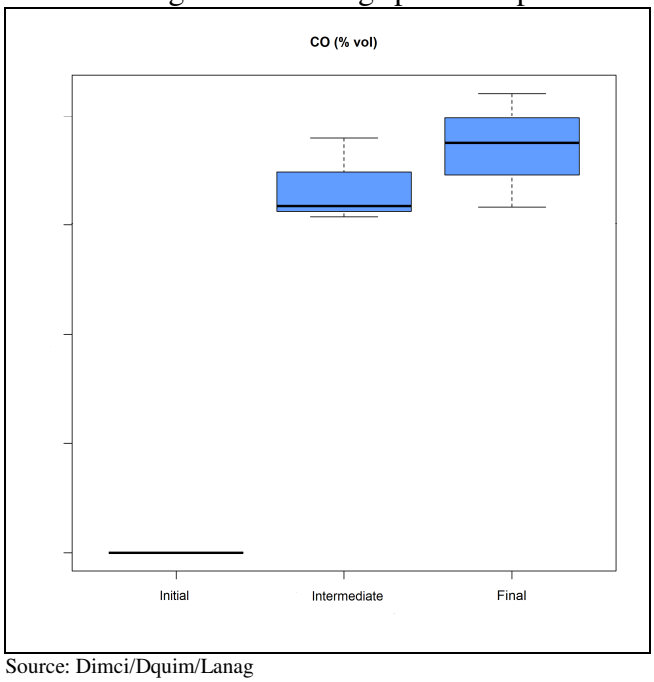


Source: Dimci/Dquim/Lanag

3.3 Boxplot for test item evaluation – idling speed and SHED

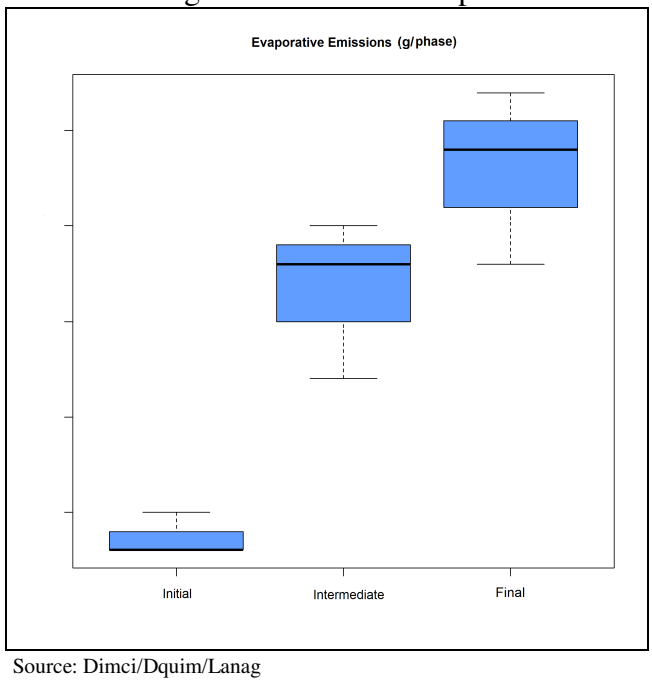
Figures 17 and 18 refer to boxplot for test item evaluation for idling speed CO and SHED.

Figure 17 – Idling speed Boxplot



Source: Dimci/Dquim/Lanag

Figure 18 – SHED Boxplot



Source: Dimci/Dquim/Lanag

As can be observed, only for NO_x (Urbano cycle), CO (Road cycle), CO (idling speed) and evaporative emissions (SHED) there was not box intersection among initial, intermediary and final measurements, while in all other parameters there seems to be minor discrepancies. However, it should be noted that the small number of repetitions (3) makes difficult a better inspection by this visualization method.

Then, the stability hypothesis among those measurements was tested by means the Wilcoxon also known as Mann-Whitney test. Table 2 below resumes the result for two samples at the 5 % level of significance.

Table 2 - Statistics and p-values for *Wilcoxon* test

Cycle	Component	p-value 1-2	p-value 1-3	p-value 2-3
Urban	CO (mg/km)	0.6625	0.6625	1.0000
	CO_2 (g/km)	0.1904	1.0000	0.1904
	THC (mg/km)	0.2683	0.2683	1.0000
	NOx (mg/km)	0.0809	0.0809	0.3827
	NMHC (mg/km)	0.3758	0.2683	0.6579
	CH_4 (mg/km)	0.0722	0.3017	0.1101
	Total Aldehydes (mg/km)	0.0809	0.6625	0.6625
	NMOG 1 (mg/km) (classic - IN 22:2020)	0.3758	0.3758	0.6531
	NMOG 2 (mg/km) (NMHC x 1,1864)	0.3758	0.1904	0.6579
	Urban Autonomy (km/L)	0.1904	1.0000	0.1904
Road	CO (mg/km)	0.1904	0.0809	0.0809
	CO_2 (g/km)	1.0000	0.6625	0.0809
	THC (mg/km)	NA	NA	NA
	Road Autonomy (km/L)	1.0000	0.6625	0.0809
	Combined Autonomy (km/L)	0.1904	0.3827	0.0809
Idling Speed	CO (% vol)	0.0636	0.0636	0.6625
SHED	Evaporative Emissions (g/phase)	0.0765	0.0765	0.2683

Source: Dimci/Dquim/Lanag

All results were the same, with p-value greater than 0.05. Thereby, it can be assured that, to a level of confidence of 95 %, there are no difference statistically significant between the mean and the sample data can be considered as coming from the same population.

Due to results confidentiality, once Hyundai Motor Brasil is also a PT participant, these results were not presented.

4. Statistical Analysis of Participants' Results

4.1. *z*-Score

For the participants' results evaluation, it was followed one of ABNT NBR ISO/IEC 17043:2011 criteria, *z*-score (distance measurement related of the laboratory measurement result in relation to the PT assigned value), that was calculated according to equation 1.

$$z_i = \frac{x_i - X}{\hat{\sigma}} \quad (1)$$

Where:

x_i is the mean measurement result of the i[th] participant;

X is the PT assigned value;

$\hat{\sigma}$ is the standard deviation for the proficiency testing, that in this round was established as described in ISO 13528:2022 standard, that is, a robust standard deviation based on participants' results.

The interpretation of *z*-score is presented as follows:

$|z| \leq 2{,}0$ - indicates "satisfactory" performance and generates no signal;

$2{,}0 < |z| < 3{,}0$ – indicates "questionable" performance and generates a warning signal;

$|z| \geq 3{,}0$ - indicates "unsatisfactory" performance and generates an action signal.

5. Assigned Values

According to available procedures for the establishment of designated values by ABNT NBR ISO/IEC 17043:2011, the designated values of this PT were calculated by statistical methods described in 7.7 item of ISO 13528:2022 standard, that is, consensus values from participant results.

ISO 13528:2022 standard describes the robust analysis involving employment of the A algorithm for the calculation of designated value and standard deviation. The robust statistical techniques are used to minimize the influence that extreme results can have on estimates of mean and standard deviation.

Initially, all values object of the analysis (values sent by participants) were put in ascending order. Next, robust values and standard deviation of these data were denoted by (x^*) and (s^*). Initial values of (x*) and (s*) were calculated according to equations below:

$$x^* = x_i \text{ median} \tag{2}$$

$$s^* = 1{,}483 \text{ x median } |x_i - x^*| \tag{3}$$

(x^*) e (s^*) values were updated as follows. It was calculated:

$$\delta = 1{,}5 s^* \tag{4}$$

For each x_i (i = 1, 2,..., p), it was calculated:

$$x_i^* = \begin{cases} x^* - \delta, & \text{if} \quad x_i < x^* - \delta \\ x^* + \delta, & \text{if} \quad x_i > x^* + \delta \\ x_i, & \text{otherwise} \end{cases} \tag{5}$$

new values of (x*) e (s*) should be calculated from the equations:

$$x^* = \sum x_i^* / p \quad (6)$$

$$s^* = 1{,}134\sqrt{\sum \left(x_i^* - x^*\right)^2 / (p-1)} \quad (7)$$

Where the summation is over *i*.

The robust estimation (x*) and (s*) can be obtained by an iterative calculation, i.e., by updating the values of (x*) and (s*) several times using the modified data, until the process converges. Convergence may be assumed when there is no change from one iteration to the next in the third significant figure of the robust standard deviation and of the equivalent figure in the robust average.

The results out of 2 standard deviation intervals after the robust average and robust standard deviation calculation were considered as outliers and new assigned value as well new robust standard deviation results were calculated, removing those outliers.

Tables 3, 4, 5 and 6 present the assigned values and the robust standard deviation for all parameters, including all PT participants, as well as the new robust average and standard deviation values after removal of the outlier results.

Where the obtained value is the result of each parameter measurement per participant.

Each participant in this report is identified by the last numeric characters of its identification code in tables, graphs and texts.

Table 3 – Assigned Values and standard deviations of the PT

Cycle	Component	Assigned values	Standard deviation	Discrepants (Participants)	Recalculated Assuigned Value	Recalculated Standard deviation
Urban	CO (mg/km)	1650.9158	270.8792			
	CO_2 (g/km)	153.5907	6.4811			
	THC (mg/km)	33.3133	6.3307	91	32.6013	5.5404
	NO_x (mg/km)	150.0151	19.2719			
	NMHC (mg/km)	24.6428	5.0262	91	24.0365	4.3057
	CH_4 (mg/km)	9.0050	1.1710			
	Total Aldehydes (mg/km)	1.1658	0.5872			
	NMOG 1 (mg/km) (classic - IN 22:2020)	25.3390	5.8720	91	24.6307	5.0303
	NMOG 2 (mg/km) (NMHC x 1.1864)	29.2157	5.8244	91	28.5132	4.9896
	Urban Autonomy (km/L)	13.9301	0.5976			
Road	CO (mg/km)	628.1921	142.5273			
	CO_2 (g/km)	112.0373	3.9516			
	THC (mg/km)	4.2766	0.9507			
	Road Autonomy (km/L)	19.2583	0.7065			
	Combined Autonomy (km/L)	15.9236	0.6902			
Idling Speed	CO (% vol)	0.0362	0.0228			
SHED	Evaporative Emissions (g/phase)	0.0320	0.0113			

Source: Dimci/Dquim/Lanag

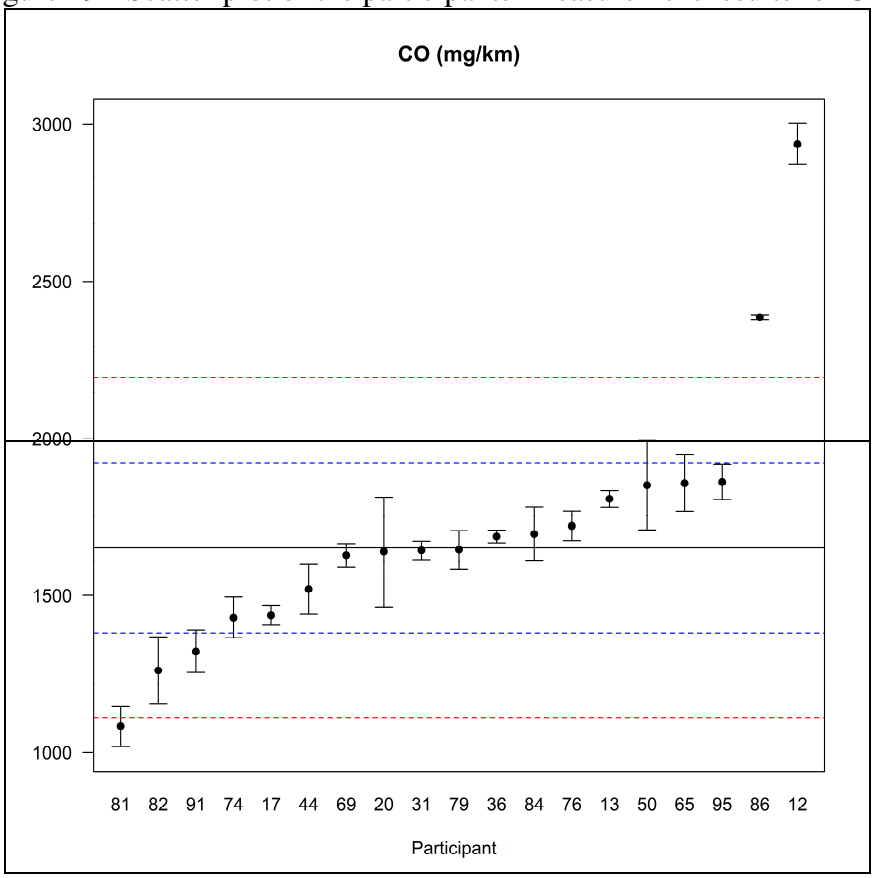
6. Results Dispersion

In the presented graphs for all tested parameters, a continuous black line represents the assigned value. The blue and red lines, respectively, are representations of Ref ± 1s and Ref ± 2s, where "Ref" is the assigned value (robust average) and "s" is the robust standard deviation.

6.1. Emissions – Urban Cycle

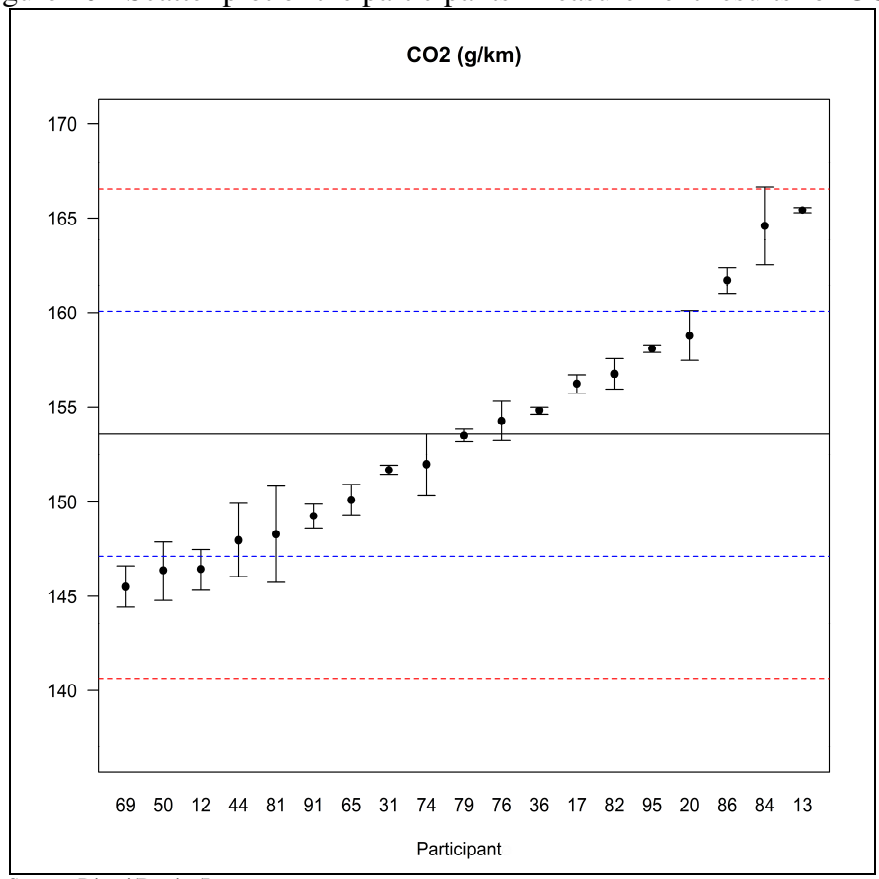
Figures 19 to 28 graphically present the means and robust standard deviation of the reported results by the participants for each urban cycle emissions analyzed parameter.

Figure 19 - Scatter plot of the participants' measurement results for CO.



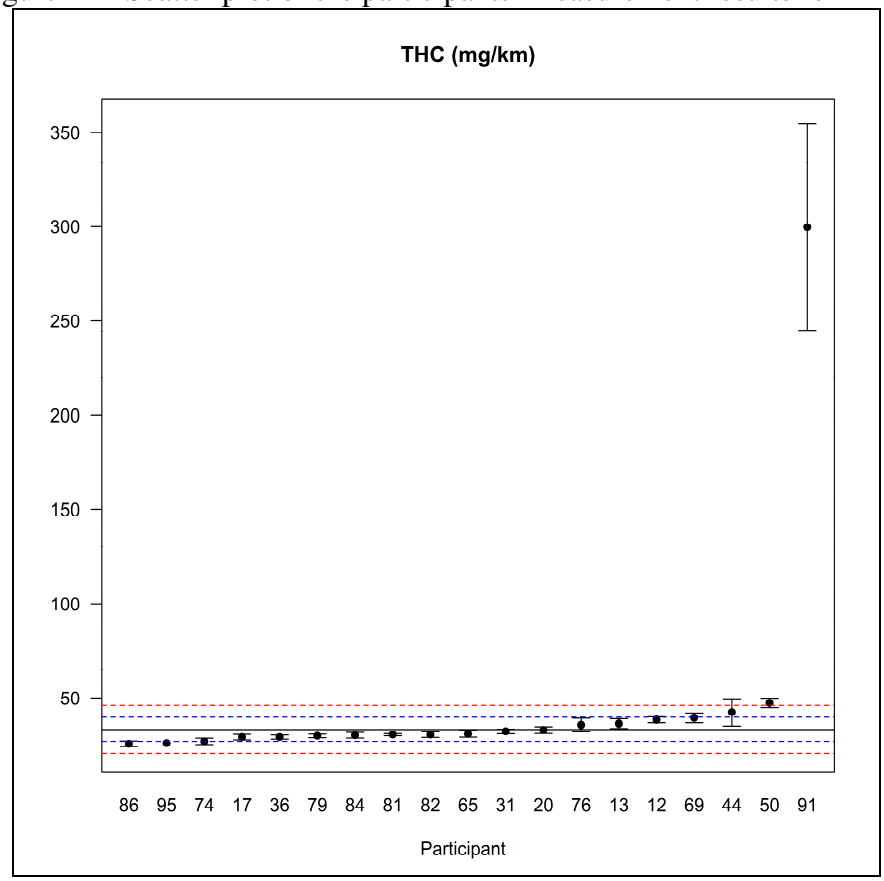
Source: Dimci/Dquim/Lanag

Figure 20 - Scatter plot of the participants' measurement results for CO_2.



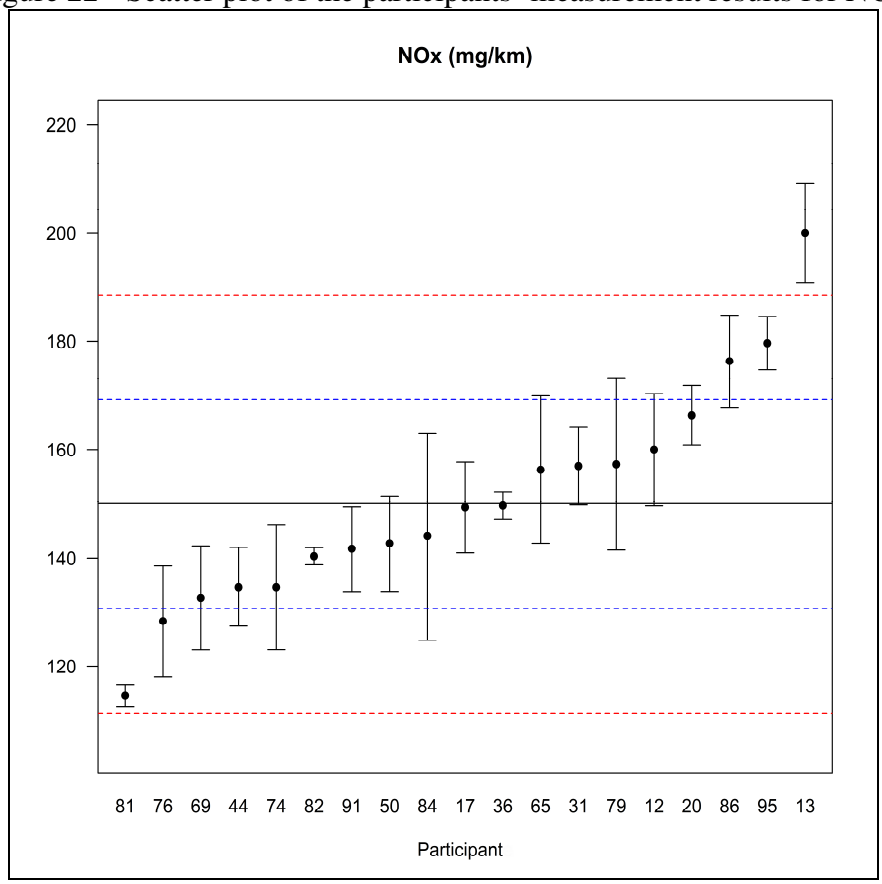
Source: Dimci/Dquim/Lanag

Figure 21 - Scatter plot of the participants' measurement results for THC.



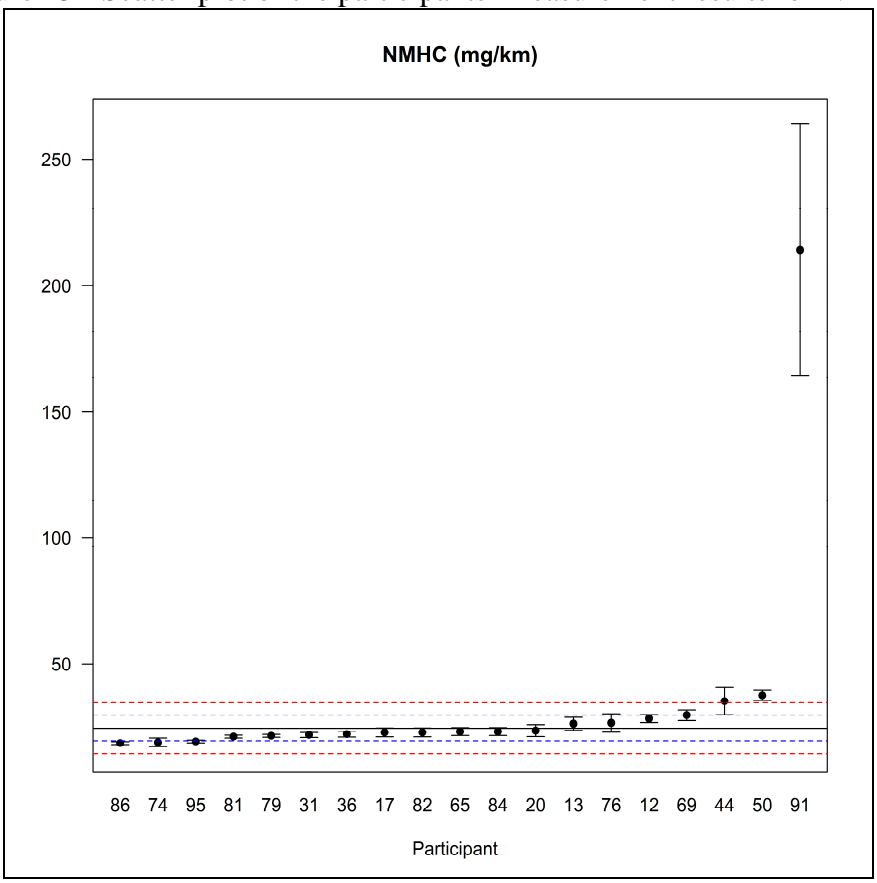
Source: Dimci/Dquim/Lanag

Figure 22 - Scatter plot of the participants' measurement results for NO_x.



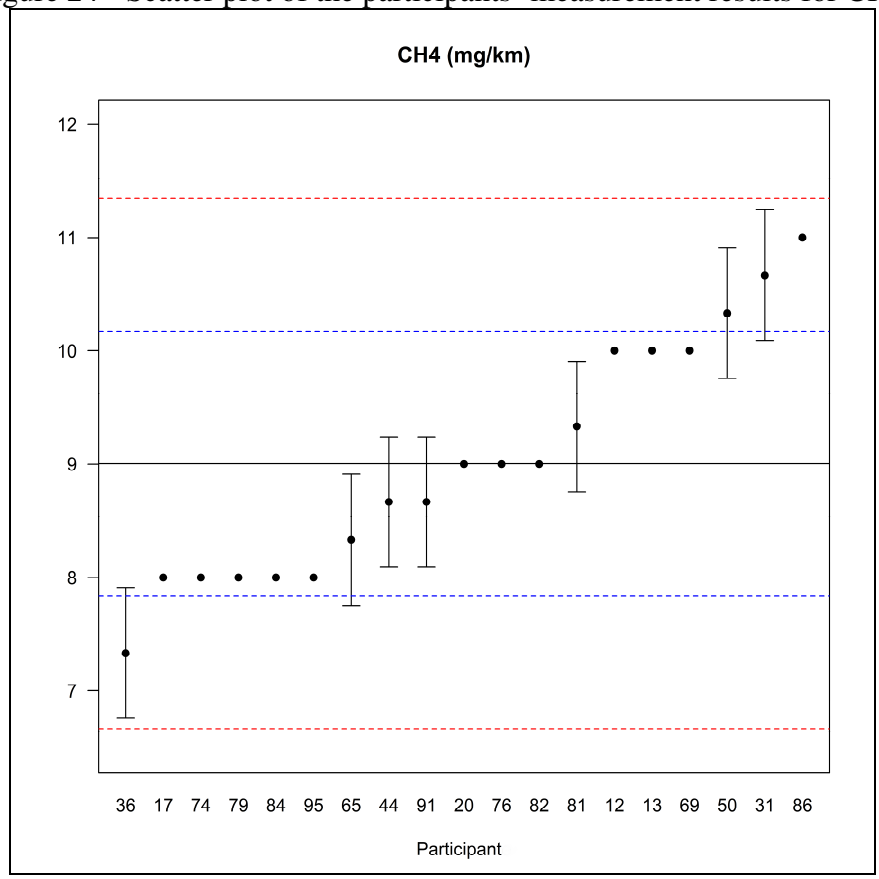
Source: Dimci/Dquim/Lanag

Figure 23 - Scatter plot of the participants' measurement results for NMHC.



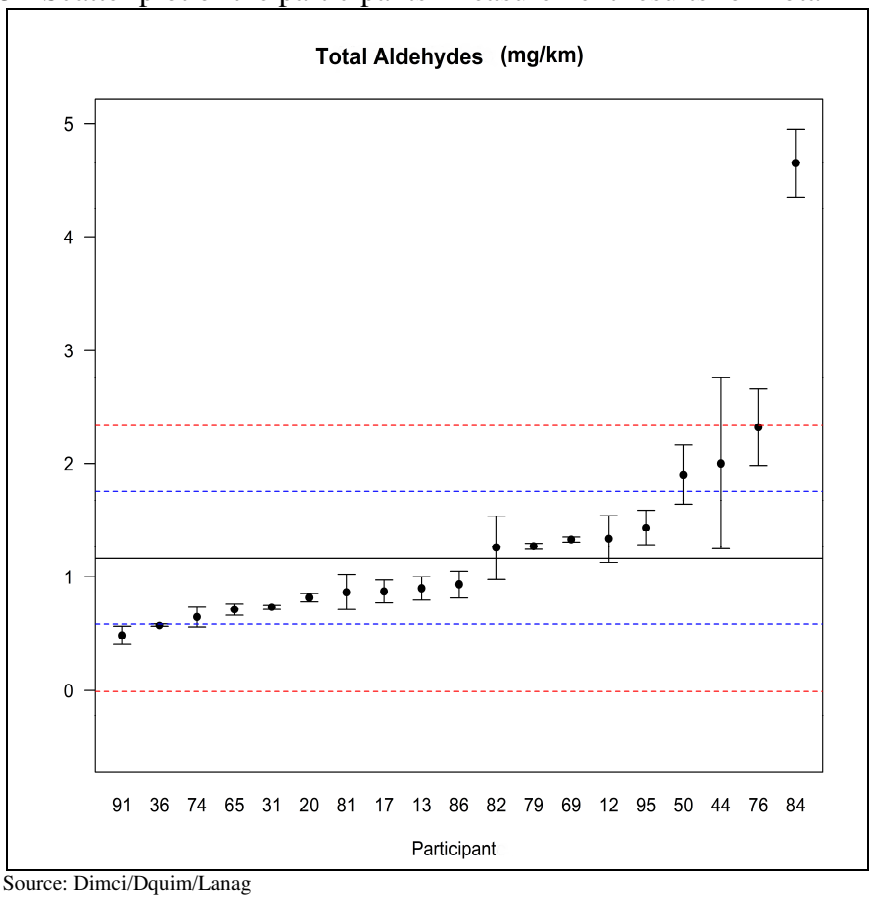
Source: Dimci/Dquim/Lanag

Figure 24 - Scatter plot of the participants' measurement results for CH_4.



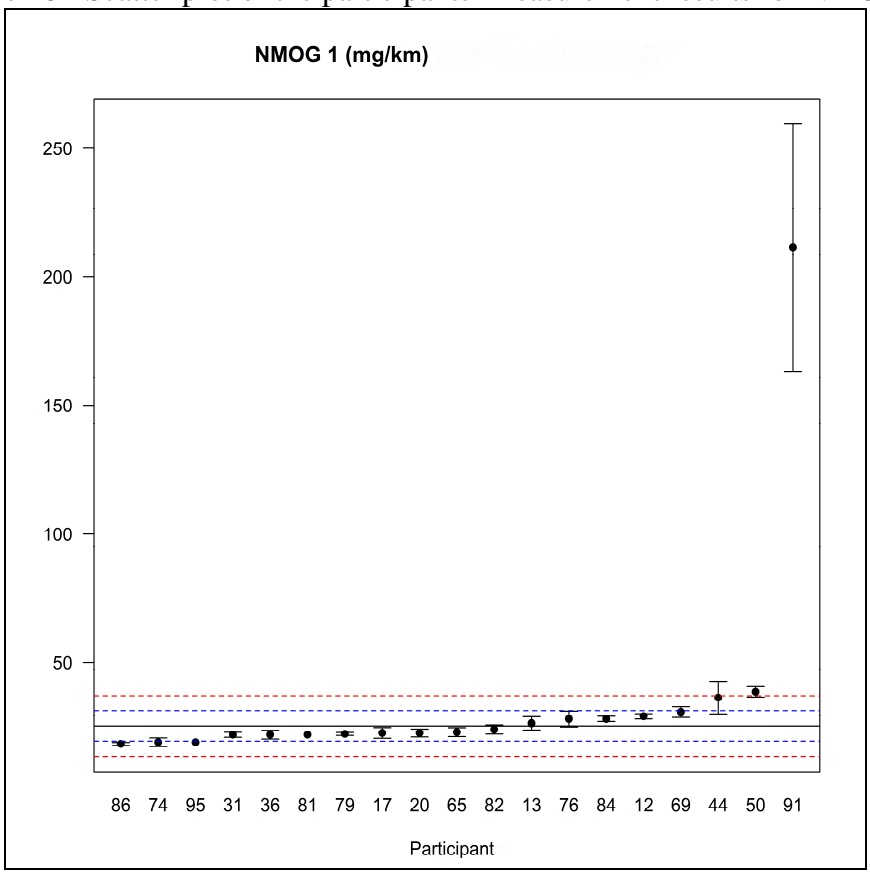
Source: Dimci/Dquim/Lanag

Figure 25 - Scatter plot of the participants' measurement results for Total Aldehydes.



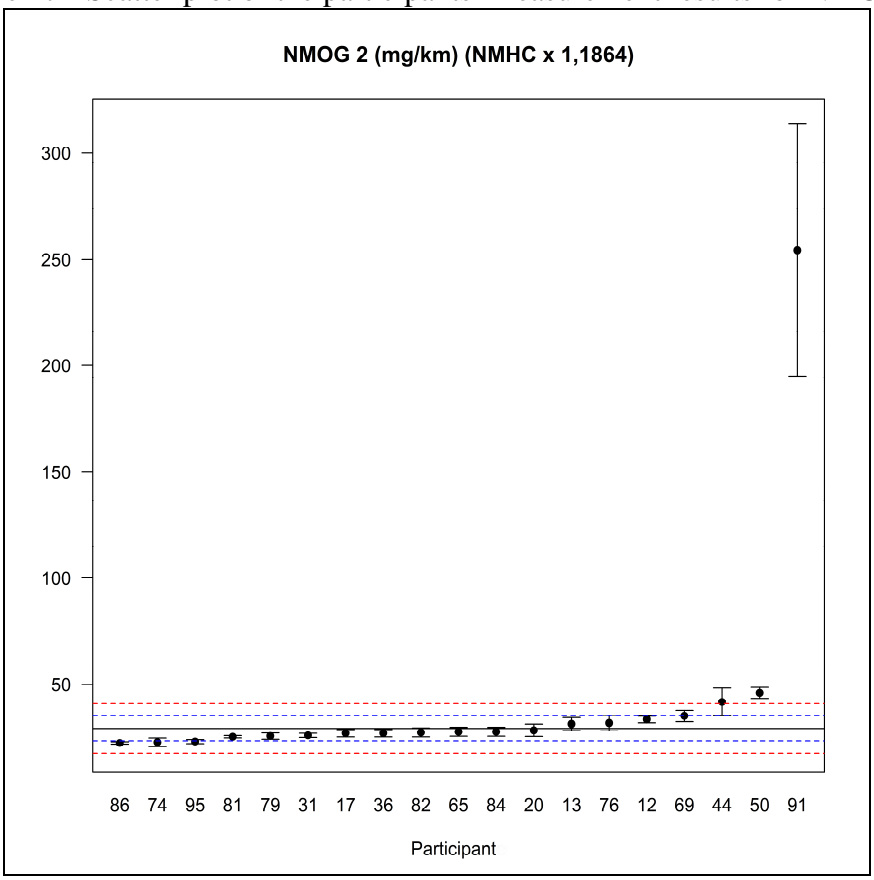
Source: Dimci/Dquim/Lanag

Figure 26 - Scatter plot of the participants' measurement results for NMOG 1.



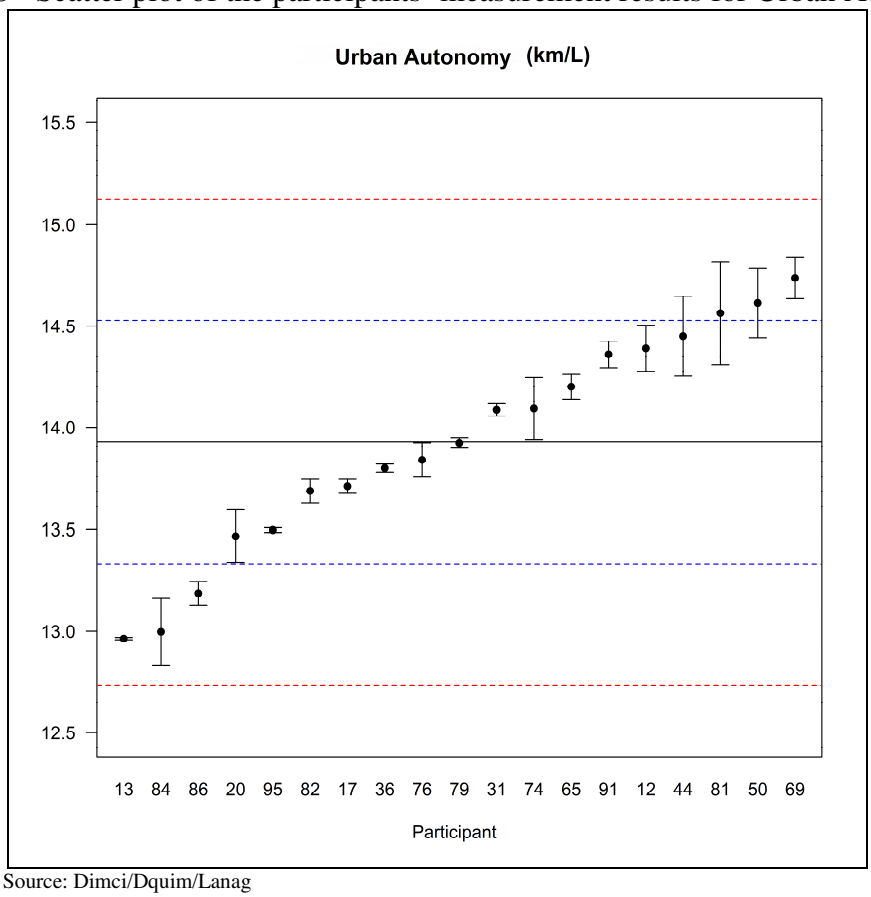
Source: Dimci/Dquim/Lanag

Figure 27 - Scatter plot of the participants' measurement results for NMOG 2.



Source: Dimci/Dquim/Lanag

Figure 28 - Scatter plot of the participants' measurement results for Urban Autonomy.



Source: Dimci/Dquim/Lanag

Through the graphics, it can be seen that:

CO (mg/km): 14 participants reported results within the Ref ± 1s interval. Participants 82 and 91 reported results within the Ref ± 2s interval and participants 81, 86 and 12 presented results out of Ref ± 2s interval.

CO_2 (g/km): 13 participants reported results within the Ref ± 1s interval. Participants 69, 50, 12, 86, 84 and 13 reported results within the Ref ± 2s interval.

THC (mg/km): 12 participants reported results within the Ref ± 1s interval. Participants 86, 95, 12, 69 and 44 reported results within the Ref ± 2s interval. Participants 50 and 91 presented results out of Ref ± 2s interval and participant 91 presented the greatest dispersion.

NOx (mg/km): 14 participants reported results within the Ref ± 1s interval. Participants 81, 76, 86 and 95 reported results within the Ref ± 2s interval. Participant 13 presented results out of Ref ± 2s interval.

NMHC (mg/km): 12 participants reported results within the Ref ± 1s interval. Participants 86, 74, 95 and 69 reported results within the Ref ± 2s interval. Participants 44, 50 and 91 presented results out of Ref ± 2s interval and participant 91 presented the greatest dispersion.

CH_4 (mg/km): 15 participants reported results within the Ref ± 1s interval. Participants 36, 50, 31 and 86 reported results within the Ref ± 2s interval.

Total Aldehydes (mg/km): 13 participants reported results within the Ref ± 1s interval. Participants 91, 36, 50, 44 and 76 reported results within the Ref ± 2s interval. Participant 84 presented results out of Ref ± 2s interval. Participant 44 presented the greatest dispersion.

NMOG 1 (mg/km): 12 participants reported results within the Ref ± 1s interval. Participants 86, 74, 95 and 69 reported results within the Ref ± 2s interval. Participants 50, 44 and 91 presented results out of Ref ± 2s interval. Participant 91 presented the greatest dispersion.

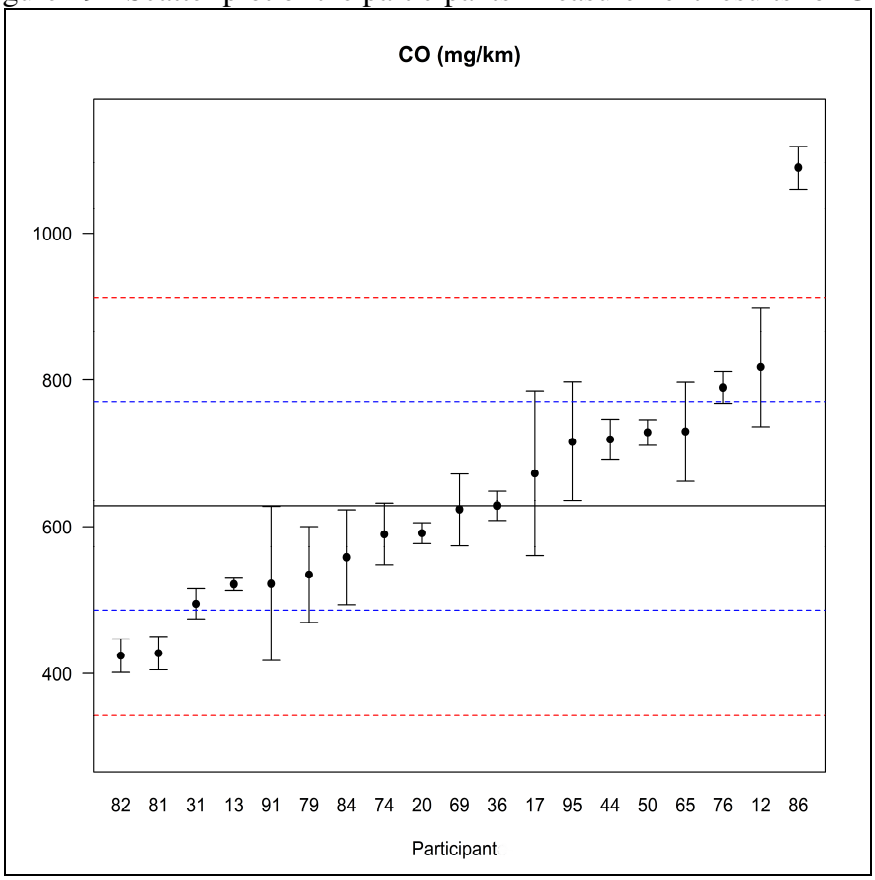
NMOG 2 (mg/km): 12 participants reported results within the Ref ± 1s interval. Participants 86, 74, 95 and 69 reported results within the Ref ± 2s interval. Participants 50, 44 and 91 presented results out of Ref ± 2s interval. Participant 91 presented the greatest dispersion.

Urban Autonomy (km/l): 13 participants reported results within the Ref ± 1s interval. Participants 13, 84, 86, 81, 50 and 69 reported results within the Ref ± 2s interval.

6.2. Road Cycle Emissions

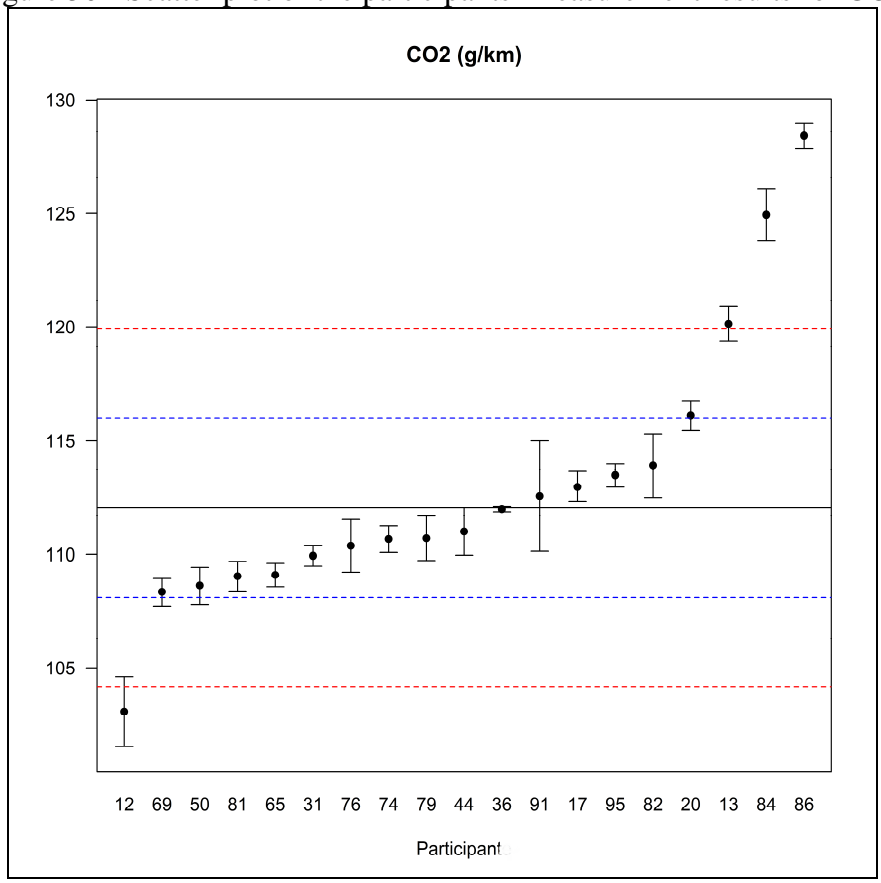
Figures 29 to 33 graphically present the means and robust standard deviation of the reported results by the participants for each Road cycle emissions analyzed parameter.

Figure 29 - Scatter plot of the participants' measurement results for CO.



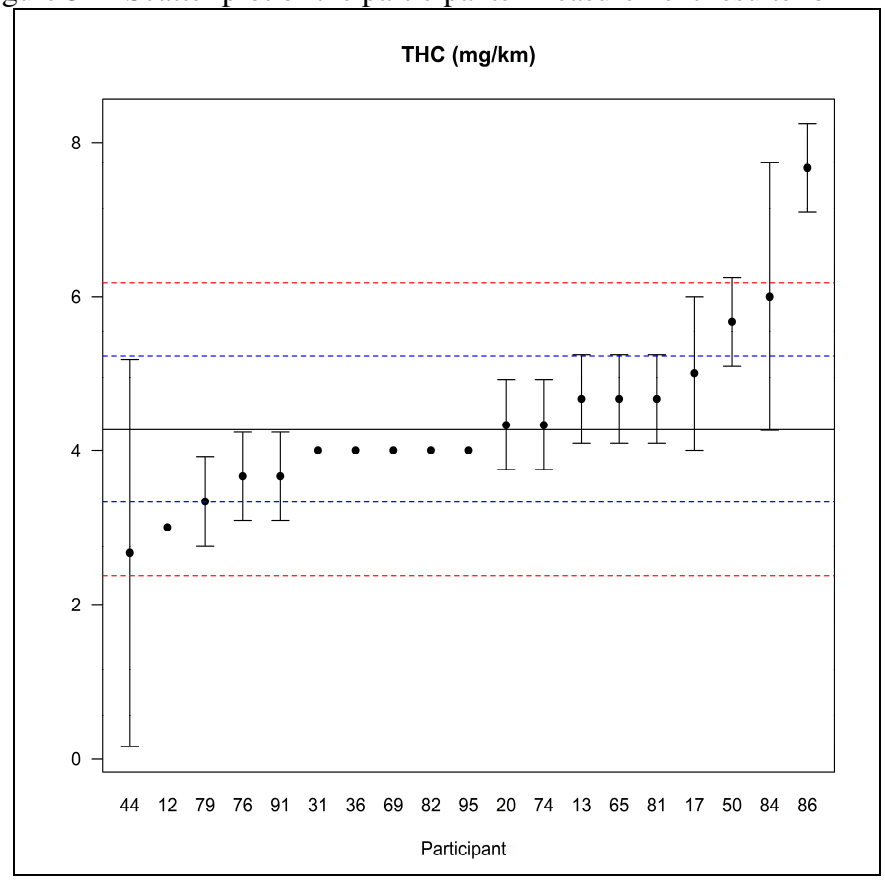
Source: Dimci/Dquim/Lanag

Figure 30 - Scatter plot of the participants' measurement results for CO_2.



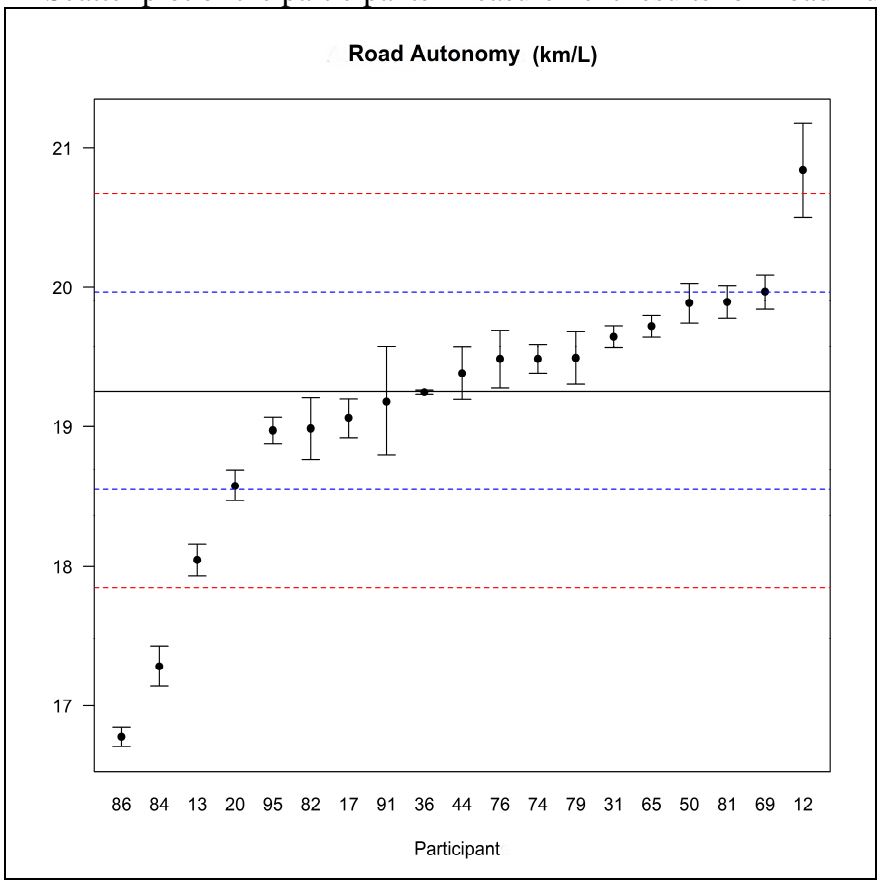
Source: Dimci/Dquim/Lanag

Figure 31 - Scatter plot of the participants' measurement results for THC.



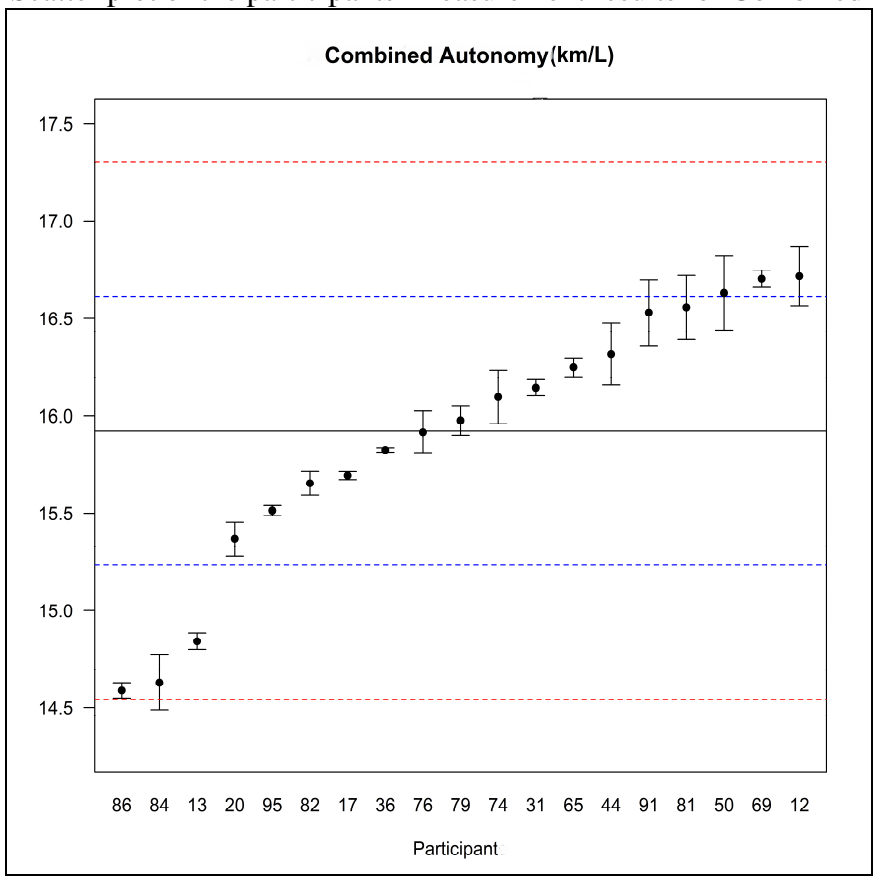
Source: Dimci/Dquim/Lanag

Figure 32 - Scatter plot of the participants' measurement results for Road Autonomy.



Source: Dimci/Dquim/Lanag

Figure 33 - Scatter plot of the participants' measurement results for Combined Autonomy.



Source: Dimci/Dquim/Lanag

Through the graphics, it can be seen that:

CO (mg/km): 14 participants reported results within the Ref ± 1s interval. Participants 82 and 81, 76 and 12 reported results within the Ref ± 2s interval. Participant 86 presented results out of Ref ± 2s interval and participants 91 and 17 presented the greatest dispersions.

CO_2 (g/km): 14 participants reported results within the Ref ± 1s interval. Participant 20 reported results within the Ref ± 2s interval and participants 13, 12, 84 and 86 presented results out of Ref ± 2s interval.

THC (mg/km): 14 participants reported results within the Ref ± 1s interval. Participants 44, 12, 50 and 84 reported results within the Ref ± 2s interval. Participant 86 presented results out of Ref ± 2s interval and participant 44 presented the greatest dispersion.

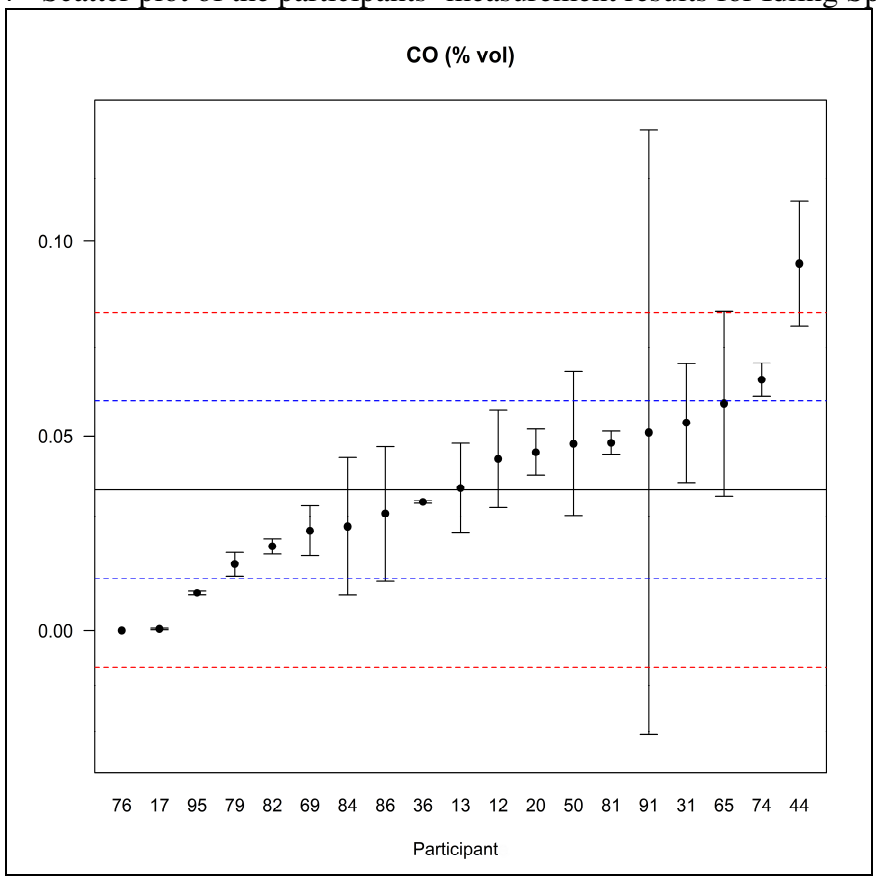
Road Autonomy (km/l): 15 participants reported results within the Ref ± 1s interval. Participant 13 reported results within the Ref ± 2s interval and participants 86, 84 and 12 presented results out of Ref ± 2s interval.

Combined Autonomy (km/l): 13 participants reported results within the Ref ± 1s interval. Participants 86, 84, 13, 20, 69 and 12 reported results within the Ref ± 2s interval.

6.3. Idling Speed

Figure 34 graphically present the means and robust standard deviation of the reported results by the participants for the Idling Speed CO parameter.

Figure 34 - Scatter plot of the participants' measurement results for Idling Speed CO.



Source: Dimci/Dquim/Lanag

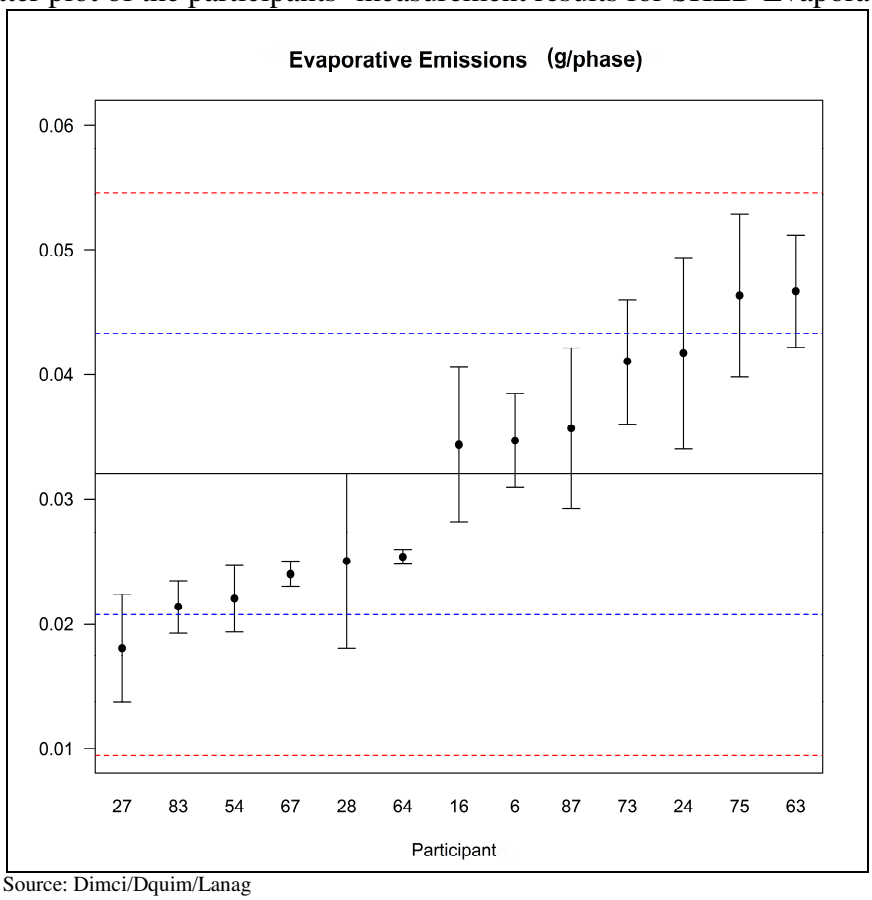
Through the graphic, it can be seen that:

Idling Speed: 14 participants reported results within the Ref ± 1s interval. Participants 76, 17, 95 and 74 reported results within the Ref ± 2s interval. Participant 44 presented results out of Ref ± 2s interval and participant 91 presented the greatest dispersion.

6.4. SHED

Figure 35 graphically present the means and robust standard deviation of the reported results by the participants for the SHED Evaporative Emissions parameter.

Figure 35- Scatter plot of the participants' measurement results for SHED Evaporative Emissions.



Source: Dimci/Dquim/Lanag

Through the graphic, it can be seen that:

SHED: 10 participants reported results within the Ref ± 1s interval. Participants 27, 75 and 63 reported results within the Ref ± 2s interval.

7. Participants' Results

Measurement results reported by participants in this PT are presented in sections 7.1 to 7.3.

Each participant in this report is identified by the last numeric characters of its identification code in tables, graphs and texts.

7.1. Average and Standard Deviations Results

7.1.1. Urban Cycle Emissions

Tables 4 and 5 present the replicates average and standard deviations of each participant for each urban cycle emissions analyzed parameter.

Table 4 – Average and standard deviation of participants for CO, CO_2, THC, NO_x e NMHC parameters

Code	CO (mg/km)		CO_2 (g/km)		THC (mg/km)		NO_x (mg/km)		NMHC (mg/km)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
12	2938	66	146.4	1.1	38	2	160	10	28	2
13	1807	27	165.4	0.2	36	3	200	9	26	3
17	1438	32	156.2	0.5	29	2	149	8	23	2
20	1639	174	158.8	1.3	33	2	166	6	24	2
31	1643	30	151.7	0.3	32	1	157	7	22	1
36	1688	21	154.8	0.2	29	1	150	3	22	1
44	1520	78	148.0	2.0	42	7	135	7	35	6
50	1852	143	146.3	1.6	47	3	143	9	38	2
65	1858	90	150.1	0.8	31	2	156	14	23	2
69	1627	38	145.5	1.1	39	3	133	10	30	2
74	1430	65	152.0	1.6	27	2	135	12	19	2
76	1722	47	154.3	1.1	36	4	128	10	27	4
79	1645	62	153.5	0.3	30	1	157	16	22	1
81	1083	64	148.3	2.5	31	1	115	2	21	1
82	1261	106	156.8	0.8	31	2	140	2	23	2
84	1696	85	164.6	2.1	30	2	144	19	23	2
86	2387	9	161.7	0.7	26	2	176	9	19	1
91	1322	67	149.2	0.7	300	55	142	8	214	50
95	1862	56	158.1	0.2	26	0	180	5	19	1

Source: Dimci/Dquim/Lanag

Table 5 – Average and standard deviation of participants for CH_4, Total Aldehydes, NMOG 1, NMOG 2 and Urban Autonomy parameters

Code	CH4 (mg/km)		Aldeídos Totais (mg/km)		NMOG 1 (mg/km)		NMOG 2 (mg/km)		Autonomia Urbana (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
12	10	0	1.33	0.21	29	1	33	2	14.39	0.11
13	10	0	0.90	0.10	26	3	31	3	12.96	0.01
17	8	0	0.87	0.10	23	2	27	2	13.71	0.03
20	9	0	0.82	0.04	23	2	28	3	13.47	0.13
31	11	1	0.73	0.02	22	1	26	1	14.09	0.03
36	7	1	0.57	0.01	22	2	27	2	13.80	0.02
44	9	1	2.00	0.75	36	6	42	7	14.45	0.20
50	10	1	1.90	0.26	39	2	46	3	14.61	0.17
65	8	1	0.71	0.05	23	2	28	2	14.20	0.06
69	10	0	1.33	0.02	31	2	35	3	14.74	0.10
74	8	0	0.65	0.09	19	2	23	2	14.09	0.15
76	9	0	2.32	0.34	28	3	32	4	13.84	0.09

Code	CH4 (mg/km)		Aldeídos Totais (mg/km)		NMOG 1 (mg/km)		NMOG 2 (mg/km)		Autonomia Urbana (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
79	8	0	1.27	0.03	22	1	26	2	13.92	0.03
81	9	1	0.87	0.16	22	0	25	1	14.56	0.25
82	9	0	1.26	0.28	24	2	27	2	13.69	0.06
84	8	0	4.65	0.30	28	1	28	2	13.00	0.17
86	11	0	0.93	0.12	18	1	22	1	13.19	0.06
91	9	1	0.48	0.08	211	48	254	59	14.36	0.07
95	8	0	1.43	0.15	19	0	23	1	13.50	0.01

Source: Dimci/Dquim/Lanag

7.1.2. Road Cycle Emissions

Table 6 presents the replicates average and standard deviations of each participant for CO (mg/km), CO_2 (g/km), THC (mg/km), Road Autonomy (km/L) and Combined Autonomy (km/L) parameters.

Table 6 – Average and standard deviation of participants for CO (mg/km), CO_2 (g/km), THC (mg/km), Road Autonomy (km/L) and Combined Autonomy (km/L) parameters

Code	CO (mg/km)		CO_2 (g/km)		THC (mg/km)		Road Autonomy (km/L)		Combined Autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
12	818	81	103.1	1.5	3	0	20.84	0.34	16.72	0.15
13	522	8	120.1	0.8	5	1	18.05	0.11	14.84	0.04
17	673	113	113.0	0.7	5	1	19.06	0.14	15.69	0.02
20	591	14	116.1	0.7	5	1	18.58	0.11	15.37	0.09
31	495	21	109.9	0.5	4	0	19.64	0.08	16.14	0.04
36	628	20	112.0	0.1	4	0	19.25	0.02	15.82	0.01
44	719	28	111.0	1.0	3	3	19.38	0.18	16.32	0.16
50	729	17	108.6	0.8	6	1	19.89	0.14	16.63	0.19
65	730	67	109.1	0.5	5	1	19.72	0.08	16.25	0.05
69	624	49	108.3	0.6	4	0	19.97	0.12	16.70	0.05
74	590	42	110.7	0.6	4	1	19.49	0.10	16.10	0.14
76	790	22	110.4	1.2	4	1	19.49	0.21	15.92	0.11
79	535	65	110.7	1.0	3	1	19.49	0.19	15.98	0.08
81	428	23	109.0	0.7	5	1	19.89	0.12	16.56	0.16
82	424	23	113.9	1.4	4	0	18.99	0.22	15.65	0.06
84	559	64	124.9	1.2	6	2	17.28	0.15	14.63	0.14
86	1090	29	128.4	0.6	8	1	16.78	0.07	14.59	0.04
91	523	105	112.6	2.4	4	1	19.18	0.39	16.53	0.17
95	716	81	113.5	0.5	4	0	18.97	0.10	15.51	0.03

Source: Dimci/Dquim/Lanag

7.1.3. Idling Speed CO (% vol)

Table 7 presents the replicates average and standard deviations of each participant for Idling Speed CO (% vol) parameter.

Table 7 – Average and standard deviation of participants for Idling Speed CO parameter

Code	CO (% vol.)	
	Average	Standard deviation
12	0.0441	0.0125
13	0.0367	0.0115
17	0.0004	0.0002
20	0.0458	0.0060
31	0.0533	0.0153
36	0.0330	0.0004
44	0.0943	0.0160
50	0.0480	0.0185
65	0.0583	0.0238
69	0.0256	0.0064
74	0.0644	0.0044
76	0.0000	0.0000
79	0.0170	0.0030
81	0.0483	0.0030
82	0.0216	0.0020
84	0.0267	0.0177
86	0.0300	0.0173
91	0.0509	0.0777
95	0.0097	0.0006

Source: Dimci/Dquim/Lanag

7.1.4. SHED - Evaporative Emissions (g/phase)

Table 8 presents the replicates average and standard deviations of each participant for SHED – Evaporative Emissions parameter.

Table 8– Average and standard deviation of participants for SHED – Evaporative Emissions parameter

Code	Evaporative Emissions (g/phase)	
	Average	Standard deviation
06	0.035	0.004

Code	Evaporative Emissions (g/phase)	
	Average	Standard deviation
16	0.034	0.006
24	0.042	0.008
27	0.018	0.004
28	0.025	0.007
54	0.022	0.003
63	0.047	0.005
64	0.025	0.001
67	0.024	0.001
73	0.041	0.005
75	0.046	0.007
83	0.021	0.002
87	0.036	0.006

Source: Dimci/Dquim/Lanag

7.2. *z*-Score

7.2.1. Urban Cycle Emissions – *z*-score

For the performance evaluation of the participants, *z*-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results for each emissions parameter. Tables 9 and 10 and figures 36 to 45 present these results.

Table 9 – *z*-score values for the CO, CO_2, THC, NO_x and NMHC – Urban Cycle parameters.

Code	CO (mg/km)	CO_2 (g/km)	THC (mg/km)	NO_x (mg/km)	NMHC (mg/km)
	z-score	*z*-score	*z*-score	*z*-score	*z*-score
12	**4.75**	-1.11	1.03	0.52	1.00
13	0.58	1.83	0.67	**2.59**	0.53
17	-0.79	0.41	-0.59	-0.04	-0.24
20	-0.04	0.80	0.07	0.85	-0.09
31	-0.03	-0.30	-0.05	0.36	-0.47
36	0.14	0.19	-0.59	-0.02	-0.40
44	-0.48	-0.87	1.76	-0.80	2.62
50	0.74	-1.12	**2.66**	-0.38	3.17
65	0.76	-0.54	-0.29	0.33	-0.16
69	-0.09	-1.25	1.22	-0.90	1.31
74	-0.82	-0.25	-1.01	-0.80	-1.17
76	0.26	0.10	0.55	-1.13	0.61
79	-0.02	-0.01	-0.47	0.38	-0.55
81	**-2.10**	-0.82	-0.35	-1.83	-0.63

Code	CO (mg/km)	CO_2 (g/km)	THC (mg/km)	NO_x (mg/km)	NMHC (mg/km)
	z-score	*z*-score	*z*-score	*z*-score	*z*-score
82	-1.44	0.49	-0.35	-0.50	-0.24
84	0.17	1.70	-0.41	-0.31	-0.16
86	**2.72**	1.25	-1.25	1.37	-1.25
91	-1.21	-0.67	**48.20**	-0.43	**44.20**
95	0.78	0.70	-1.19	1.54	-1.09

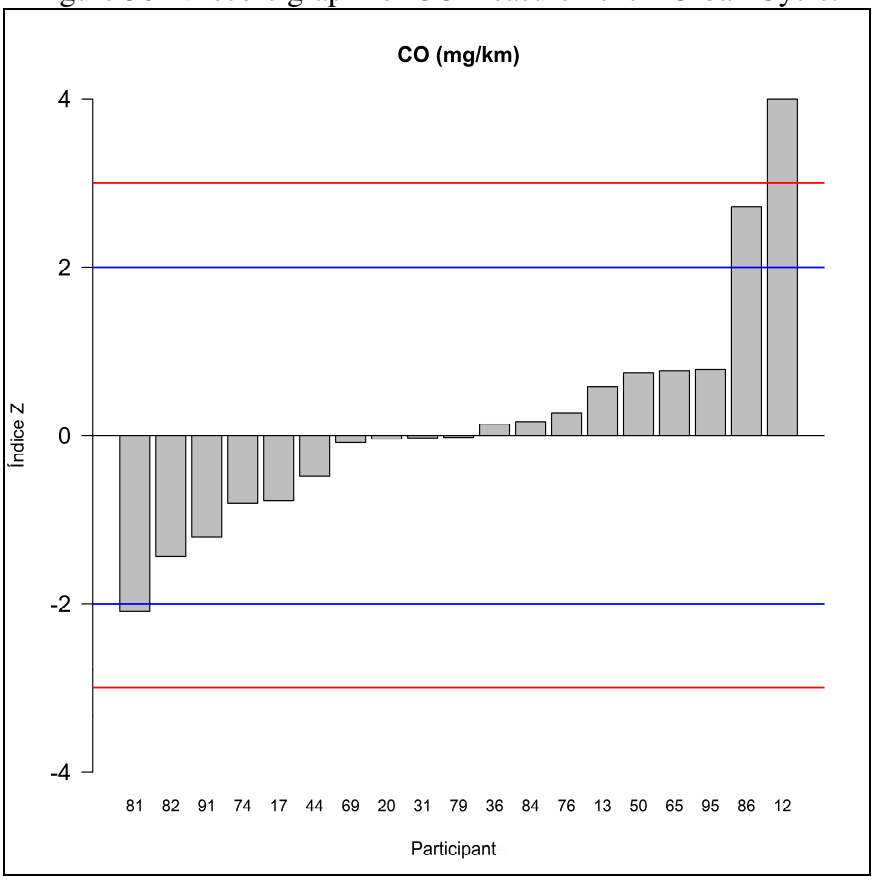
Source: Dimci/Dquim/Lanag
* Satisfactory result
* Questionable result
* Unsatisfactory result

Table 10 – *z*-score values for the CH_4, Total Aldehydes, NMOG 1, NMOG 2 and Urban Autonomy – Urban Cycle parameters.

Code	CH_4 (mg/km)	Total Aldehydes (mg/km)	NMOG 1 (mg/km)	NMOG 2 (mg/km)	Urban Autonomy (km/L)
	z-score	*z*-score	*z*-score	*z*-score	*z*-score
12	0.85	0.29	0.87	0.97	0.77
13	0.85	-0.45	0.34	0.55	-1.62
17	-0.86	-0.50	-0.39	-0.30	-0.37
20	0.00	-0.59	-0.39	-0.04	-0.78
31	1.42	-0.74	-0.52	-0.50	0.26
36	-1.43	-1.01	-0.52	-0.30	-0.22
44	-0.29	1.42	2.33	**2.64**	0.87
50	1.13	1.25	**2.79**	**3.50**	1.14
65	-0.57	-0.77	-0.32	-0.17	0.45
69	0.85	0.27	1.20	1.30	1.35
74	-0.86	-0.88	-1.12	-1.17	0.27
76	0.00	1.97	0.67	0.63	-0.15
79	-0.86	0.17	-0.46	-0.57	-0.01
81	0.28	-0.51	-0.52	-0.64	1.06
82	0.00	0.15	-0.13	-0.24	-0.41
84	-0.86	**5.93**	0.67	-0.17	-1.56
86	1.70	-0.40	-1.25	-1.24	-1.24
91	-0.29	-1.16	**37.12**	**45.26**	0.72
95	-0.86	0.46	-1.12	-1.10	-0.73

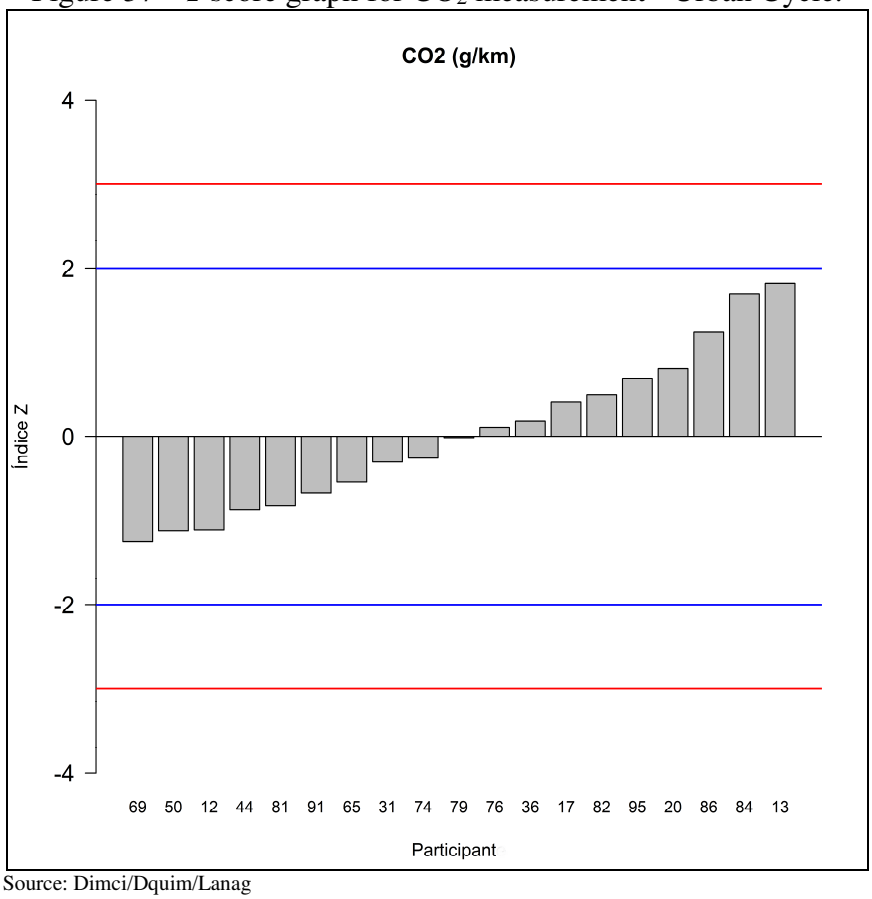
Source: Dimci/Dquim/Lanag
* Satisfactory result
* Questionable result
* Unsatisfactory result

Figure 36 – *z*-score graph for CO measurement – Urban Cycle.



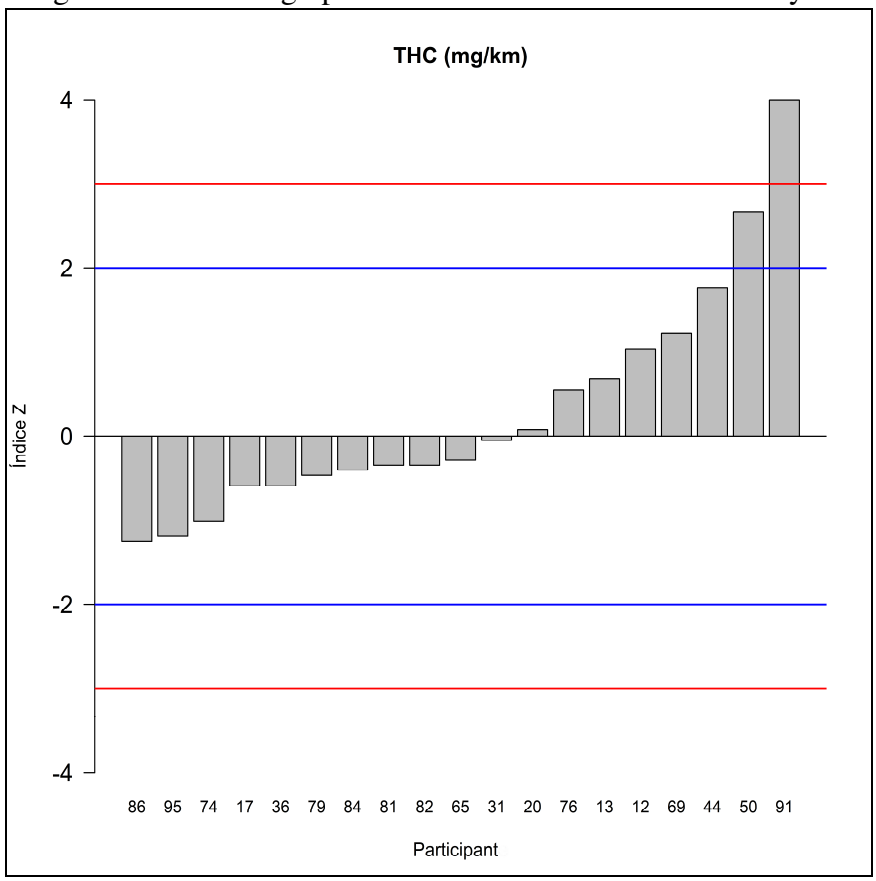
Source: Dimci/Dquim/Lanag

Figure 37 – *z*-score graph for CO_2 measurement - Urban Cycle.



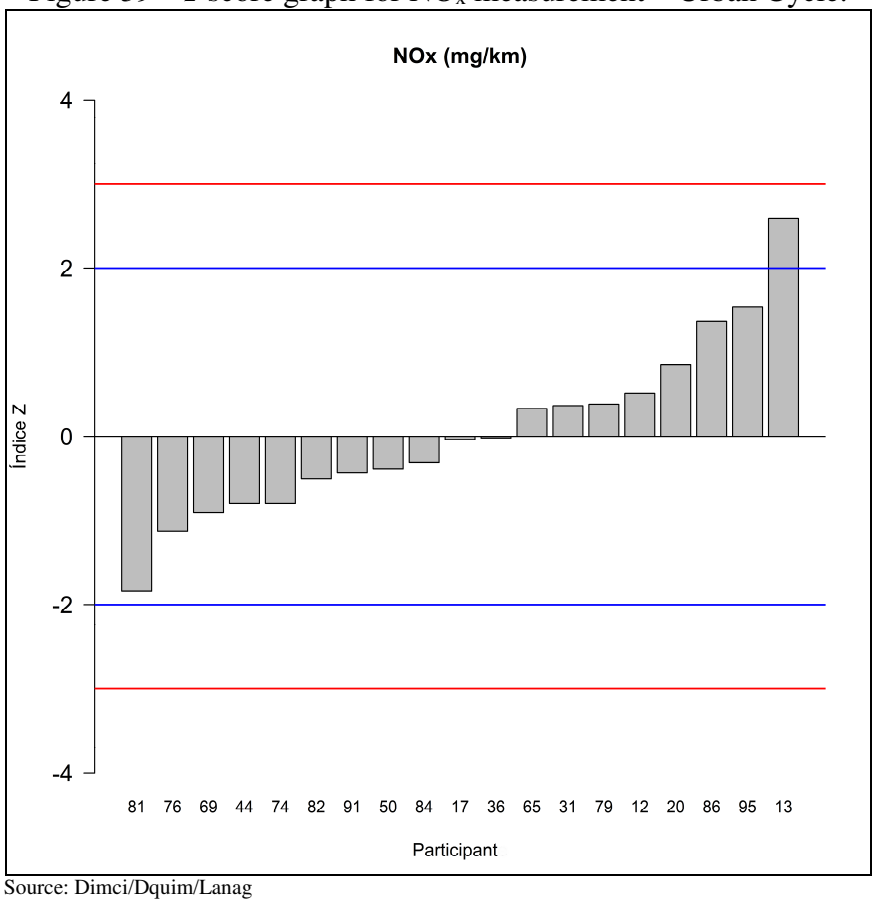
Source: Dimci/Dquim/Lanag

Figure 38 – *z*-score graph for THC measurement – Urban Cycle.



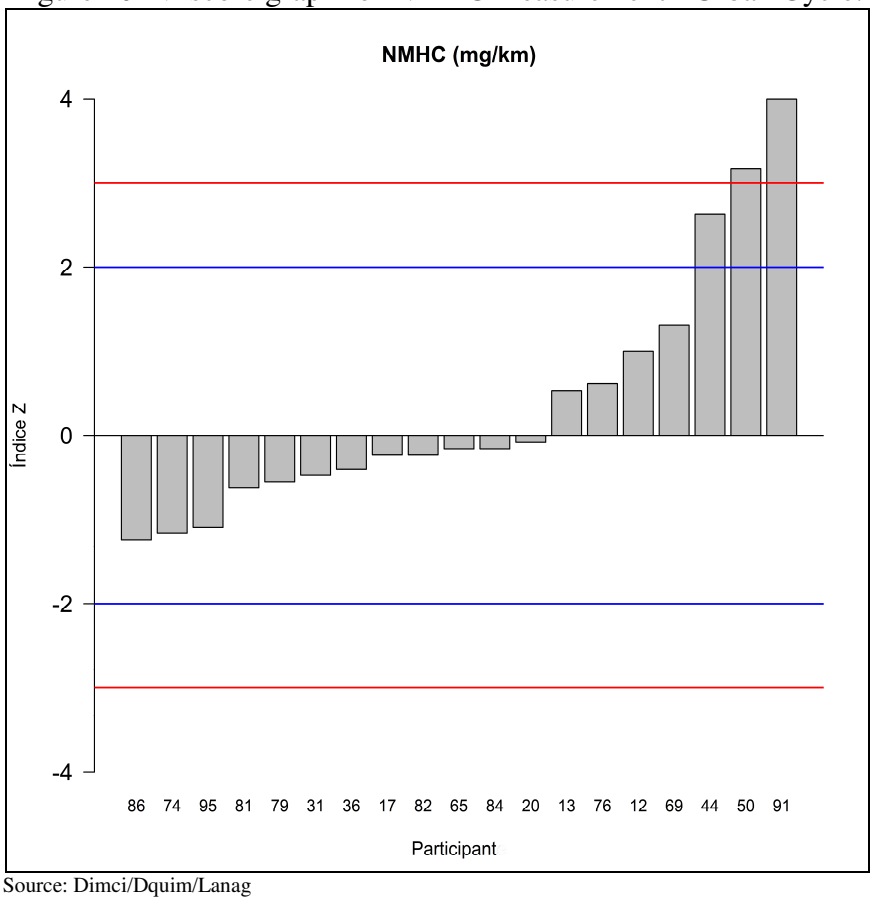
Source: Dimci/Dquim/Lanag

Figure 39 – *z*-score graph for NO_x measurement – Urban Cycle.



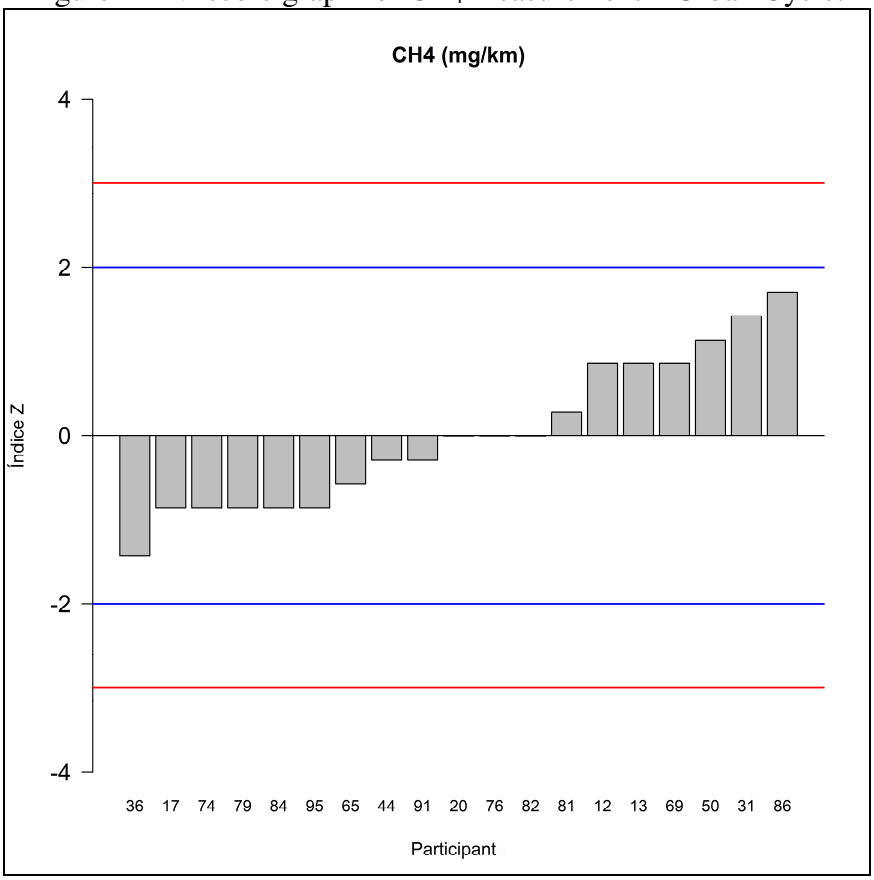
Source: Dimci/Dquim/Lanag

Figure 40 – *z*-score graph for NMHC measurement - Urban Cycle.



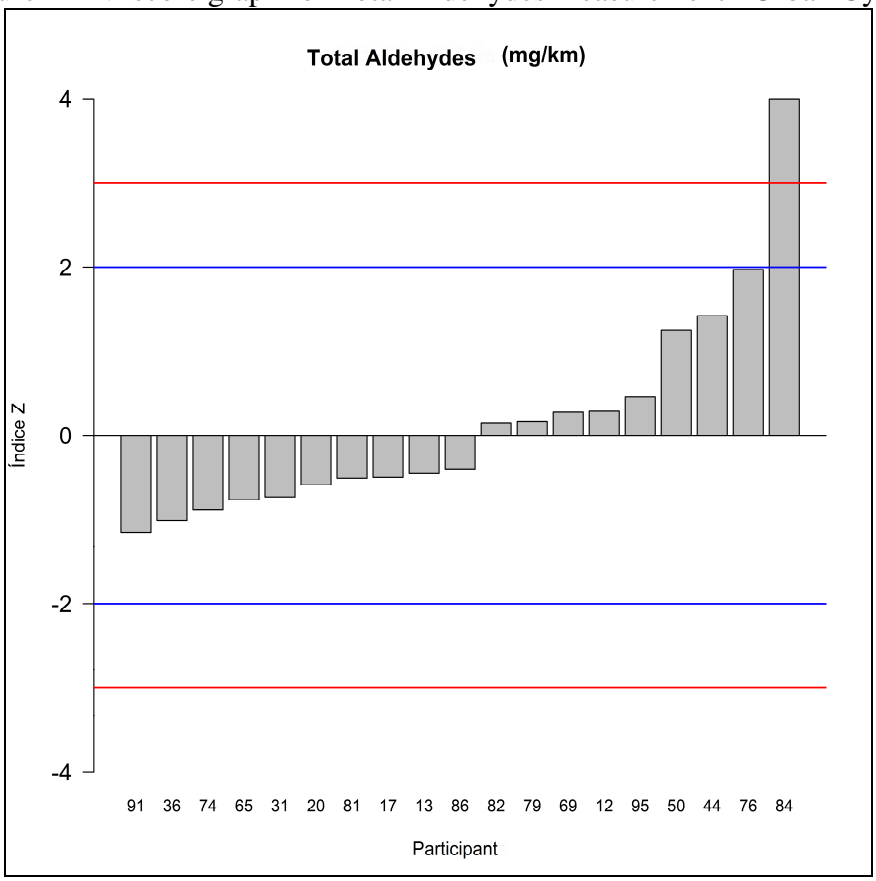
Source: Dimci/Dquim/Lanag

Figure 41 – *z*-score graph for CH_4 measurement – Urban Cycle.



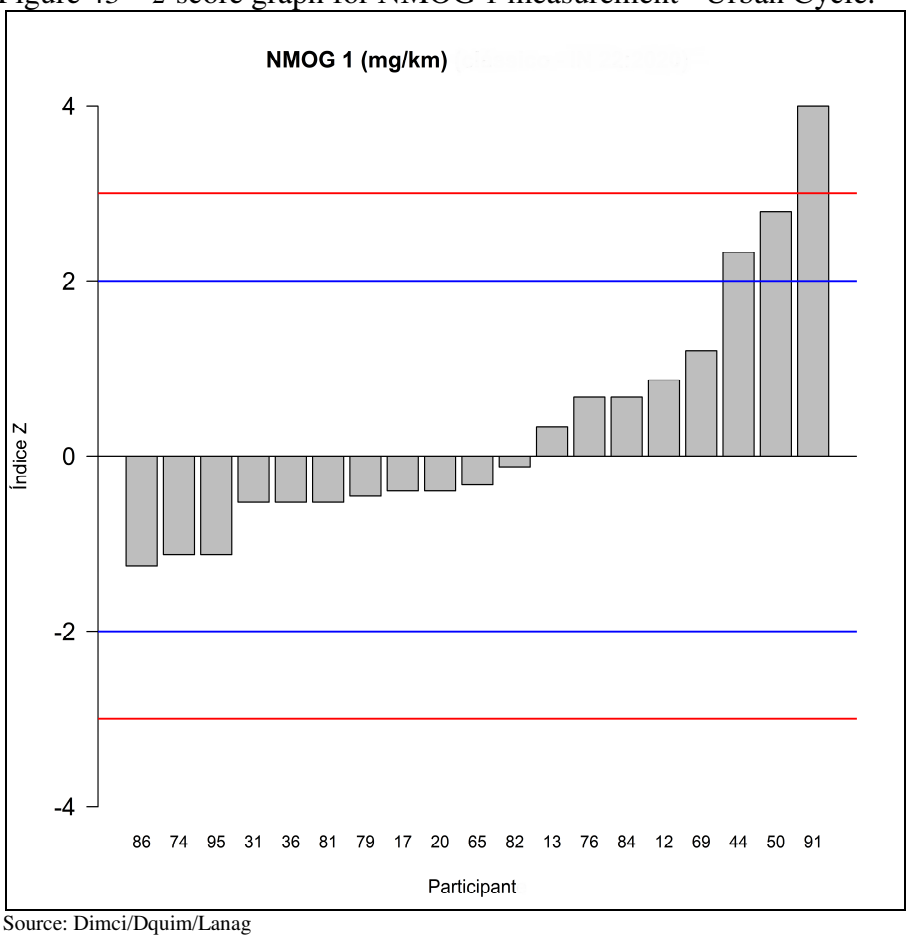
Source: Dimci/Dquim/Lanag

Figure 42 – *z*-score graph for Total Aldehydes measurement - Urban Cycle.



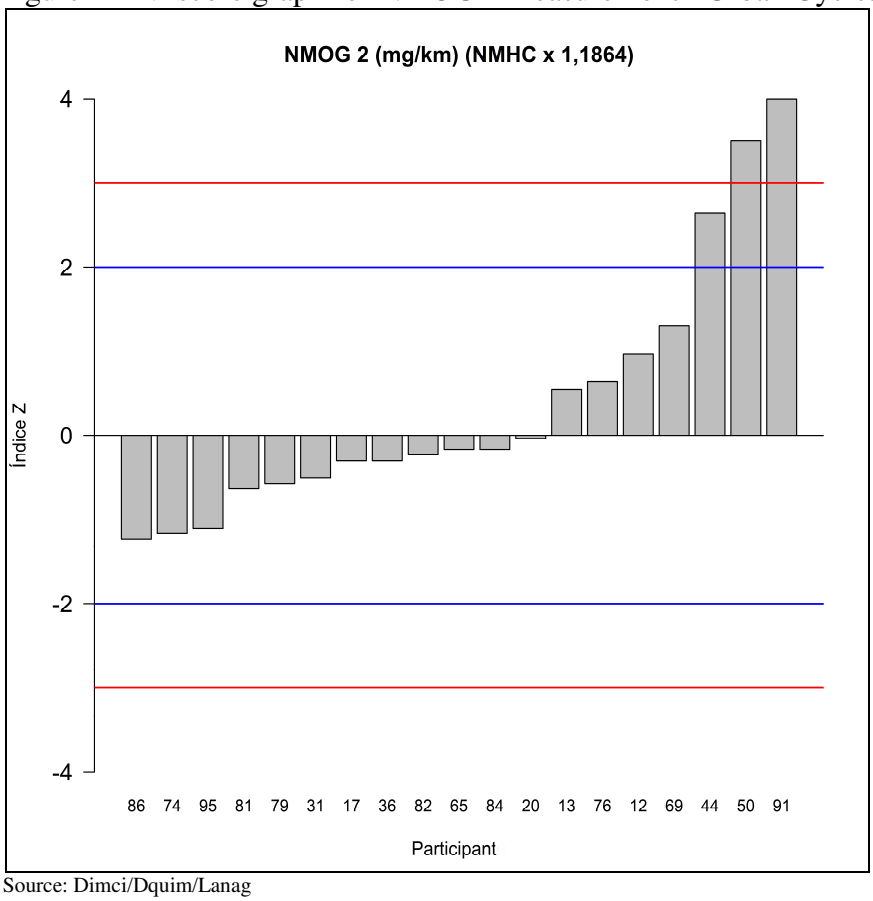
Source: Dimci/Dquim/Lanag

Figure 43 – *z*-score graph for NMOG 1 measurement - Urban Cycle.



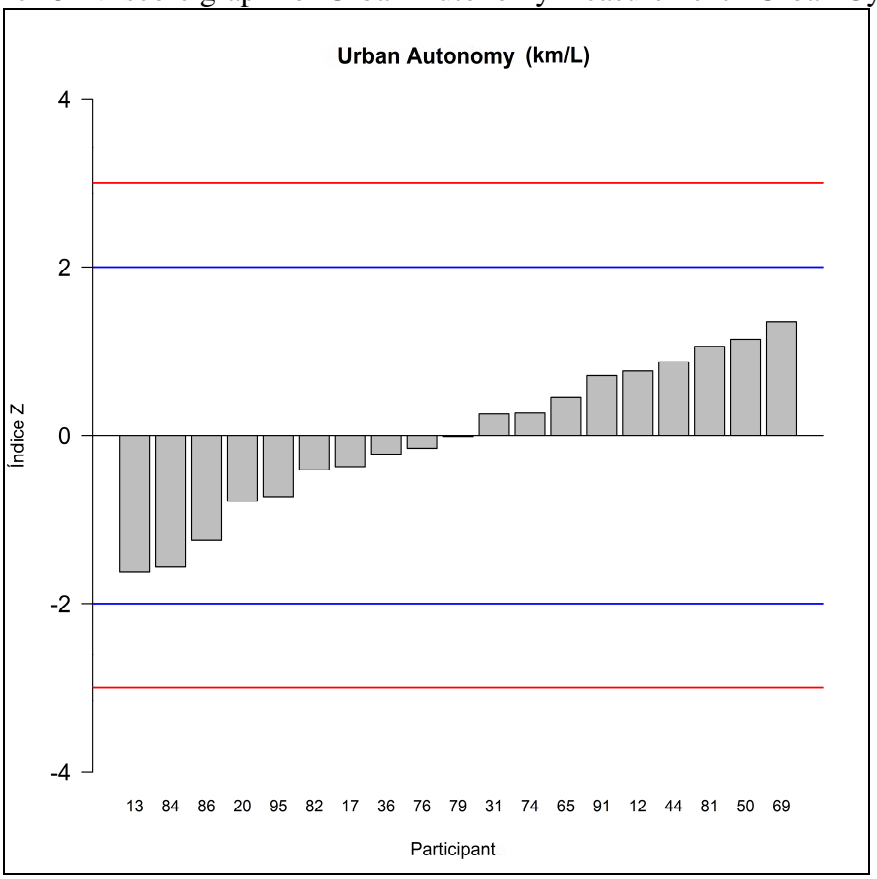
Source: Dimci/Dquim/Lanag

Figure 44 – *z*-score graph for NMOG 2 measurement - Urban Cycle.



Source: Dimci/Dquim/Lanag

Figure 45 – *z*-score graph for Urban Autonomy measurement - Urban Cycle.



Source: Dimci/Dquim/Lanag

Through *z*-score graphic analysis, it can be seen that:

CO (mg/km): 16 participants presented satisfactory results. Participants 81 and 86 presented questionable results and participant 12 presented unsatisfactory result.

CO_2 (g/km): 19 participants presented satisfactory results.

THC (mg/km): 17 participants presented satisfactory results. Participant 50 presented questionable results and participant 91 presented unsatisfactory result.

NOx (mg/km): 18 participants presented satisfactory results and participant 13 presented questionable result.

NMHC (mg/km): 16 participants presented satisfactory results. Participant 44 presented questionable results and participants 50 and 91 presented unsatisfactory results.

CH_4 (mg/km): 19 participants presented satisfactory results.

Total Aldehydes (mg/km): 18 participants presented satisfactory results and participant 84 presented unsatisfactory result.

NMOG 1 (mg/km): 16 participants presented satisfactory results. Participants 44 and 50 presented questionable results and participant 91 presented unsatisfactory result.

NMOG 2 (mg/km): 16 participants presented satisfactory results. Participant 44 presented questionable result and participants 50 and 91 presented unsatisfactory results.

Urban Autonomy (km/l): 19 participants presented satisfactory results.

7.2.2. Road Cycle Emissions – *z*-score

For the performance evaluation of the participants, *z*-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results of Road cycle parameter. Table 11 and figures 46 to 50 present these results.

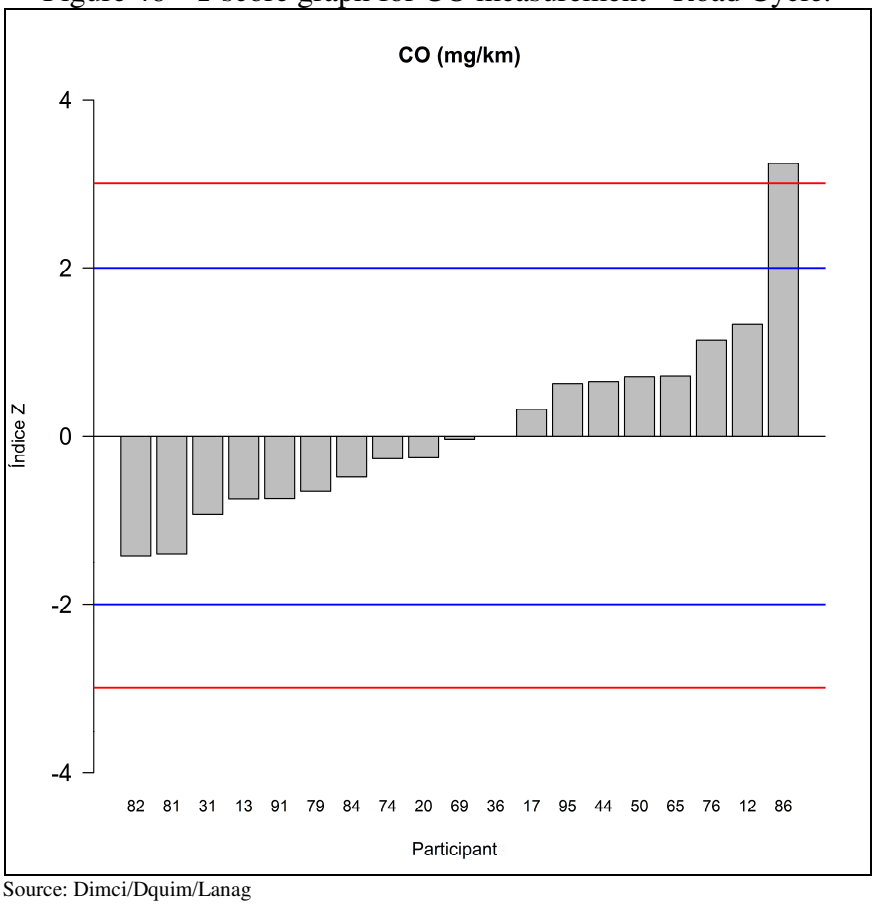
Table 11 – *z*-score values for the CO, CO_2, THC, Road Autonomy and Combined Autonomy parameters – Road Cycle

Code	CO (mg/km)	CO_2 (g/km)	THC (mg/km)	Road Autonomy (km/L))	Combined Autonomy (km/L)
	z-score	*z*-score	*z*-score	*z*-score	*z*-score
12	1.33	**-2.27**	-1.34	**2.24**	1.15
13	-0.75	**2.05**	0.41	-1.72	-1.57
17	0.32	0.24	0.76	-0.28	-0.33
20	-0.26	1.03	0.06	-0.96	-0.81
31	-0.93	-0.53	-0.29	0.54	0.32
36	0.00	-0.02	-0.29	-0.01	-0.15

Code	CO (mg/km)	CO_2 (g/km)	THC (mg/km)	Road Autonomy (km/L))	Combined Autonomy (km/L)
	z-score	*z*-score	*z*-score	*z*-score	*z*-score
44	0.64	-0.26	-1.69	0.18	0.57
50	0.71	-0.87	1.46	0.89	1.02
65	0.71	-0.75	0.41	0.66	0.47
69	-0.03	-0.94	-0.29	1.00	1.13
74	-0.27	-0.35	0.06	0.32	0.25
76	1.14	-0.42	-0.64	0.32	-0.01
79	-0.66	-0.34	-0.99	0.33	0.08
81	-1.41	-0.76	0.41	0.90	0.92
82	-1.43	0.47	-0.29	-0.38	-0.39
84	-0.49	**3.26**	1.81	-2.80	-1.87
86	**3.24**	**4.14**	**3.57**	**-3.51**	-1.93
91	-0.74	0.13	-0.64	-0.11	0.88
95	0.62	0.36	-0.29	-0.40	-0.59

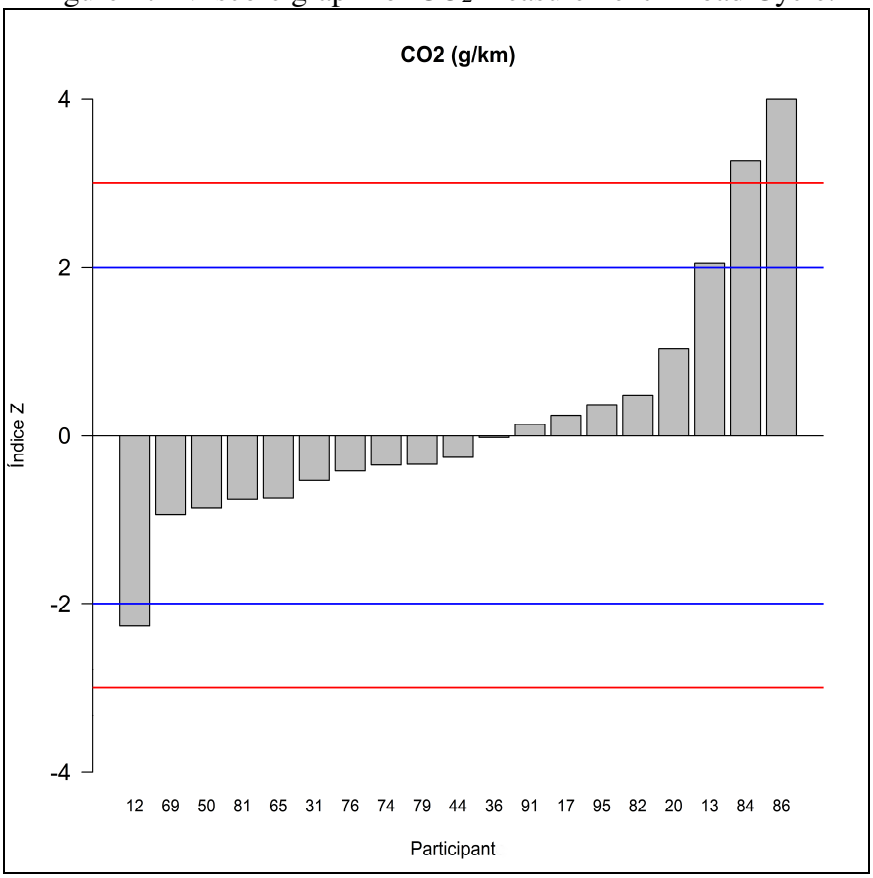
Source: Dimci/Dquim/Lanag
* Satisfactory result
* Questionable result
* Unsatisfactory result

Figure 46 – *z*-score graph for CO measurement - Road Cycle.



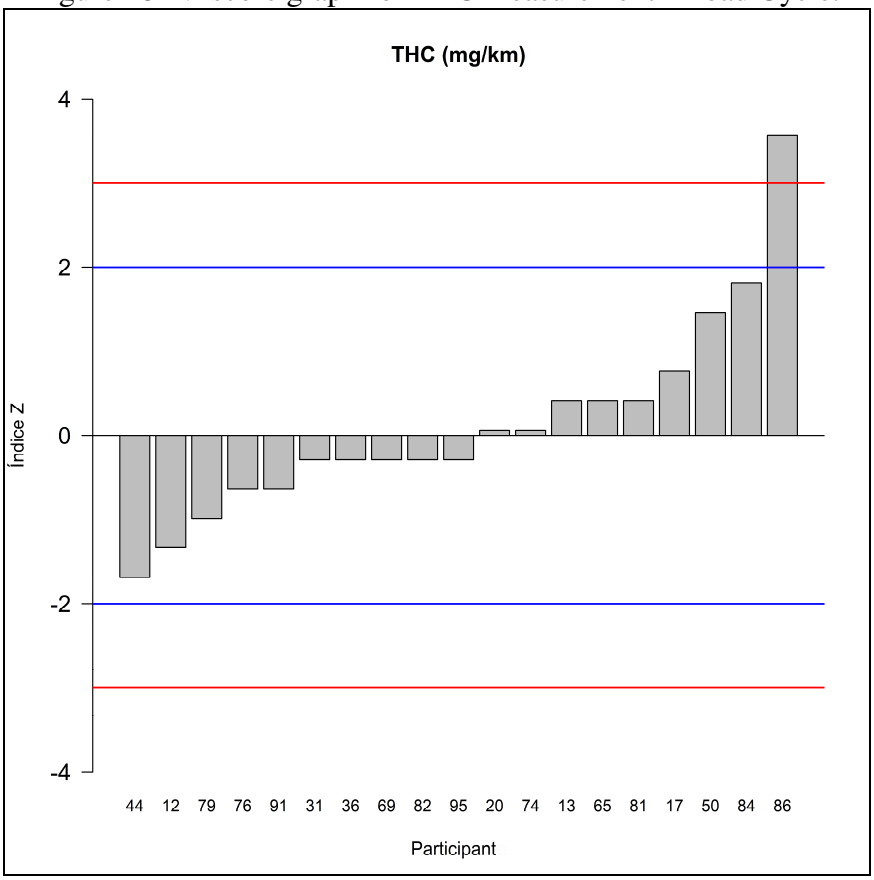
Source: Dimci/Dquim/Lanag

Figure 47 – *z*-score graph for CO_2 measurement - Road Cycle.



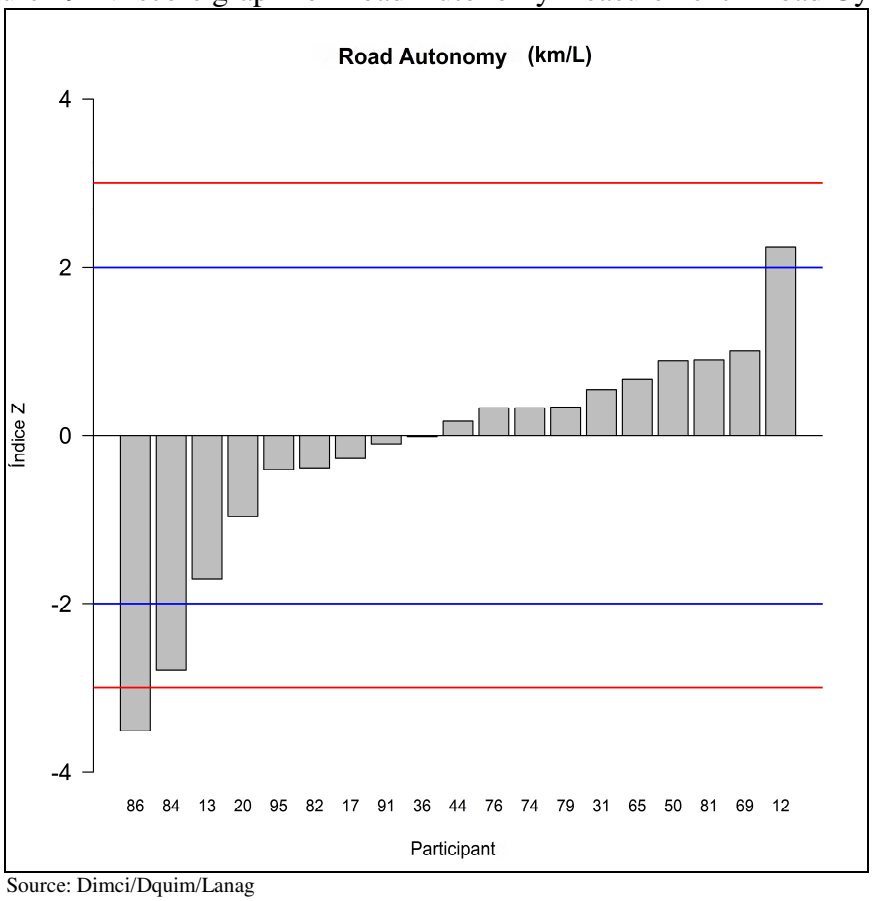
Source: Dimci/Dquim/Lanag

Figure 48 – *z*-score graph for THC measurement - Road Cycle.



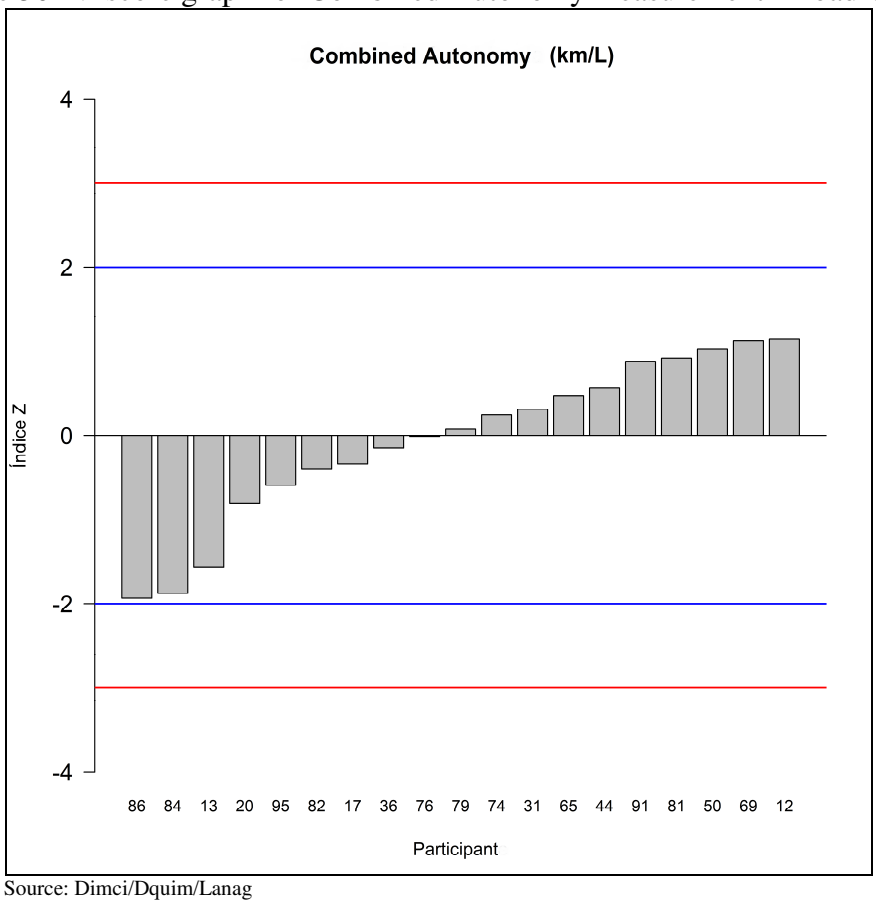
Source: Dimci/Dquim/Lanag

Figure 49 – *z*-score graph for Road Autonomy measurement - Road Cycle.



Source: Dimci/Dquim/Lanag

Figure 50 – *z*-score graph for Combined Autonomy measurement - Road Cycle.



Source: Dimci/Dquim/Lanag

Through *z*-score graphic analysis, it can be seen that:

Road CO (mg/km): 18 participants presented satisfactory results and participant 86 presented unsatisfactory result.

Road CO_2 (g/km): 15 participants presented satisfactory results. Participants 12 and 13 presented questionable results and participants 84 and 86 presented unsatisfactory results.

THC (mg/km): 18 participants presented satisfactory results and participant 86 presented unsatisfactory result.

Road Autonomy (km/l): 16 participants presented satisfactory results. Participants 12 and 84 presented questionable results and participant 86 presented unsatisfactory result.

Combined Autonomy (km/l): 19 participants presented satisfactory results.

7.2.3. Idling Speed - CO (% vol.) - *z*-score

For the performance evaluation of the participants, z-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results of Idling Speed CO (% vol.) parameter. Table 12 and figure 51 present these results.

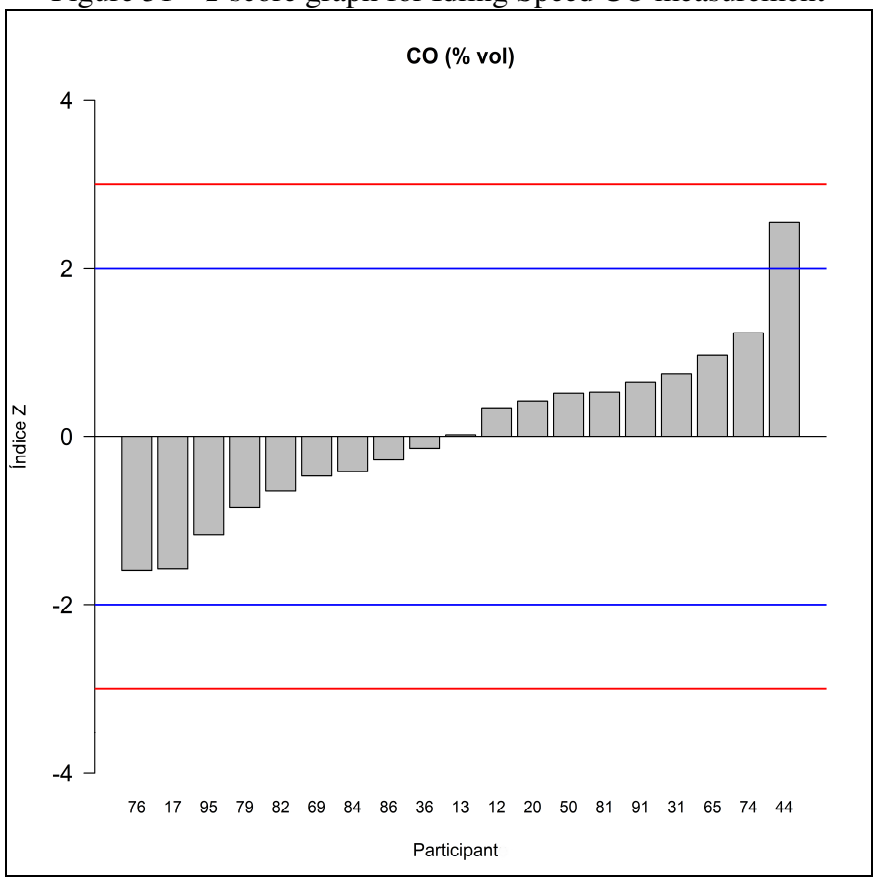
Table 12 – *z*-score values for the Idling Speed CO (% vol.) parameter

Code	CO (% vol.)
	z-score
12	0.35
13	0.02
17	-1.57
20	0.42
31	0.75
36	-0.14
44	2.55
50	0.52
65	0.97
69	-0.46
74	1.24
76	-1.59
79	-0.84
81	0.53
82	-0.64
84	-0.42
86	-0.27
91	0.65

Code	CO (% vol.)
	z-score
95	-1.17

Source: Dimci/Dquim/Lanag
* Satisfactory result
* Questionable result
* Unsatisfactory result

Figure 51 – *z*-score graph for Idling Speed CO measurement



Source: Dimci/Dquim/Lanag

Through *z*-score graphic analysis, it can be seen that:

Idling Speed: 18 participants presented satisfactory results and participant 44 presented questionable result.

7.2.4. Evaporative Emissions - SHED – (g/phase) - *z*-score

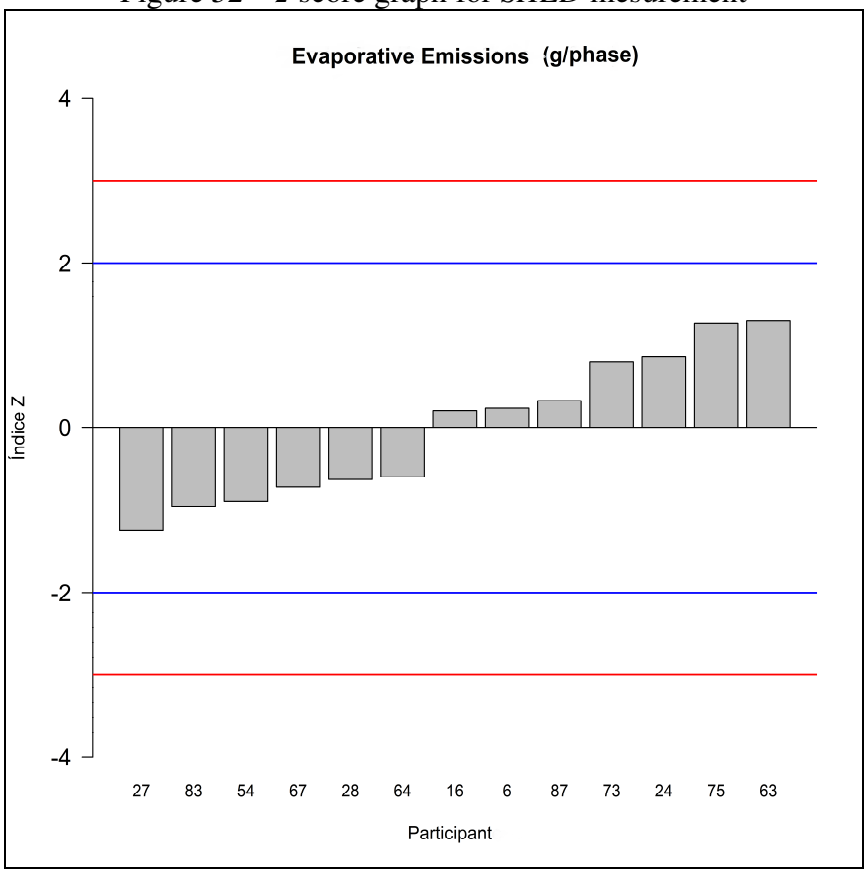
For the performance evaluation of the participants, z-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results of Evaporative Emissions - SHED (g/phase) parameter. Table 13 and figure 52 present these results.

Table 13 – *z*-score values for the SHED (g/phase) parameter

Code	Evaporative Emissions (g/phase)
	Índice *z*
06	0.24
16	0.21
24	0.86
27	-1.24
28	-0.62
54	-0.89
63	1.30
64	-0.59
67	-0.71
73	0.80
75	1.27
83	-0.95
87	0.33

Source: Dimci/Dquim/Lanag
* Satisfactory result
* Questionable result
* Unsatisfactory result

Figure 52 – *z*-score graph for *SHED* mesurement



Source: Dimci/Dquim/Lanag

Through *z*-score graphic analysis, it can be seen that:

***SHED*:** 13 participants presented satisfactory results.

8. Analysis Testimony

As established in the proficiency testing protocol, a Cetesb representative witnessed one of the PT three measurements at each participant laboratory. Cetesb sent a conclusion regarding its testimony result to the PT Coordination by email, indicating there was no occurrence of non-compliance, not being necessary to send the witnessed results reports to the PT Coordination.

It should be noted that, in case Cetesb registered the occurrence of non-compliance to the PT Coordination, the participant's results would be invalidated and, thus, its data would not figure in the PT report.

9. Confidenciality

Each participant was identified by an individual code that is only known by the participant and the PT coordination. As stated on the registration form, the identification of accredited laboratories and laboratories in stage of accreditation will be forwarded for information of the General Accreditation Coordination (Cgcre). The participant received, by email, his own identification code corresponding to the participation in this PT. This code was used to identify the participant in the results registration form. The results may be used in studies and publications by Inmetro respecting the confidentiality of each participant.

As established in section 4.10.4 of ABNT ISO/IEC 17043:2011, in exceptional circumstances, a regulatory authority may require the results and the identification of the participants to the PT provider. If this occurs, the provider will notify the PT participants about this action.

10. Conclusions

This PT had as its main characteristic the large number of analysed parameters, standing out in particular, the NMOG parameter, for which diferent calculation methods were compared, thus directly helping the understanding and decision-making of which is the best technique each participant can adopt. In addition, it can be concluded that the results have been quite satisfactory and PT performance has been of great importance for the industry and society throughout these thirteen rounds carried out within the Inmetro-AEA partnership.

This round once again sought to advance. The Brazilian automotive industry understands that expanding its participation in Mercosur is very important. For this, a specific proficiency test was carried out through European Regulations R83-06 and R101. This evaluation shows us the strength and commitment of this industry that fits and adapts to new rules and new situations, with the aim of always being competitive in new markets. In addition, we can conclude that the results have been quite satisfactory and their achievement has been of great importance for industry and society throughout these twelve rounds carried out within the Inmetro-AEA partnership.

This PT round involved a large number of variables and was monitored by a regulatory body (Cetesb). With this large number of variables existing in emissions tests and a large number of parameters measured within this round, a careful evaluation by the participant will be important. In addition, it is recommended that participants with questionable and unsatisfactory performance critically review their measurement methods.

Among 17 (seventeen) parameters evaluated by the *z*-score, totaling 317 results, 92.7% indicated unsatisfactory performance, 3.15 % indicated questionable performance among 8 (eight) distinct parameters and 3.47% indicated unsatisfactory performance in 10 (ten) parameters.

It should always be emphasized the importance of the participation of different laboratories in a proficiency test, since it is a useful tool to monitor the analysis procedures used in the routine and to evaluate the results of the laboratory measurements, enabling the improvement of the quality of the results and ensuring greater reliability to measurements.

It is up to the PT participant to perform a critical analysis of the results, and the entire process and laboratory experience must be considered. Therefore, participation in proficiency tests on an ongoing basis can guarantee information to participants about their measurement capability and is of great importance for monitoring the validity of their results.

11. Participants

Twenty-two participants were registered in the 13th round of the Proficiency Testing in Vehicles Emissions, but 3 participants did not send their results report and informed it to the PT coordination. Thus, nineteen participants remained.

The list of laboratories that sent results to this PT coordination is presented in table 14. It is important to note that the numbering of laboratories in the table only indicates the number of PT participants; under no circumstances, it is associated to laboratory identification in presenting their results.

Table 14 – Participants

	Institution
1.	AVL South América Ltda.
2.	Brazil Trading Ltda. Gandini Centro Tecnológico
3.	CAOA Montadora de Veículos S.A Centro de Pesquisa e Eficiência Energética
4.	CETESB- Companhia Ambiental do Estado de São Paulo Laboratório de Emissão Veicular
5.	FCA Fiat Chrysler Automóveis Brasil Ltda. Laboratório de Emissões e Consumo LEC - FCA
6.	Ford Motor Company Brasil Ltda. Laboratório de Emissões do Campo de Provas de Tatuí
7.	General Motors do Brasil Laboratório de Emissões do Campo de Provas de Cruz Alta
8.	General Motors do Brasil Ltda. Laboratório de Emissões Veiculares – Global Propulsion Systems
9.	Honda Automóveis do Brasil Ltda. Laboratório de Emissões Honda Automóveis
10.	Hyundai Motor Brasil Montadora de Automóveis Ltda. Laboratório de Emissões do R&D Center da Hyundai Motor Brasil
11.	IDIADA Tecnologia Automotiva Ltda. Laboratório de Emissões Veiculares IDIADA
12.	Instituto de Tecnologia para o Desenvolvimento LEME – Laboratório de Emissões Veiculares
13.	Marelli Sistemas Automotivos Indústria e Comércio Brasil Ltda.
14.	Peugeot Citroen do Brasil Automóveis Ltda. Laboratório de Emissões Stellantis Porto Real
15.	Renault do Brasil S/A LEV - Laboratório de Emissões Veiculares
16.	Robert Bosch Ltda. Laboratório de Emissões Veiculares - LEV
17.	Toyota do Brasil Ltda. Laboratório de Emissões Toyota do Brasil - Indaiatuba
18.	Umicore do Brasil Ltda. CDB 352
19.	Volkswagen do Brasil Indústria de Veículos Automotores Ltda. Laboratório de Emissões Veiculares da Volkswagen do Brasil

Total participants: 19 participants.

12. References

- ABNT NBR ISO/IEC 17025:2017: Requisitos gerais para a competência de laboratórios de ensaio e calibração.

- Instrução Normativa IBAMA Nº 22 de 24/09/2020 - Regulamenta a determinação das emissões de gases orgânicos não metano (NMOG) provenientes do escapamento de veículos rodoviários leves de passageiros e leves comerciais.
- ABNT NBR 6601:2021: Veículos rodoviários automotores leves — Determinação de hidrocarbonetos, monóxido de carbono, óxidos de nitrogênio, dióxido de carbono e material particulado no gás de escapamento.
- ABNT NBR 7024:2017: Veículos rodoviários automotores leves - Medição do consumo de combustível - Método de ensaio.
- ABNT NBR 12026:2021: Veículos rodoviários automotores leves - Determinação da emissão de aldeídos e cetonas contidos no gás de escapamento, por cromatografia líquida - Método DNPH.
- ABNT NBR 10972:2010: Veículos rodoviários automotores leves - Medição da concentração de monóxido de carbono no gás de escapamento em regime de marcha lenta - Ensaio de laboratório.
- ABNT NBR 11481:2010: Veículos rodoviários automotores leves — Medição da emissão evaporativa.
- ABNT NBR 16927:2021: Veículos rodoviários automotores leves com motor de ignição por centelha - Medição de emissões evaporativas diurnas, no resfriamento do veículo e no abastecimento de combustível.
- ABNT NBR 15598:2016: Veículos rodoviários automotores leves - Determinação de etanol não queimado contido no gás de escapamento, por cromatografia gasosa - Método de ensaio.
- ABNT NBR ISO/IEC 17043:2011: Avaliação de Conformidade – Requisitos Gerais para ensaios de proficiência.
- ISO 13528:2022, “Statistical methods for use in proficiency testing by interlaboratory comparisons”.

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