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CASAP IX
CONGRESO COLOMBIANO Y CONFERENCIA INTERNACIONAL DE CALIDAD DE AIRE, CAMBIO CLIMÁTICO Y SALUD PÚBLICA

Effects of signal synchronization on the determination of vehicle environmental performance by on-road tests

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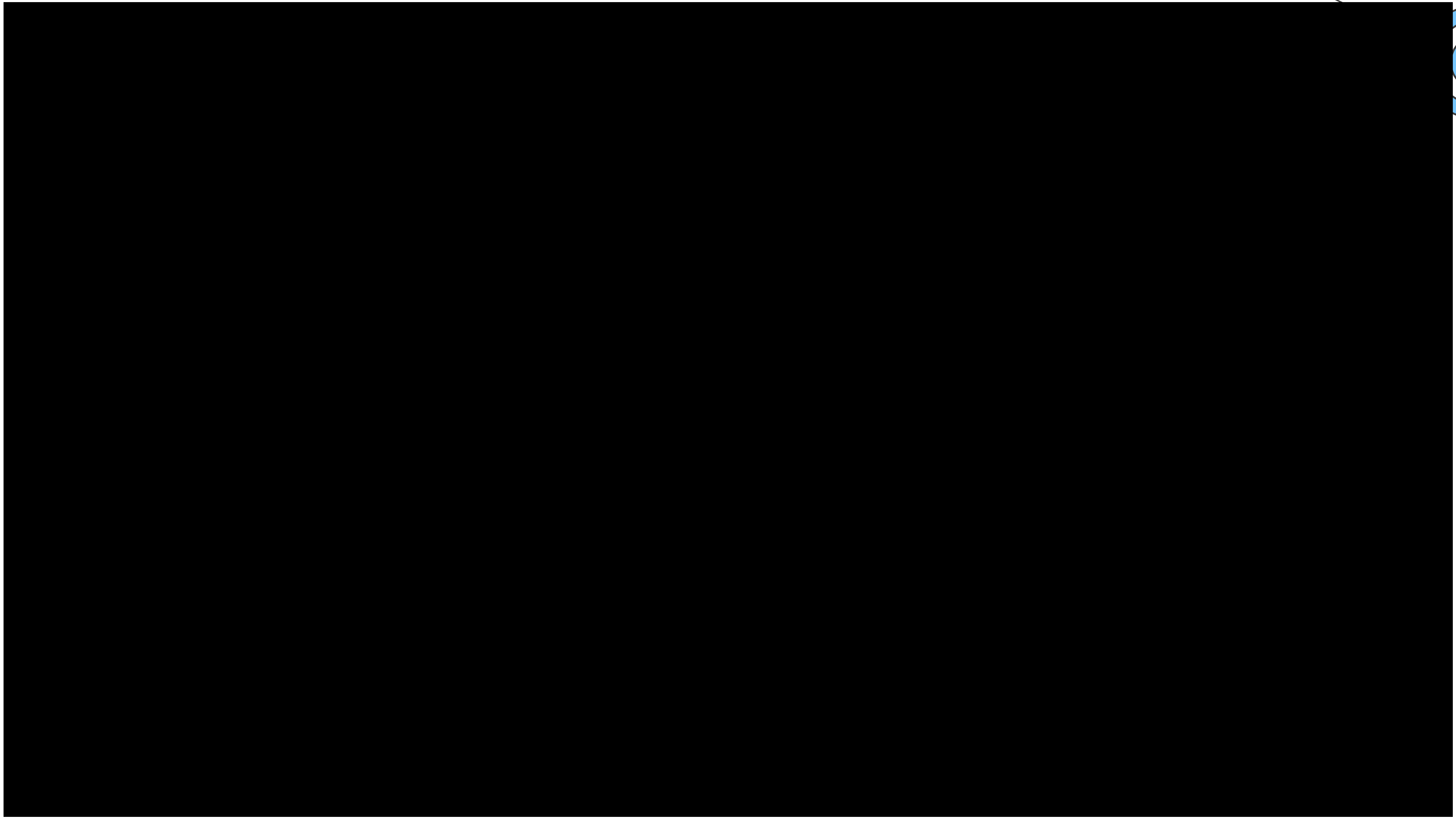
UNIVERSIDAD EAFIT Vigilada Mineducación · Tecnológico de Monterrey · upme Unidad de Planeacion Minero Energetica · UNIVERSIDAD DE ANTIOQUIA · UNIVERSIDAD NACIONAL DE COLOMBIA · RELIEVE



Current problem

Measurement of Tailpipe mass emissions

By:

GPS

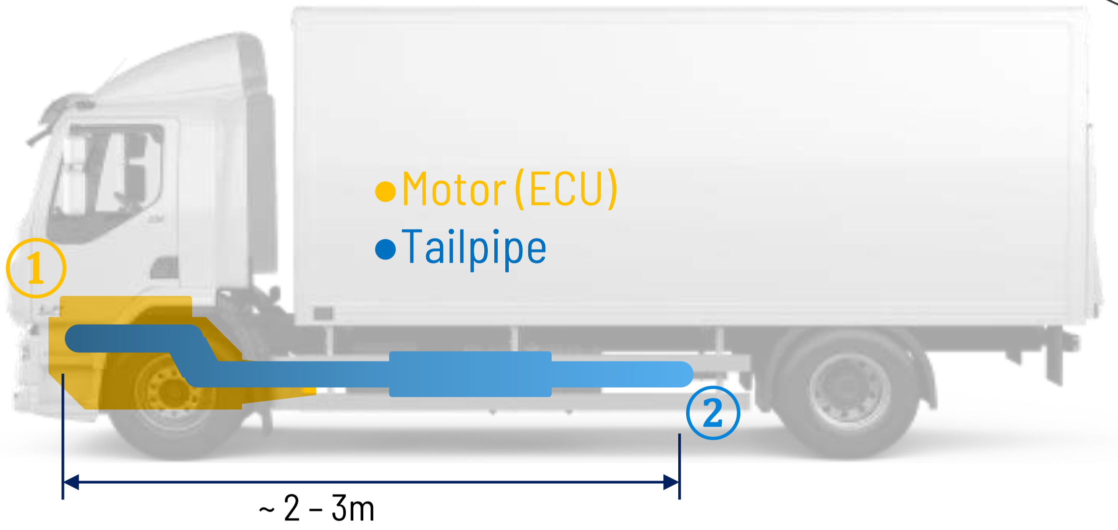
Motor

Tailpipe

OBD

- Latitude
- Longitude
- Lambda probe
- Fuel flow
- Exhaust flow
- Pollutant concentration

PEMS



Involves:

Signal offsets

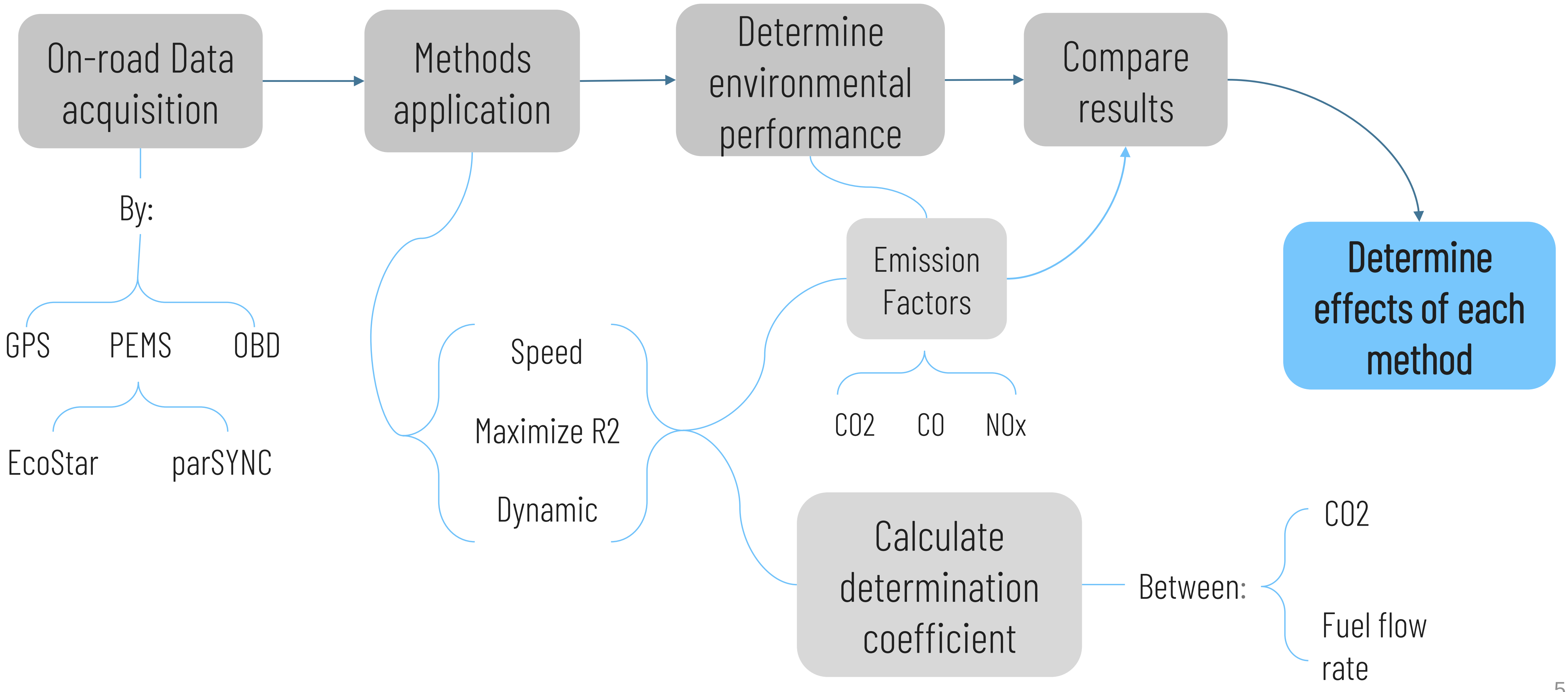
Caused by:

- Different response times
- Measurements before and after combustion
- Time differences in the instrument's activation/ start
- Physical distances between measurements points

OBJECTIVE

- Process measurements realized in vehicles applying different synchronization methods
- Establish criteria for comparing these synchronization methods
- Identify the most appropriate and reliable synchronization methods
- Evaluate and identify the effects on the results obtained for emission factors by each method

Methodology



Scope

Location

- CDMX and Toluca - Mexico
- Bogotá – Colombia

Vehicle

Heavy – duty

- Buses
- Trucks

Instruments

- GPS
- OBD
- PEMS

Equipment

Table 2. Technical specifications of PEMS used

	EcoStar	ParSync
Pollutants measured	CO, CO2, NO, NO2	CO, CO2, NO, NO2
Particles measured	-	PM, PN
Size (cm)	43.7 x 40.6 x 23.4	12 x 22 x 13
Weight (kg)	19,8	4.1
Energy supply	12V	Internal,12V Battery
Measurement range	NO: 0-3000ppm NO2: 0-500ppm CO2: 0-20% CO: 0-8%	NO: 0-5000ppm NO2: 0-300ppm CO2: 0-20% CO: 0-15%
Accuracy	NO: 0.3ppm NO2: 0.3 ppm CO2: 0.01% CO: 0.001%	NO: 1-2ppm NO2: 0.1ppm CO2: 0.3% CO: 0.02%
Exhaust Flow measurement (EFM)	YES	NO

Sensors Inc
SEMTECH ECOSTAR

Figure 6. PEMS used in México
Source: Sensors, Inc. - Innovative Gas Measurement Solutions (sensors-inc.com)

3DATX
Par SYNC

Figure 7. PEMS used in Colombia
Source: https://3datx.com/parsync/

Synchronization methods

1. Speed
2. Maximizing R2
3. Dynamic

1. Speed synchronization

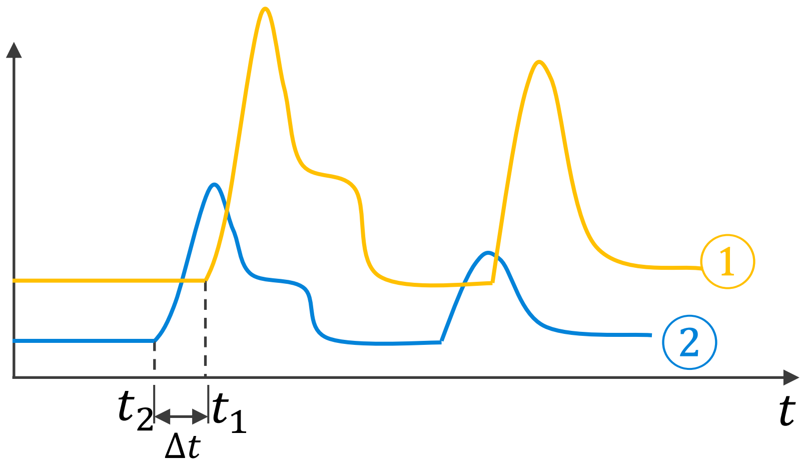


Figure 8. Identification offsets between two signals

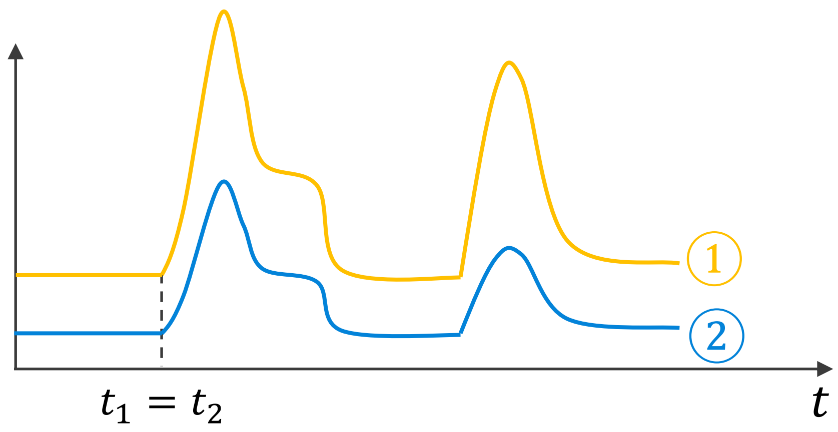
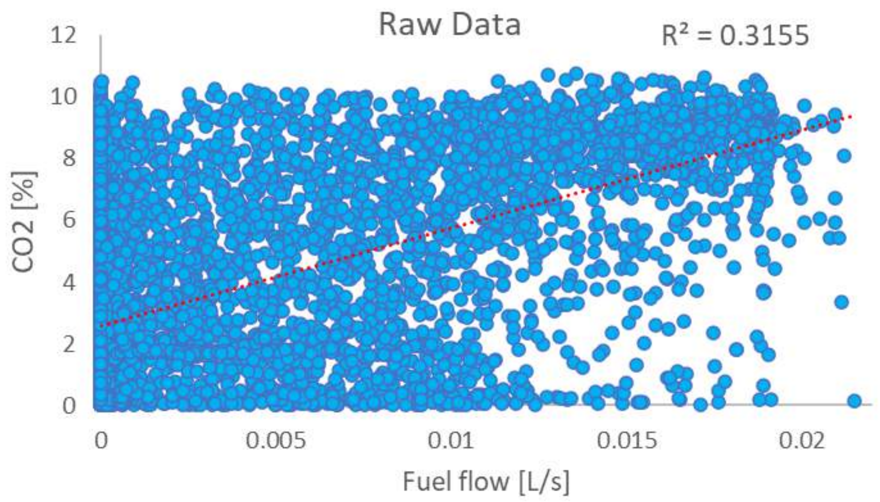
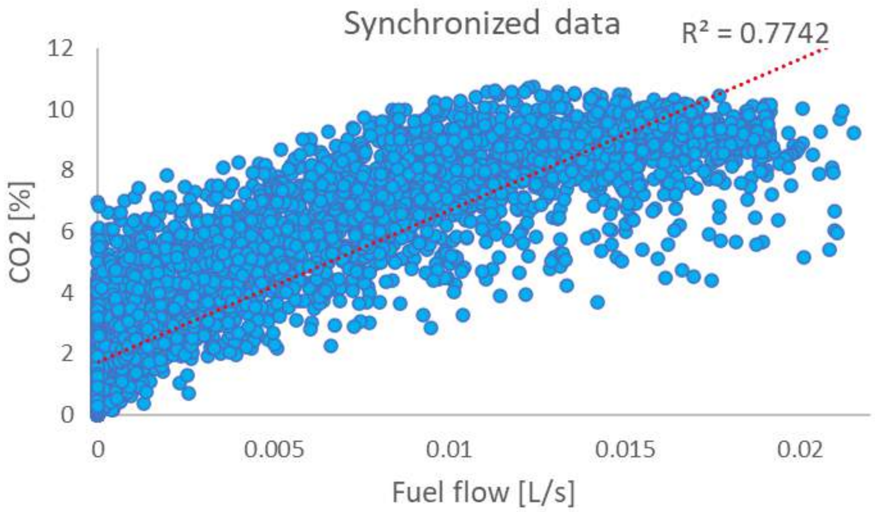


Figure 9. Synchronized signals





2. Synchronization maximizing R2

The signal is shifted while:

$$R_i^2 \geq R_{i-1}^2$$

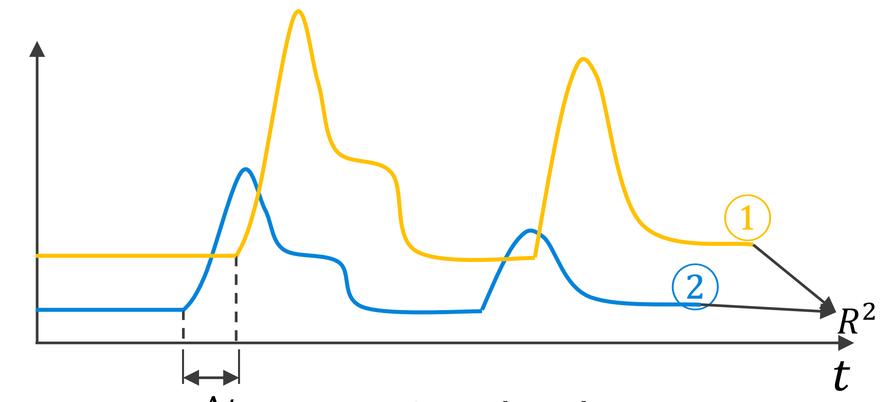


Figure 10. Initial signals

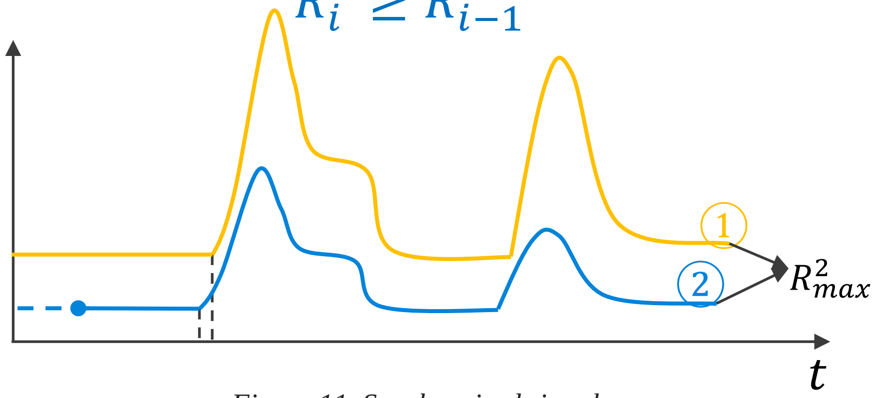
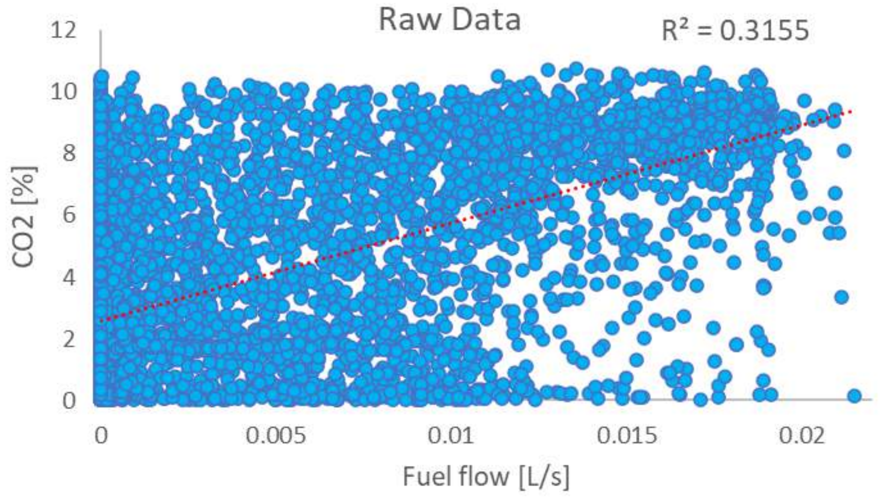
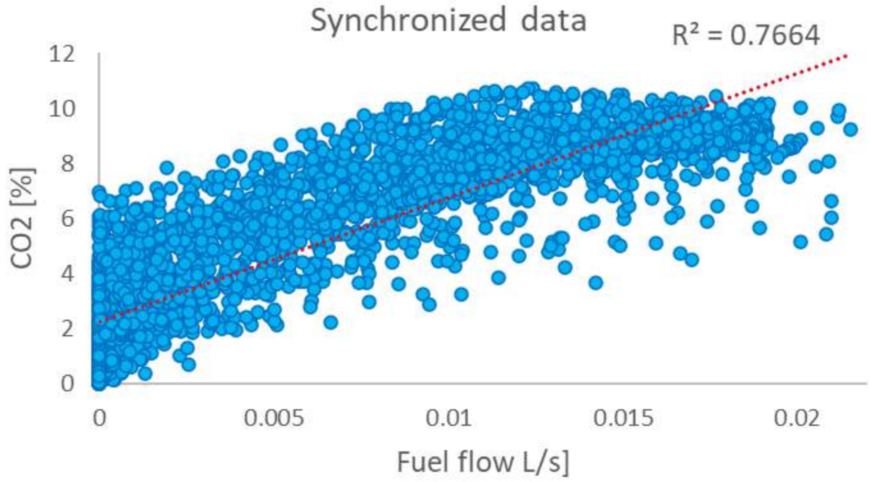


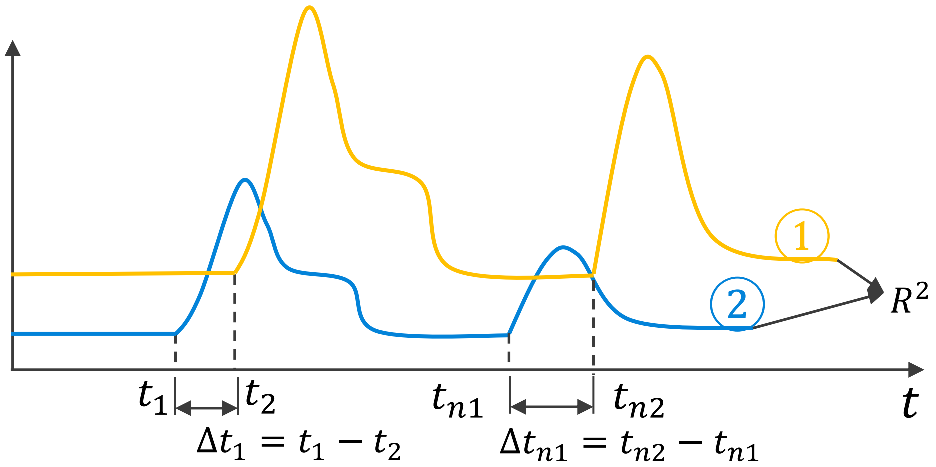
Figure 11. Synchronized signals

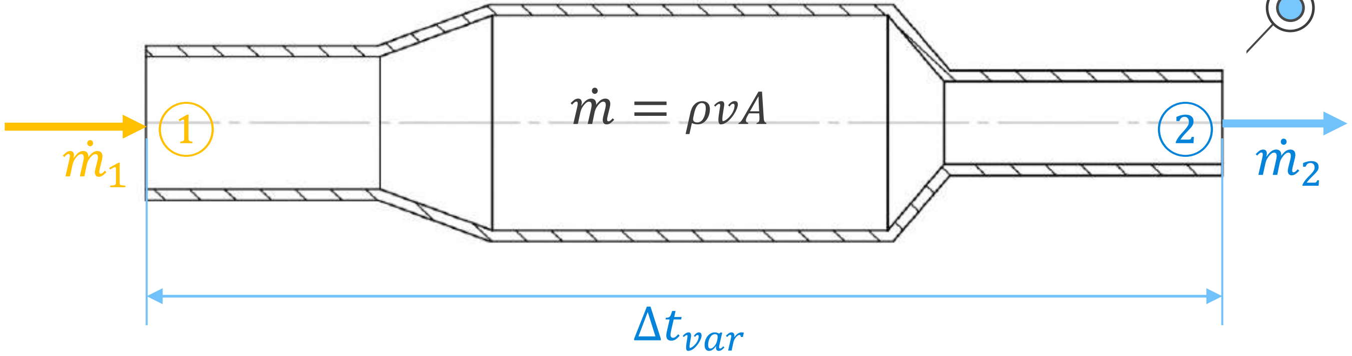




It must be done using two physically related signals, for example: CO_2 and $\dot{m}_{air}$ or CO_2 and $\dot{m}_{fuel}$

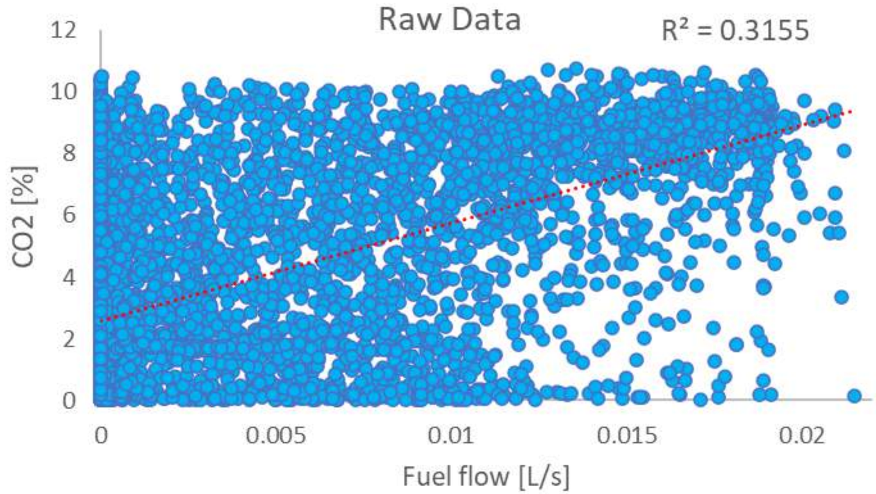
3. Dynamic Synchronization

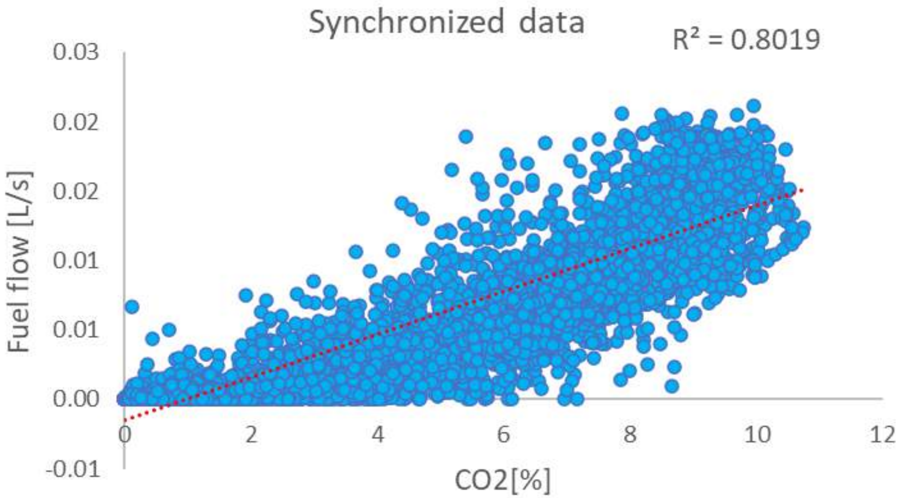




$$\Delta t_n = \Delta t_{cte} + \Delta t_{var.n}$$

$$\Delta t_{var} = \alpha \cdot \frac{1}{\dot{m}} \qquad \Delta t_{var} = \beta \cdot \frac{1}{\dot{V}}$$





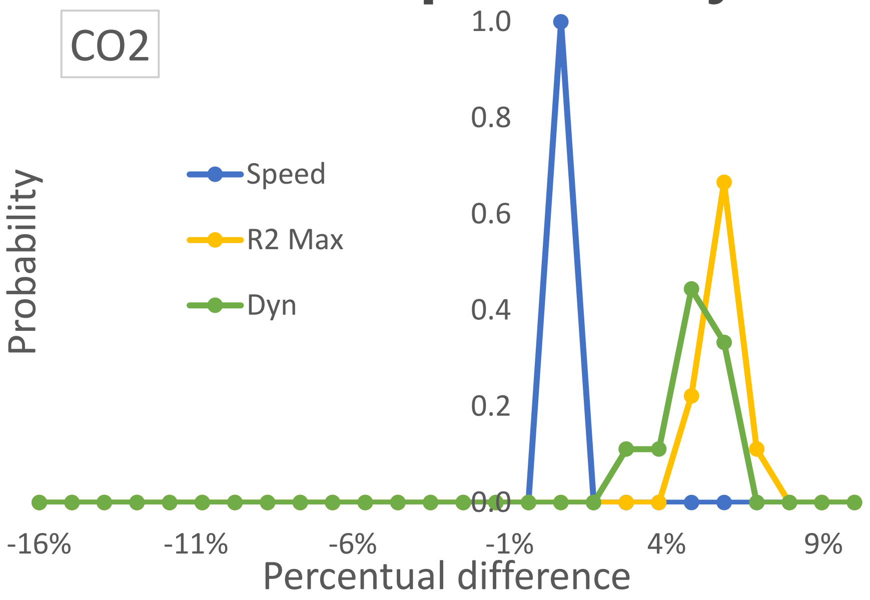
Determination coefficients (R2)

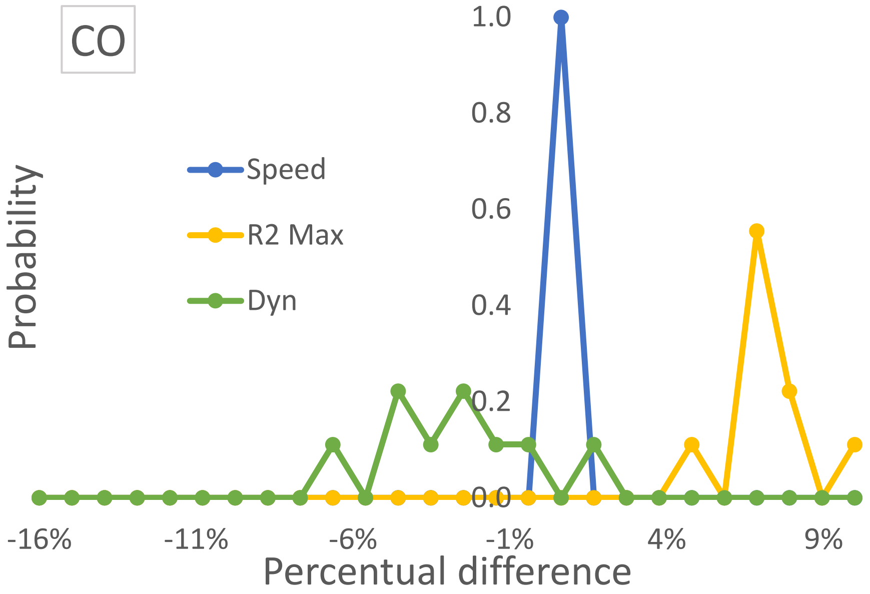
Table 3. R2 coefficients obtained by different synchronization methods

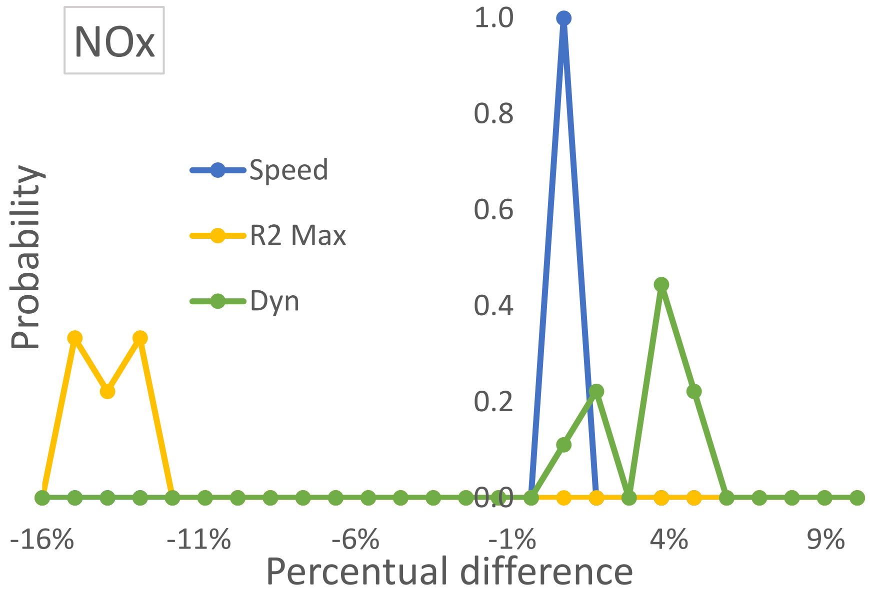
CO_2 vs m_{fuel}		R^2 Original	R^2 Speed	R^2 maxim	R^2 Dyn
EcoStar	ES_1	0.18393	0.18684	0.7257	0.7469
	ES_2	0.30694	0.30683	0.6942	0.7193
	ES_4	0.06784	0.06750	0.7182	0.7147
	ES_5	0.00574	0.00574	0.0509	0.4086
	ES_6	0.31552	0.77424	0.7742	0.8018
	ES_7	0.26810	0.24503	0.5973	0.7455
	ES_8	0.31268	0.35209	0.7407	0.7444
	ES_9	0.30164	0.46341	0.5679	0.6872
	ES_10	0.33551	0.33551	0.5558	0.6941
parSYNC	PS_1	0.30390	0.30371	0.7515	0.8017
	PS_2	0.28988	0.28977	0.7544	0.8049
	PS_3	0.13295	0.13257	0.5560	0.6514

ES_#[=] Data obtained by EcoStar for the trip number #
PS_#[=]Data obtained by parSYNC for the trip number#

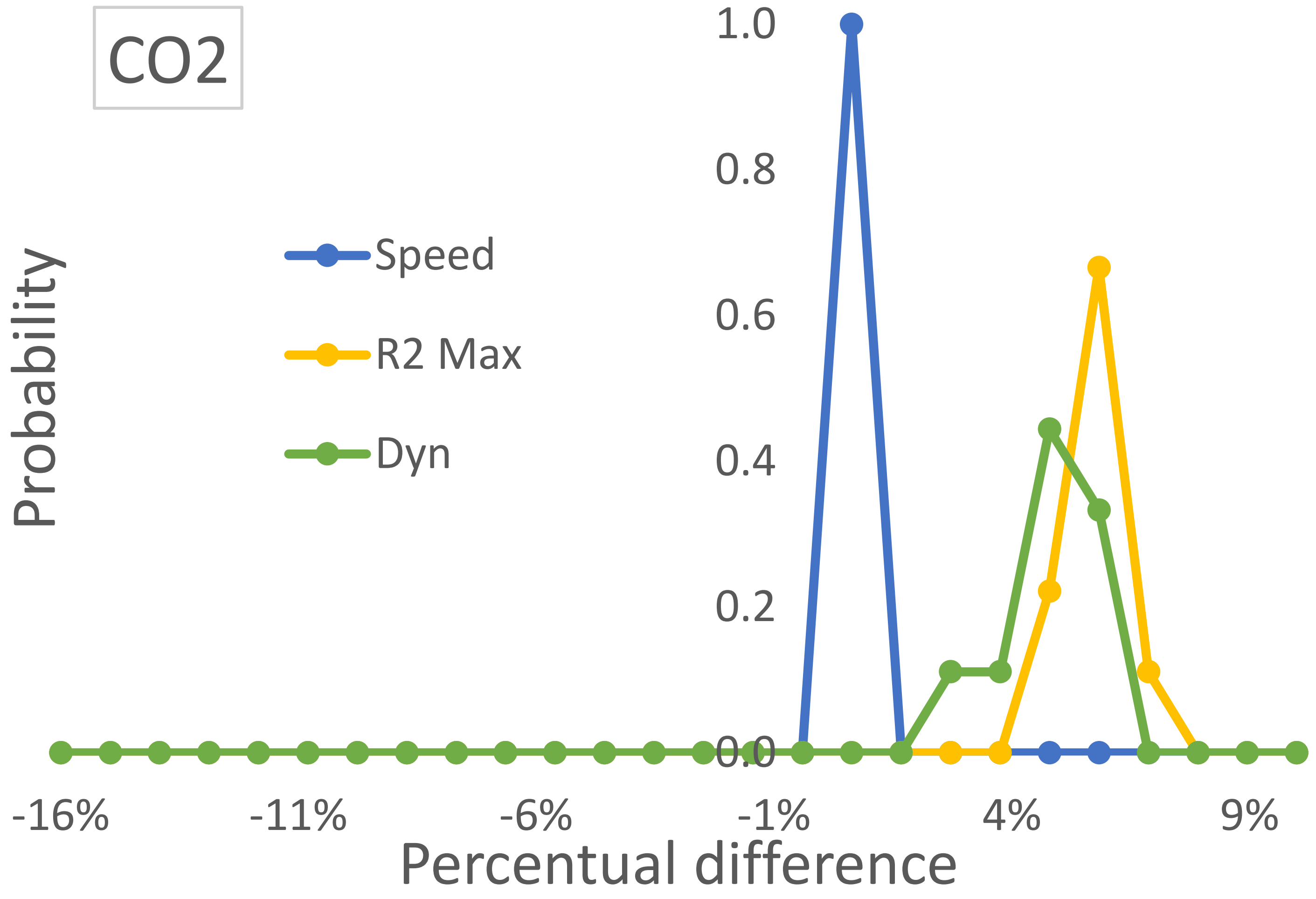
Percentual differences probability



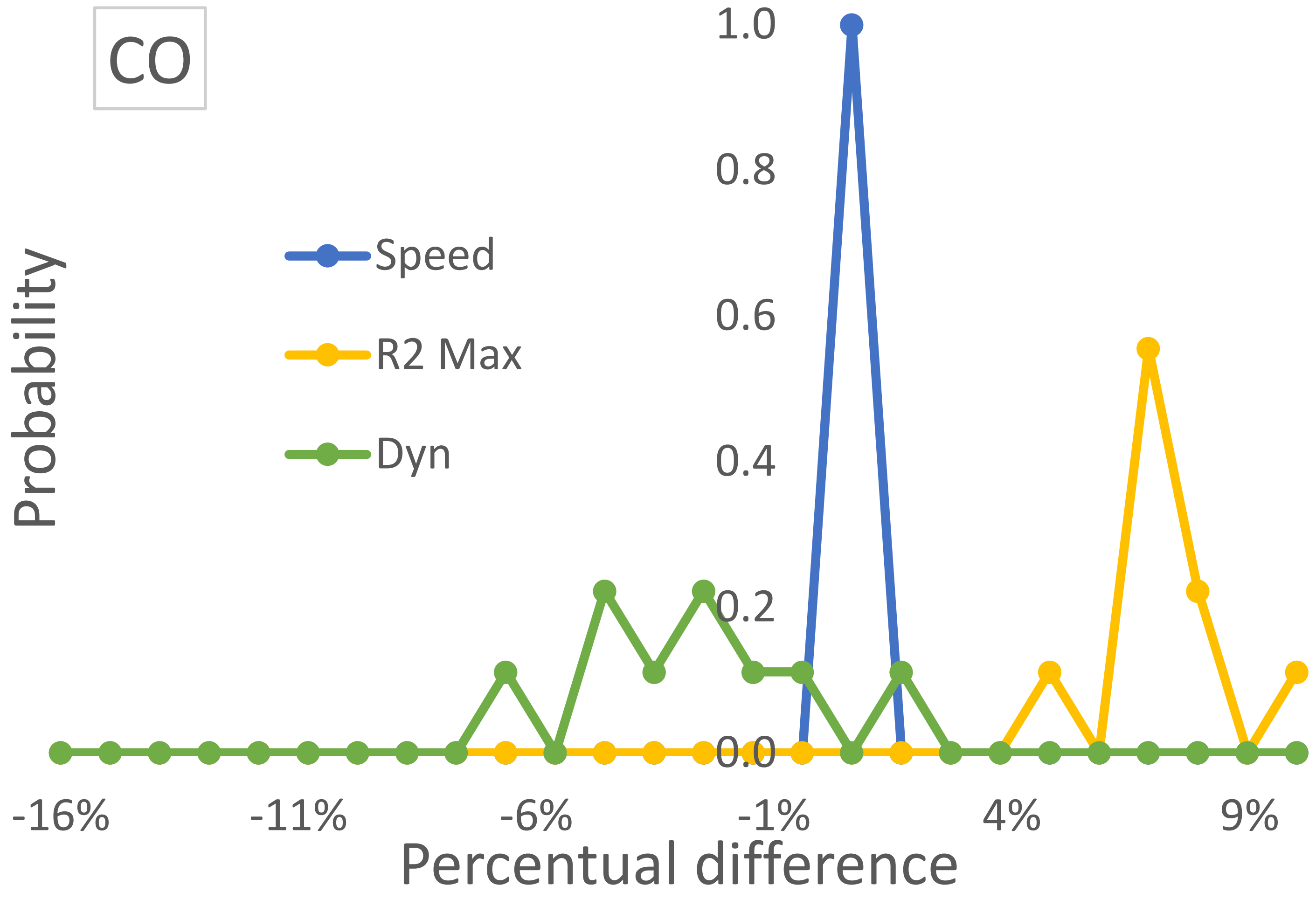




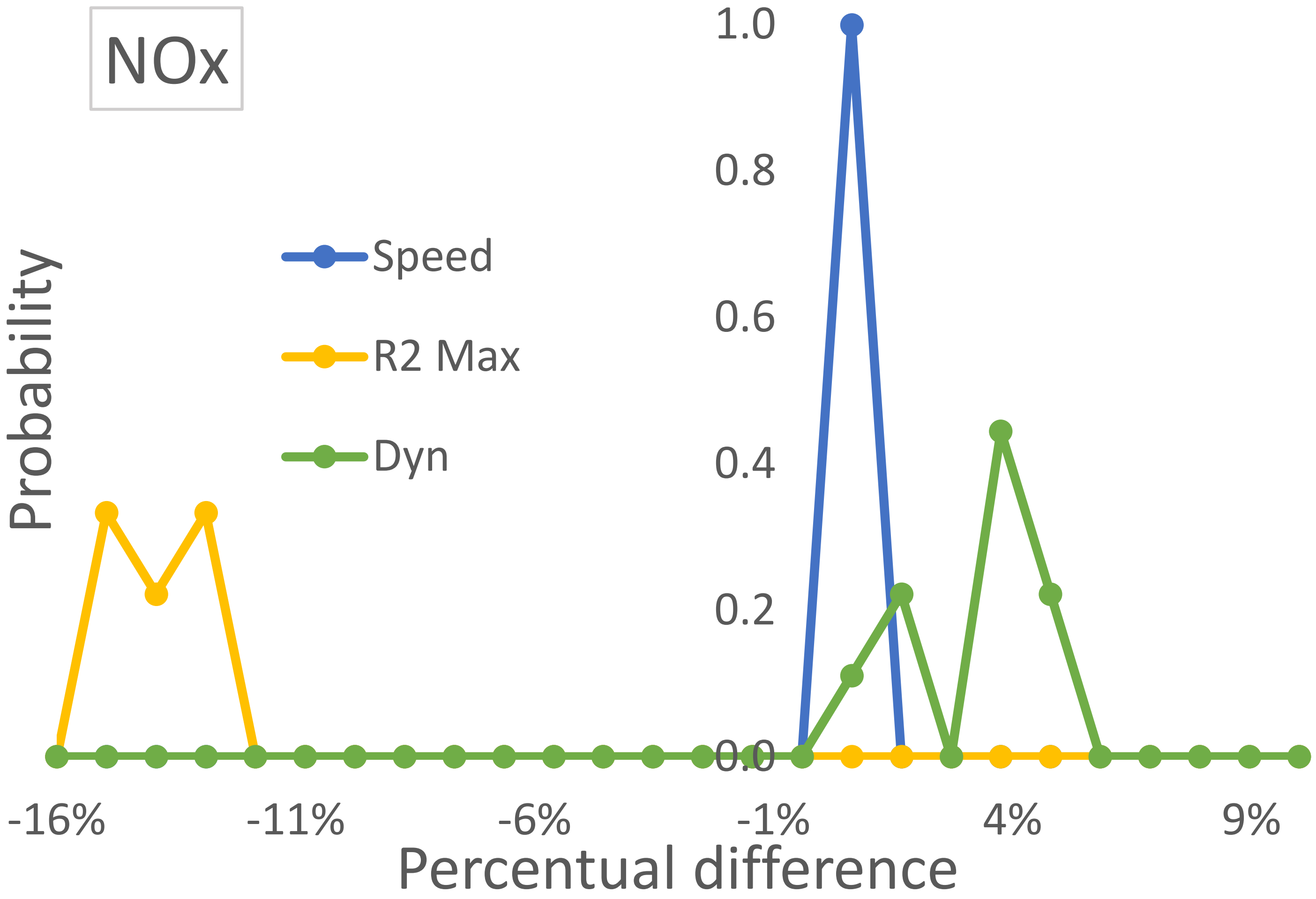
Percentual differences probability



Percentual differences probability



Percentual differences probability



Preliminary Conclusions

- Synchronization methods do affect the results obtained for emission indexes, with differences of up to 10% between each method analyzed.
- Preliminary results indicate that dynamic synchronization is likely to be the most reliable method.
- The most sensitive pollutant to the methods has been NOx, more analysis is required to establish if this is a repetitive behavior.

Future Work

- Obtain results for all measurements realized with parSYNC.
- Identify and evaluate more refined interpolation methods for dynamic synchronization.
- Interpret the differences found between the results and their effects on the determination of environmental performance.

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RELIEVE

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References

- Gallus, J., Kirchner, U., Vogt, R., Börensen, C., & Benter, T. (2016). On-road particle number measurements using a portable emission measurement system (PEMS). *Atmospheric Environment*, *124*(x), 37–45. https://doi.org/10.1016/j.atmosenv.2015.11.012

- Giraldo, M., & Huertas, J. I. (2019). Real emissions, driving patterns and fuel consumption of in-use diesel buses operating at high altitude. *Transportation Research Part D: Transport and Environment*, *77*, 21–36. https://doi.org/10.1016/j.trd.2019.10.004

- He, L., You, Y., Zheng, X., Zhang, S., Li, Z., Zhang, Z., Wu, Y., & Hao, J. (2022). The impacts from cold start and road grade on real-world emissions and fuel consumption of gasoline, diesel and hybrid-electric light-duty passenger vehicles. *Science of the Total Environment*, *851*(April). https://doi.org/10.1016/j.scitotenv.2022.158045

- Huang, C., Lou, D., Hu, Z., Feng, Q., Chen, Y., Chen, C., Tan, P., & Yao, D. (2013). A PEMS study of the emissions of gaseous pollutants and ultrafine particles from gasoline- and diesel-fueled vehicles. *Atmospheric Environment*, *77*, 703–710. https://doi.org/10.1016/j.atmosenv.2013.05.059

- Huertas, J. I., Stöffler, S., Fernández, T., García, X., Castañeda, R., Serrano-guevara, O., Mogro, A. E., & Alvarado, D. A. (2021). Methodology to assess sustainable mobility in latam cities. *Applied Sciences (Switzerland)*, *11*(20), 1–34. https://doi.org/10.3390/app11209592

- O'Driscoll, R., ApSimon, H. M., Oxley, T., Molden, N., Stettler, M. E. J., & Thiyagarajah, A. (2016). A Portable Emissions Measurement System (PEMS) study of NOx and primary NO2 emissions from Euro 6 diesel passenger cars and comparison with COPERT emission factors. *Atmospheric Environment*, *145*(2), 81–91. https://doi.org/10.1016/j.atmosenv.2016.09.021

- Quirama, L. F., Giraldo, M., Huertas, J. I., Tibaquirá, J. E., & Cordero-Moreno, D. (2021). Main characteristic parameters to describe driving patterns and construct driving cycles. *Transportation Research Part D: Transport and Environment*, *97*(July). https://doi.org/10.1016/j.trd.2021.102959

- Sandhu, G. S., Frey, H. C., Bartelt-Hunt, S., & Jones, E. (2021). Real-world activity, fuel use, and emissions of heavy-duty compressed natural gas refuse trucks. *Science of the Total Environment*, *761*, 143323. https://doi.org/10.1016/j.scitotenv.2020.143323

- Yu, Q., Yang, Y., Xiong, X., Sun, S., Liu, Y., & Wang, Y. (2021). Assessing the impact of multi-dimensional driving behaviors on link-level emissions based on a Portable Emission Measurement System (PEMS). *Atmospheric Pollution Research*, *12*(1), 414–424. https://doi.org/10.1016/j.apr.2020.09.022

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Thanks!

Do you have any questions?

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Más información

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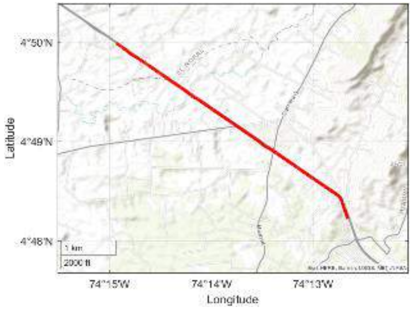
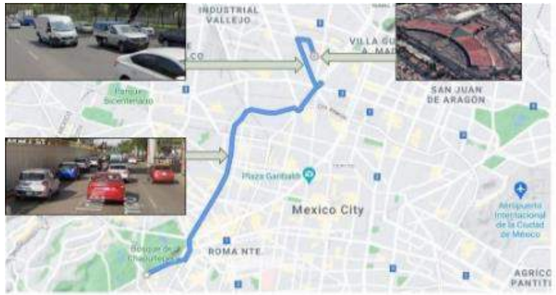
Literature review

Title	Reference	Year	City - Country	Altitude [masl]	Equipment	Synchronization method	Remarks
A PEMS study of the emissions of gaseous pollutants and ultrafine particles from gasoline- and diesel-fueled vehicles	(Huang et al., 2013)	2013	Shangai - China	4	Horiba OBS 2200	Not specified	Only the different response times of the sensors are mentioned.
A Portable Emissions Measurement System (PEMS) study of NOx and primary NO2 emissions from Euro 6 diesel passenger cars and comparison with COPERT emission factors	(O'Driscoll et al., 2016)	2016	Greater London - UK	11	EcoStar	Other method	The coincidence of the peaks in the signals is verified.
Assessing the impact of multi-dimensional driving behaviors on link-level emissions based on a Portable Emission Measurement System (PEMS)	(Yu et al., 2021)	2020	Beijing- China	44	EcoStar OBD	Other method	The time of each module of PEMS is aligned
Main characteristic parameters to describe driving patterns and construct driving cycles	(Quirama et al., 2021)	2021	Ciudad de Mexico, Toluca - Mexico	2256-2624	EcoStar	Synchronization maximizing R2	-
Methodology to asssess sustainable mobility in latam cities	(Huertas et al., 2021)	2021	Saltillo- Mexico	1592	RSD Remote Sensing device	Not specified	-
On-road particle number measurements using a portable emission measurement system (PEMS)	(Gallus et al., 2016)	2015	Aachen - Germany	173	Ecostar	Speed synchronization	Coincidence between PN and CO peaks
Real emissions, driving patterns and fuel consumption of in-use diesel buses operating at high altitude	(Giraldo & Huertas, 2019)	2019	Ciudad de Mexico - Mexico	2256	EcoStar	Synchronization maximizing R2	-
The impacts from cold start and road grade on real-world emissions and fuel consumption of gasoline, diesel and hybrid-electric light-duty passenger vehicles	(He et al., 2022)	2022	Macao - China	22	EcoStar	Synchronization maximizing R2	Synchronization between speed data measured by OBD and GPS
Real-world activity, fuel use, and emissions of heavy-duty compressed natural gas refuse trucks	(Sandhu et al., 2021)	2021	California		GlobalMRV-Axion	Other method	Coincidence between CO concentration and Motor RPM

Location

Geographic location	Route length [km]	Altitude [masl]	Temperature	Atmospheric pressure [kPa]
	11	2685	8-17	74,3
	11,5	2240	6-27	75,9
	18,8	2660	0-23	73,6

Vehicles evaluated

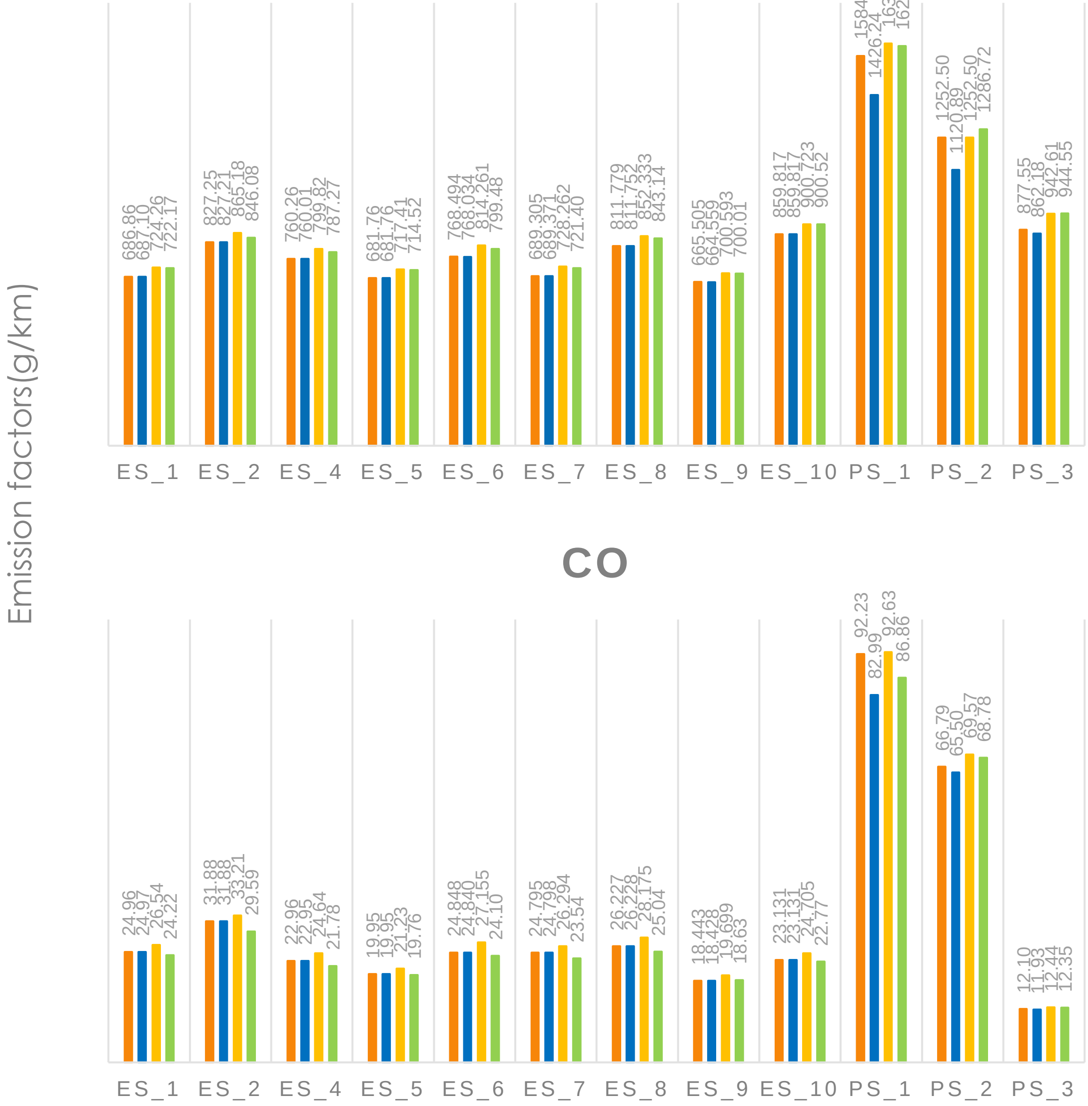
Figure 4. Vehicle evaluated in Mexico
Source:https://movilbus.blogspot.com/2011/07/busscar-visstabuss-elegance-360.html

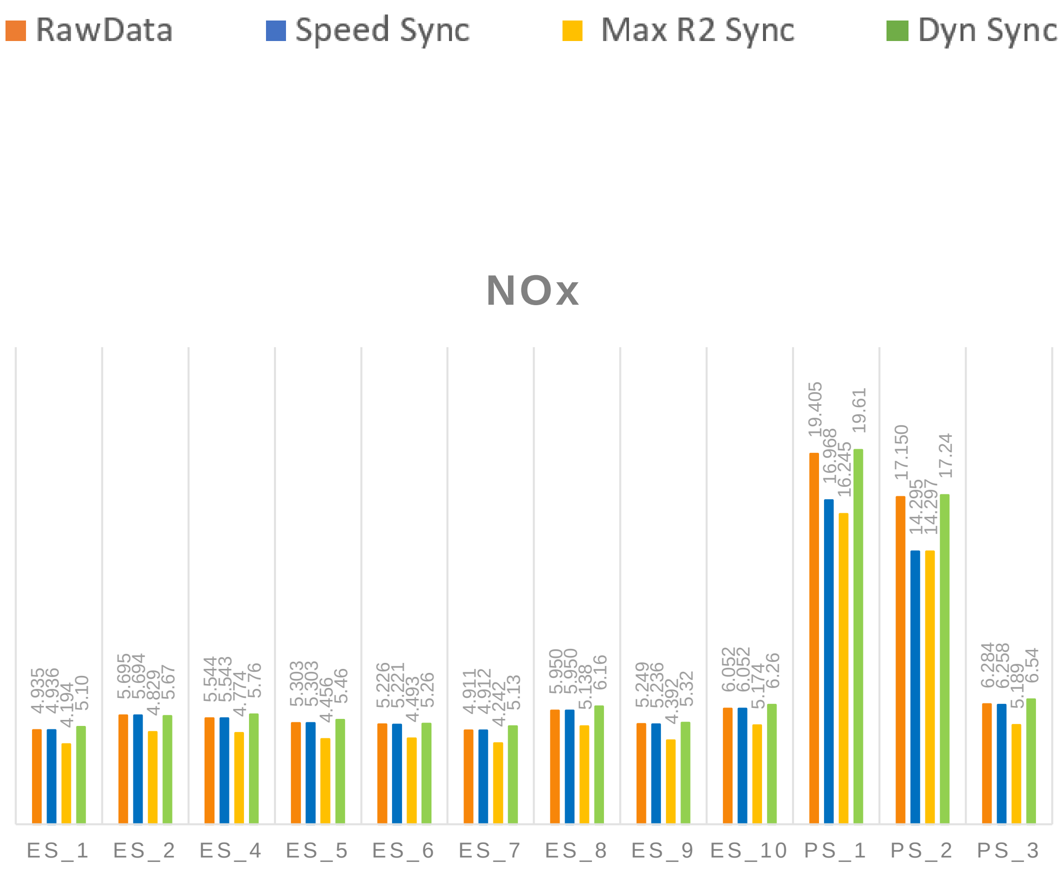
Table 1. Technical specifications of vehicles evaluated

	México	Bogotá
Size(m)	12.85 x 3.6 x 2.6	7.425 x 2.2 x 2.5
Capacity	49 Passengers 2100kg	5000-8000kg
Fuel	Diesel	Diesel
Curb vehicle weight(kg)	13850	10400
Motor	Cummins ISM 425, 6 cylinders, 10.8L, compression ratio16.3, 425HP, 2102 Nm	ISUZU 4HK1-TCC, 4 cylinders, 5.2L, compression ratio17.5, 187HP, 509.95Nm
Tires	305/75/R24.5	235/75/R17.5
Model	2012-2014	2022
Emission control Technology	USEPA 2004	EURO IV
Particle filter	NO	-
EGR	YES	YES
DOC	NO	YES
SCR	NO	-
Frontal Area (m2)	8.47	-
Drag coefficient	0.64	-
Rolling resistance. coefficient	0.06	-

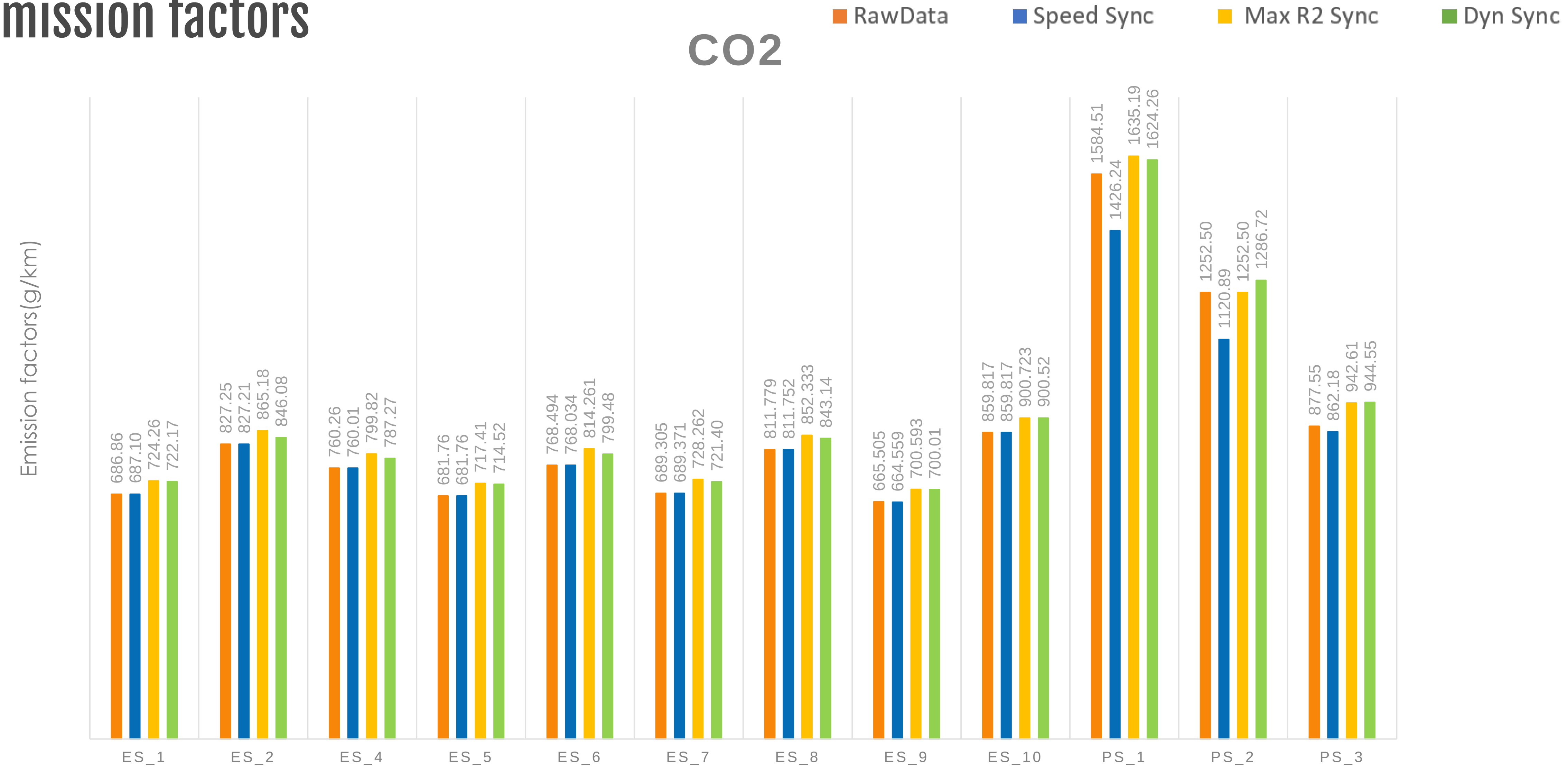
Figure 5. Vehicle evaluated in Colombia
Source:https://www.ayuramotorchevrolet.co/vehiculos/chevrolet-frr-forward

Emission factors

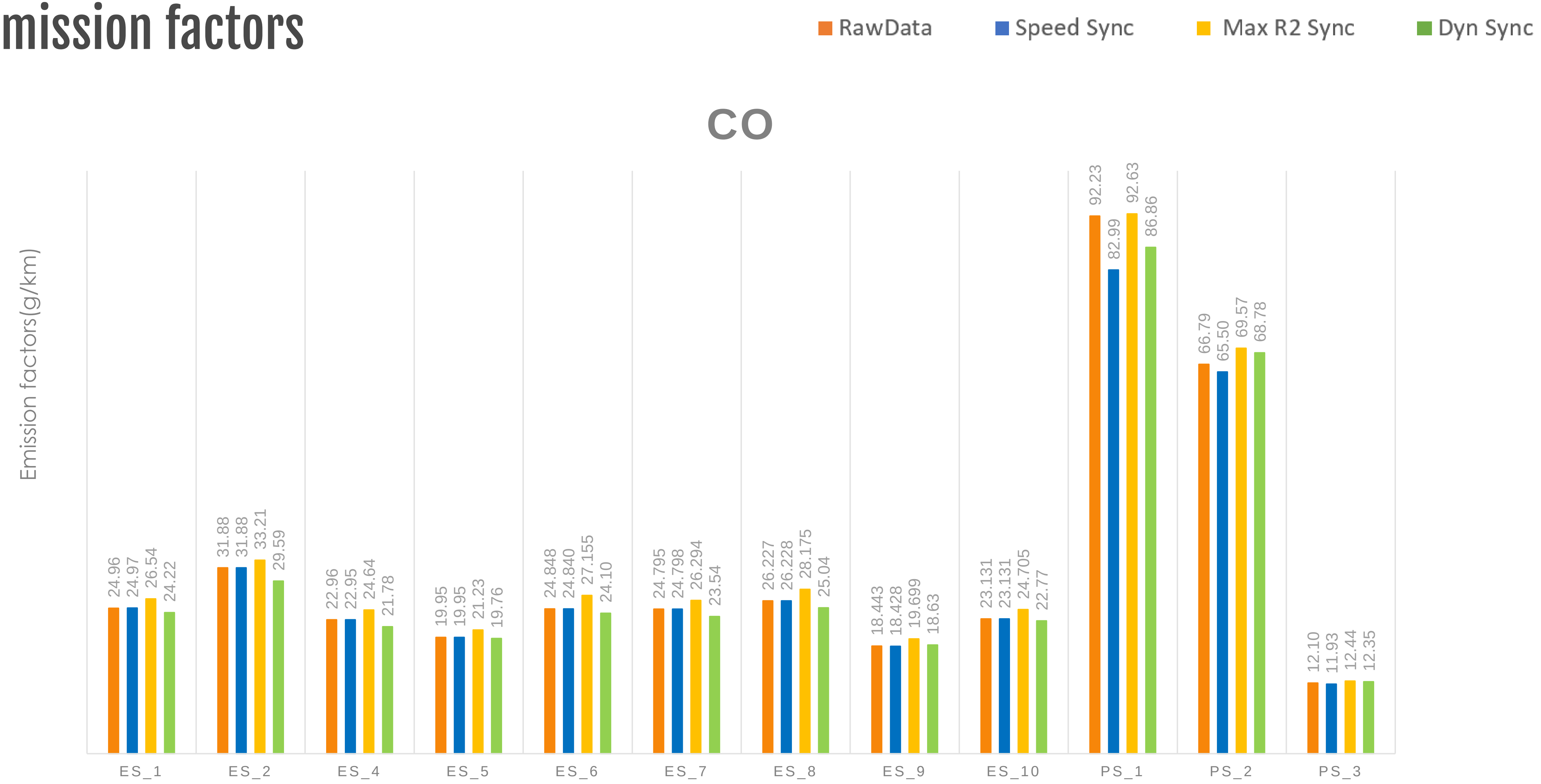




Emission factors



Emission factors



Emission factors