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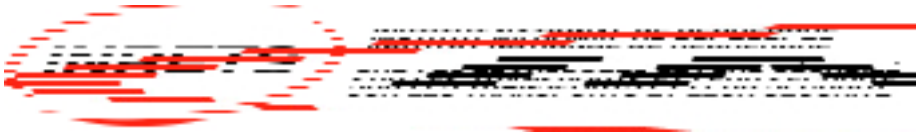
IMPACT OF THE GEARSHIFT STRATEGY ON EMISSION MEASUREMENTS

Artemis 3142 report

Report n° LTE 0307
March 2003



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13 Summary

The impact of the gearshift strategy pattern on emissions is investigated. To this aim, 5 (resp. 4) different patterns for the Artemis (resp. PNR-Ademe) data are compared. Two patterns are based on set values of vehicle or engine speed. A gentle driving strategy is derived from set vehicle speed values, and an aggressive driving strategy is derived from set engine speed values. The other strategies represent real-world strategies, more or less adapted to the vehicle and more or less reproducible. The patterns are analyzed from a kinematic point of view. Then, for 6 (resp. 9) vehicles for Artemis (resp. PNR-Ademe) data, the measured emissions are compared according to the gearshift strategy. For CO_2 a hierarchisation of the strategies is proposed. For the other pollutants, no strategy appears more polluting than another. The effect of the sample size and of the emission level are much more significant than the strategy effect itself.

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13 Résumé

On étudie l'influence du schéma de changement de rapports de vitesse sur les émissions. Pour cela, on propose 5 (resp. 4) schémas différents pour les données issues du projet Artemis (resp. PNR-Ademe). Parmi ceux-ci, 2 schémas sont basés sur des valeurs consignes de vitesse ou de régime moteur. Le schéma basé sur des consignes de vitesse nous sert à définir une stratégie de type conduite souple tandis que celui basé sur des consignes de régime moteur est utilisé comme stratégie de conduite agressive. Les autres représentent des stratégies réelles, plus ou moins adaptées au vehicle et plus ou moins reproductibles. Les schémas sont analysés d'un point de vue cinématique. Ensuite, pour 6 (resp. 9) vehicules pour les données du projet Artemis (resp. PNR-Ademe), on compare les émissions mesurées pour chacun de ces schémas. Pour le CO_2 une hiérarchisation des strategies est proposée. Pour les autres polluants, aucune stratégie n'apparaît plus polluante qu'une autre. L'effet taille d'échantillon et le niveau des émissions sont beaucoup plus importants que l'effet stratégie lui-même.

14 Mots clés boite de vitesse, mesure, émission, stratégie de changement de rapport, polluant, style de conduite, vehicle particulier, caractéristique vehicle, cycle de conduite, méthode		15 Diffusion restreinte X libre	
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Contents

Introduction

The Artemis (Assessment and Reliability of Transport Emission Models and Inventory Systems) study is aiming at developing a harmonised emission model for road, rail, air and ship transport to provide consistent emission estimates at the national, international and regional level.

The workpackage 300 entitled "Improved methodology for emission factor building and application to passenger cars and light duty vehicles" is aiming at improving the exhaust emission factors for the passenger cars and light duty vehicles, by investigating the accuracy of the emission measurements, by enlarging the emission factor data base especially for non-regulated pollutants, recent passenger cars and light duty vehicles, and by building emission factors according to the different purposes of Artemis.

Amongst the parameters used for measuring emissions, the gearshift strategy choice can have a significant impact. Such an impact is assessed. The purpose of this study is twofold: to quantify the impact of various gearshift strategies on emissions and to provide qualitative and quantitative items for defining the best possible strategy over cycles liable to be further developed. It corresponds to the task 3142 of the Artemis project.

This study is also the object of a contract between Inrets and Ademe, so-called PNR-Ademe. The project aims at extending knowledge of the emissions of the passenger cars in three directions: the most recent technologies, the cold start emissions and the non-regulated pollutants. This study is primarily based on the development of new driving cycles adapted to the range of vehicle (characterized by their power or their power-to-mass ratio) and the taking into account of the gearshift strategies with respect to the emissions.

The gearshift strategy consists in identifying the engaged gear at each time interval of the driving cycle. Under real-world driving conditions, the selected gear depends on:

- the driver's style
- the vehicle
- the driving conditions.

It should be noted that these three parameters are closely linked: a driver with a sport driving style would find difficult to drive a puffing vehicle in a sporty manner. The acceleration of a Citroën AX equipped with a diesel engine cannot be compared to a Ferrari…

The difficulty, in defining a gearshift strategy, lies therefore in the reconciliation of these three parameters. As for the driving cycles, the aim is to obtain representative results for real-world driving conditions and the proposed patterns should both be adapted to the tested vehicle and enable a comparison between the vehicles.

This report investigates respectively 5 and 4 possible strategies respectively within the Artemis and PNR-Ademe projects in order to determine the gearshifts over a prescribed cycle. In a first part, the various strategies are described and the advantages and drawbacks of each of them are analysed. Then, emission factors are studied in order to quantify the impact of the gearshift strategies on emission measurements.

1. Vehicle samples

This report contains the analysed data of the vehicles measured within the Artemis and PNR-Ademe projects. In these two studies, the influence of the gearshift on emission is considered.

In Artemis study 6 vehicles (4 from Inrets, 2 from KTI) are tested, whereas in PNR-Ademe study 9 vehicles are tested. The cycles used are quite the same ones. They were built from the same database (André, 2002; André 2003). So we decided to pool these two vehicle samples to have as many vehicles as possible.

The vehicle characteristics are given in Annex 1. The average characteristics are given in the Table 1.

Study	Fuel type	Vehicle number				Capa-city	Max power	Mass	P/M	Age	Mileage
		Euro 1	Euro 2	Euro 3	total	(cm^3)	(kW)	(kg)	(W/kg)	(Year)	(km)
Artemis	Gasoline	2	2	0	4	1505	79	1015	78	4	47 575
	Diesel	0	2	0	2	1812	56	1170	48	3.5	25 000
	Total	**2**	**4**	**0**	**6**	**1689**	**68**	**1093**	**63**	**3.75**	**36 288**
PNR-Ademe	Gasoline	1	1	2	4	1322	61	1126	54	3.5	45 875
	Diesel	2	2	1	5	1889	59	1153	51	3.8	86 619
	Total	**3**	**3**	**3**	**9**	**1606**	**60**	**1140**	**53**	**3.65**	**66 247**
Artemis + PNR-Ademe	Gasoline	3	3	2	8	1414	70	1071	65	3.75	46 725
	Diesel	2	4	1	7	1851	58	1162	50	3.65	55 810
	Total	**5**	**7**	**3**	**15**	**1633**	**64**	**1117**	**58**	**3.7**	**51 268**

Table 1: Average characterics of the tested vehicles.

2. The used driving cycles

For the two studies (Artemis and PNR-Ademe), new cycles were created (André, 2002 & André, 2003). The cycle characteristics are given below in Table 2, Table 3 and Table 4. The graphic representations are in Figure 1, Figure 2 and in Figure 3.

It is proposed here to test the various gearshift patterns over the urban and rural Artemis cycles (André, 2001) and over urban, rural and motorway VP Motorization (André, 2003). These last cycles were developed on the same basis, but take into account the power-to-mass-ratio of the vehicle. All the cycles used are divided into 4 or 5 subcycles named cycle_1 to cycle_5 (or 4)

As the selected strategies were strictly identical over the urban, rural and motorway cycles, the analyses were performed with instantaneous measurements since it was the only way for analysing the sub-cycle emissions.

2.1. Urban cycles

The Table 2 describes the statistics of the used urban cycles. The Figure 1 represents the used urban cycles. The "engine start phase" or “pré Urbain” data are not included in the analysis.

Cycle Name		Start (s)	End (s)	Duration (s)	Distance (km)	Average speed (km/h)	Max. speed (km/h)	Stop duration (s)	Stop number	Running speed (km/h)	Stop duration (‰)	Stop nber / km
Artemis	**Urban**	**72**	**993**	**921**	**4472**	**17.5**	**57.7**	**260**	**22**	**24.4**	**28.2**	**4.92**
	Urban_1	72	308	236	1016	15.5	48.9	69	6	21.9	29.2	5.9
	Urban_2	308	506	198	1748	31.8	57.7	16	4	34.6	8.1	2.29
	Urban_3	506	749	243	590	8.7	46.2	141	6	20.8	58	10.17
	Urban_4	749	877	128	420	11.8	39.8	23	7	14.4	18	16.67
	Urban_5	877	993	116	698	21.7	44	11	3	23.9	9.5	4.3
VP faible motorisation	**urbain**	**83**	**1028**	**945**	**4799**	**18.3**	**55.7**	**280**	**18**	**26**	**29.6**	**3.75**
	urbain_1	83	317	234	1074	16.5	50.5	79	5	24.9	33.8	4.66
	urbain_2	317	533	216	1852	30.9	55.2	23	5	34.5	10.6	2.7
	urbain_3	533	768	235	652	10	55.7	134	6	23.2	57	9.21
	urbain_4	768	890	122	319	9.4	26.9	30	3	12.5	24.6	9.42
	urbain_5	890	1028	138	904	23.6	46.9	14	3	26.2	10.1	3.32
VP forte motorisation	**urbain**	**80**	**998**	**918**	**4924**	**19.3**	**57.6**	**253**	**20**	**26.7**	**27.6**	**4.06**
	urbain_1	80	304	224	1110	17.8	50.7	56	7	23.8	25	6.31
	urbain_2	304	548	244	2009	29.6	57.6	37	5	34.9	15.2	2.49
	urbain_3	548	773	225	712	11.4	56.7	125	5	25.6	55.6	7.02
	urbain_4	773	884	111	376	12.2	31.3	25	5	15.8	22.5	13.29
	urbain_5	884	998	114	716	22.6	46.3	10	2	24.8	8.8	2.79

Table 2: Kinematics statistics of the used urban cycles

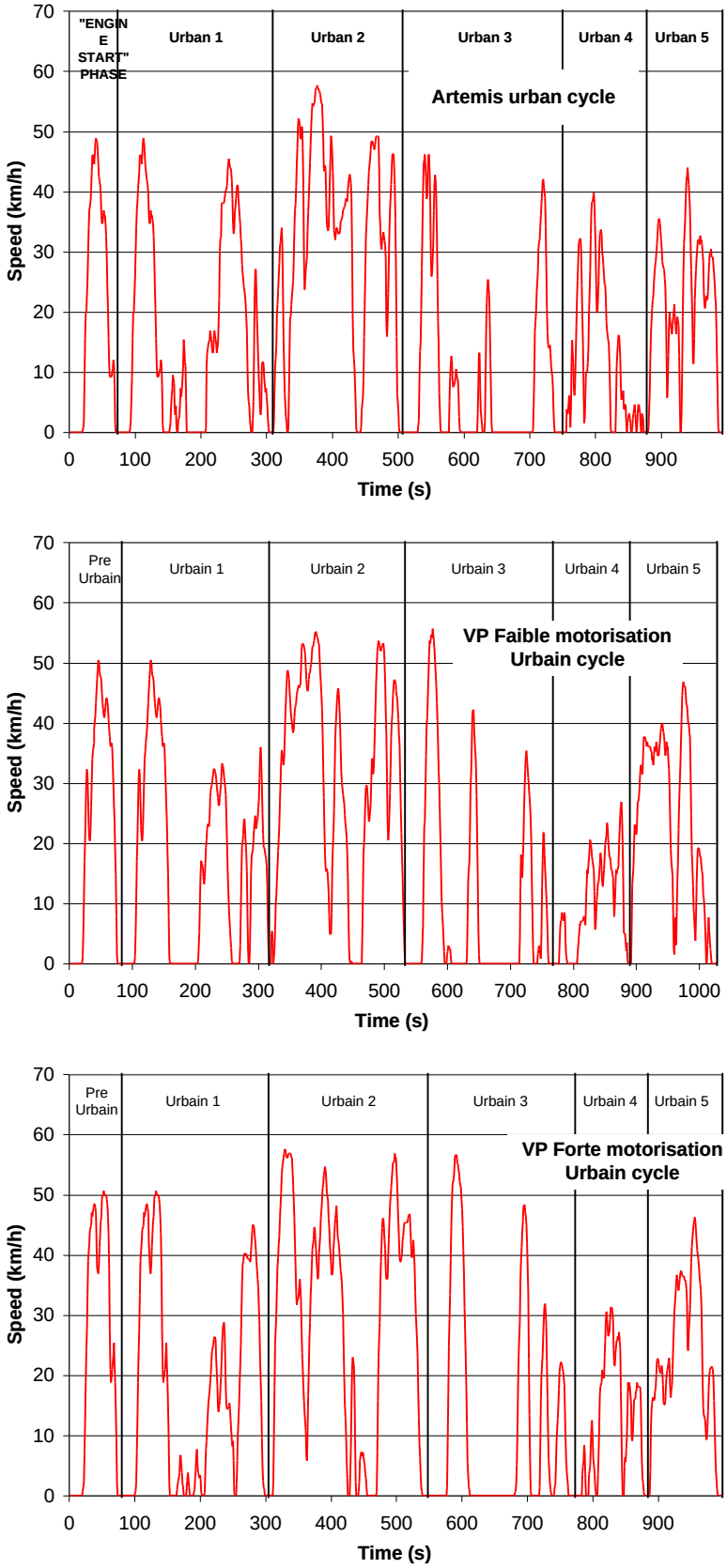


Figure 1: Representation of the used urban cycles 'Artemis urban', 'VP faible motorisation urbain' and 'VP forte motorisation urbain'

2.1. Rural cycles

The Table 3 describes the statistics of the used rural cycles. The Figure 2 represents the used rural cycles. The "pre cycle" and "post cycle" data are not included in the analysis.

Cycle Name		Start (s)	End (s)	Duration (s)	Distance (km)	Average speed (km/h)	Max. speed (km/h)	Stop duration (s)	Stop number	Running speed (km/h)	Stop duration (‰)	Stop nber / km
Artemis	**Rural**	**101**	**1082**	**981**	**16441**	**60.3**	**111.5**	**24**	**4**	**61.8**	**2.4**	**0.24**
	Rural_1	101	341	240	3328	49.9	76.9	14	2	53	5.8	0.6
	Rural_2	341	512	171	3129	65.9	83.8	0	0	65.9	0	0
	Rural_3	512	695	183	2190	43.1	68.5	5	1	44.3	2.7	0.46
	Rural_4	695	872	177	3866	78.6	111.5	0	0	78.6	0	0
	Rural_5	872	963	91	2211	87.5	104.4	0	0	87.5	0	0
VP faible motorisation	**route**	**107**	**928**	**821**	**13149**	**57.7**	**111.5**	**30**	**4**	**59.8**	**3.7**	**0.3**
	route_1	107	350	243	3240	48	74.5	17	2	51.6	7	0.62
	route_2	350	475	125	2264	65.2	86.8	0	0	65.2	0	0
	route_3	475	711	236	2659	40.6	68.5	13	2	42.9	5.5	0.75
	route_4	711	847	136	3008	79.6	111.5	0	0	79.6	0	0
	route_5	847	928	81	1978	87.9	104	0	0	87.9	0	0
VP forte motorisation	**route**	**91**	**935**	**844**	**14223**	**60.7**	**110.5**	**30**	**3**	**62.9**	**3.6**	**0.21**
	route_1	91	346	255	3463	48.9	76.9	20	2	53	7.8	0.58
	route_2	346	477	131	2412	66.3	82.5	0	0	66.3	0	0
	route_3	477	678	201	2454	43.9	65.6	10	1	46.2	5	0.41
	route_4	678	859	181	4000	79.6	110.5	0	0	79.6	0	0
	route_5	859	935	76	1894	89.7	101.9	0	0	89.7	0	0

Table 3: Kinematic statistics of the used rural cycles

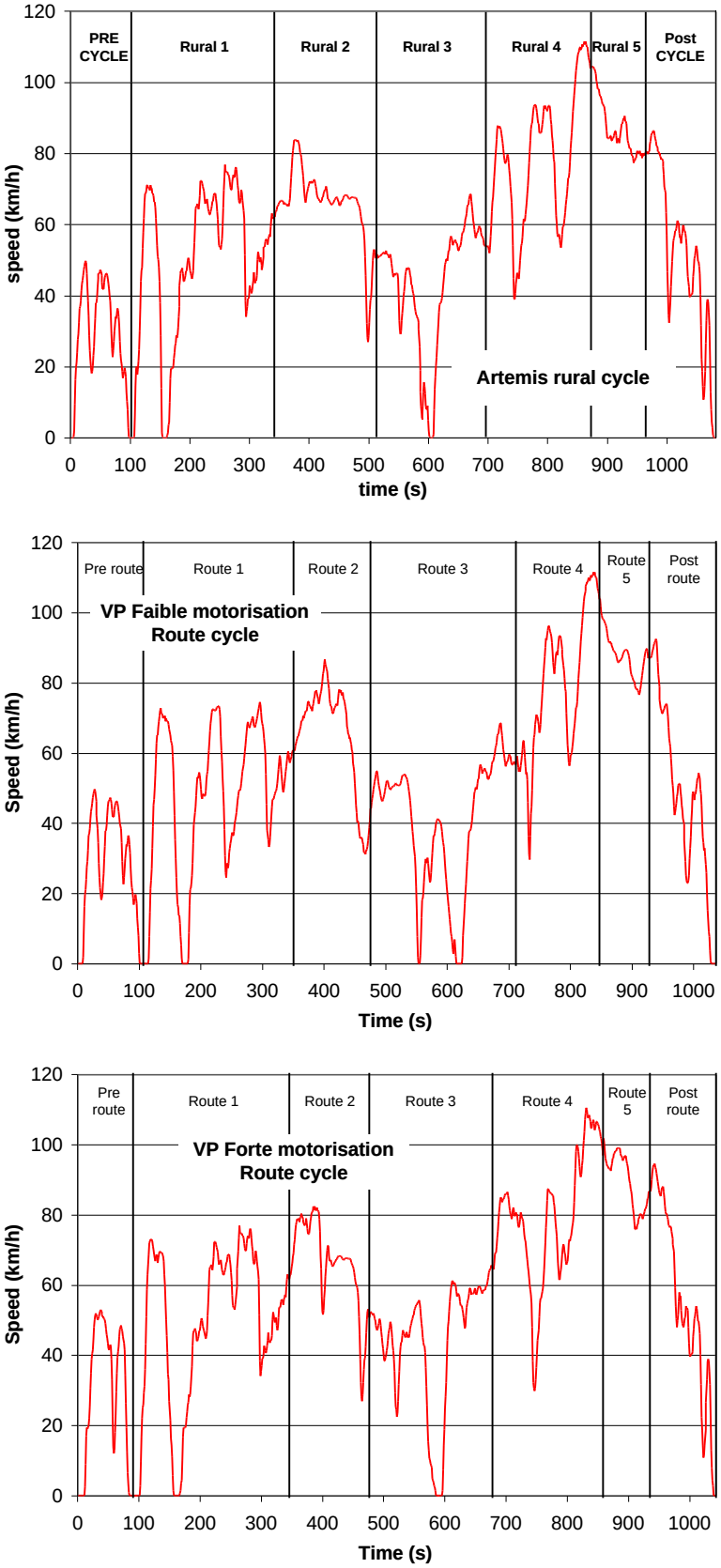


Figure 2: Representation of the used rural cycles 'Artemis rural', 'VP faible motorisation route' and 'VP forte motorisation route'.

2.3. Motorway cycle

The Table 4 describes the statistics of the used motorway cycles. The Figure 3 represents the used motorway cycles. The "pre cycle" and "post cycle" data are not included in the analysis.

Cycle Name		Start (s)	End (s)	Duration (s)	Distance (km)	Average speed (km/h)	Max. speed (km/h)	Stop duration (s)	Stop number	Running speed (km/h)	Stop duration (‰)	Stop nber / km
VP faible motorisation	**autoroute**	**177**	**906**	**729**	**24090**	**119**	**150,7**	**0**	**0**	**119**	**0**	**0**
	autoroute_1	177	449	272	9182	121,5	133,9	0	0	121,5	0	0
	autoroute_2	449	630	181	5188	103,2	128	0	0	103,2	0	0
	autoroute_3	630	811	181	6243	124,2	145,7	0	0	124,2	0	0
	autoroute_4	811	906	95	3477	131,8	150,7	0	0	131,8	0	0
VP forte motorisation	**autoroute**	**175**	**925**	**750**	**25377**	**121,8**	**157,1**	**0**	**0**	**121,8**	**0**	**0**
	autoroute_1	175	446	271	9517	126,4	142,5	0	0	126,4	0	0
	autoroute_2	446	630	184	5224	102,2	142,5	0	0	102,2	0	0
	autoroute_3	630	809	179	6246	125,6	151	0	0	125,6	0	0
	autoroute_4	809	925	116	4391	136,3	157,1	0	0	136,3	0	0

Table 4: Kinematics statistics of the used motorway cycles

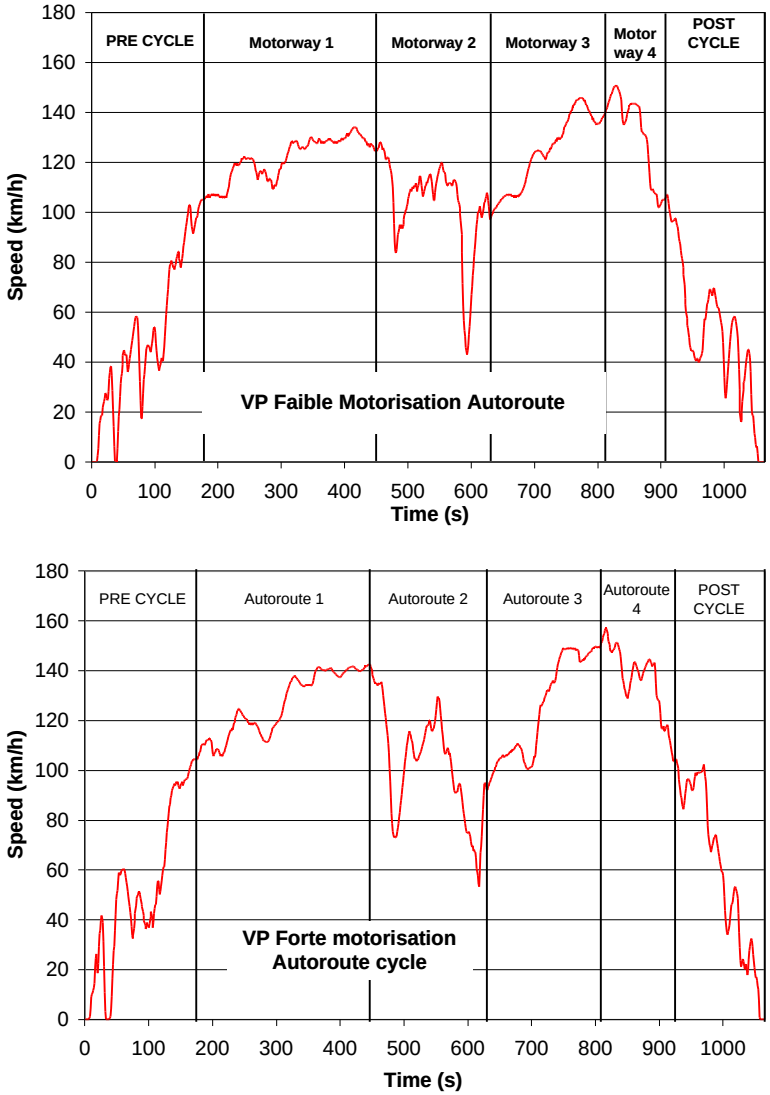


Figure 3: Representation of the used motorway cycles 'VP faible motorisation autoroute' and 'VP forte motorisation autoroute'.

3. Gearshift strategies

For a prescribed driving cycle, there are several ways of defining the gearshifts. Five gearshift strategies are compared, i.e. five methods of gear shifting. The first one, so-called 'cycle' strategy, is included in the design of the corresponding driving cycles. The second and fourth ones impose given gearshifts independently of the vehicle characteristics (as foreseen in the NEDC cycle or as recorded on the road). The third strategy depends on the vehicle characteristics, and the fifth strategy is up to the laboratory driver.

3.1. 'Cycle' strategy

3.1.1. 'Cycle (Artemis)' strategy

The method selected for the Artemis cycles, so-called Artemis strategy, is derived from a method developed previously by Inrets (André et al., 1995). It enables to consider simultaneously:

- The driving conditions, since the engine speed and the power demand are taken into account
- The driver styles since the database used includes measurement values for various drivers
- The vehicle characteristics, since the gearshift statistics are classified according to dimensionless variables, which are direct functions of the power-to-mass ratio and the engine speed at the maximum power of the vehicle.

In the original method gearshifts are determined each second for each vehicle tested, according to its characteristics. In the Artemis strategy, calculation is no more performed for each vehicle, but the gearshifts are defined per vehicle layer or class. The main advantage of the vehicle classification is that the number of strategies is limited: 4 vehicle classes are defined and therefore 4 gearshift strategies (see Annex 2) are available: the cycles are perfectly identical for a same category of vehicles. The drawback is that the gearshift pattern is less adapted to each vehicle, in particular for the vehicles far from the class centres.

Thus 4 'cycle (Artemis)' gearshift strategies are called Artemis 1 to Artemis 4.

3.1.2. 'Cycle (VP Motorization)' strategy

Specific cycles are designed for the PNR-Ademe study. They are constructed with the same method than this one used for designing the Artemis cycles. The only difference lies in the fact that kinematics are adapted to the range of the vehicle. The vehicles are classified in 2 ranges, which are related to their level of motorization (see Andre, 2003). The level of motorization is evaluated by considering the specific power of the vehicle (i.e. the power-to-mass ratio P/M). If P/M < 60 W/kg (with P the maximum power of the vehicle and M the mass of the vehicle), the vehicle are low motorized (low category). If not, it is high motorized (high category). Kinematics are different for each range: resp. "VP faible motorisation" and "VP forte motorisation".

Then, as for the Artemis strategy, the gearshift strategy depends on the vehicle characteristics,

with the same rules (see Annex 2). Thus per driving cycle type, we have only 3 gearshift strategies: numbered 2, 3 or 4 for the low motorization cycles and 1, 2 or 3 for the high motorization cycles. So, the strategies are more adapted to the vehicle motorization.

3.2. The 'NEDC' strategy

The NEDC strategy is identical to that used for the legislative NEDC cycle: gearshifting is performed at vehicle speed set values. It can be relatively easily implemented and depends only on the vehicle kinematics: it is identical for all the vehicles with the same kinematic but it is not representative of real driving. It is well adapted to steady-speed cycles such as the NEDC cycle. But it is less appropriate for real-world driving cycles. For these cycles, in most of the cases, speed is not steady and it often varies by several km/h around the threshold speeds. When the threshold speeds are close to the set speed values, gearshifts are frequent (Figure 4). Sometimes the time spent in a given gear is very short, for instance 5 seconds.

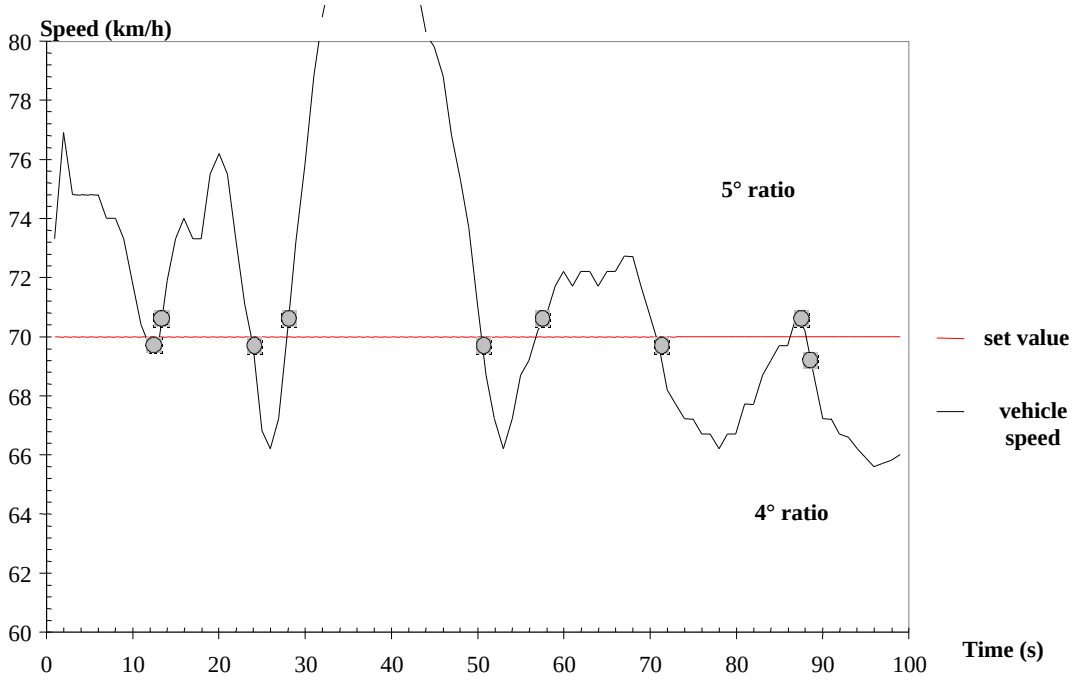


Figure 4: Example of close gearshifts for low speed fluctuations about the set value – rural cycle.

The same set values are selected than those selected for the NEDC cycle. Two reasons can be mentioned:

- ✓ Firstly, these values are relatively low and therefore do not penalise low-power engined vehicles. It corresponds to a gentle-driving mode. Thus, this strategy can be considered as not very aggressive.
- ✓ Secondly, there is no set speed which would prevent threshold problems. For real-world cycles, there are several speed thresholds for various average speeds. Selecting a set value for speed usually enables to avoid frequent gearshifts for a prescribed speed range,

but not to avoid them for all the cycle ranges.

Gear ratios are as follows:

- 0 < v(t) < 15 km/h: ratio = 1
- 15 < v(t) < 35 km/h: ratio = 2
- 35 < v(t) < 50 km/h: ratio = 3
- 50 < v(t) < 70 km/h: ratio = 4
- 70 < v(t): ratio = 5

Gearshifting is performed provided that there has not been any change during the previous second.

3.3. The strategy of imposed engine speeds ‘RPM’

This strategy, the so-called "RPM" strategy, takes into account the kinematic parameters and the vehicle characteristics in the gearshift pattern. Therefore, this pattern differs from one vehicle to another, providing 15 so-called RPM patterns corresponding to the 15 vehicles tested. This strategy aims at defining set values for engine speeds involving a gear change. For each driving speed, the rotation speed of the engine is thus calculated as a function of the vehicle speed and the selected gear. If the rotation speed value is not within the set limits, a gearshift is performed.

This strategy can be implemented easily. The engine speed limits are selected in order the strategy to be aggressive. Thus, this strategy can be easily compared to the previous, gentler strategy. The engine speed limits are as follows:

- if rpm(t) > 75% of engine speed at maximum power, ratio(t) = ratio(t) +1
- if rpm(t) < 1500 rpm, ratio(t) = ratio(t)-1

Gearshifting is performed provided that there has not been any change during the previous second.

3.4. The ‘record’ strategy

This strategy is only applied for the vehicles tested in the Artemis Study.

This strategy includes the gearshifts recorded simultaneously with the speed kinematic over instrumented vehicles from the DRIVE-modem database (André et al., 1995; André, 2001). This is the most realistic strategy: it is well adapted to the vehicle for which the sequence was recorded, but not necessarily to the vehicle tested on a chassis dynamometer. In addition, as for speed recordings, the gradient and load impacts in real road conditions cannot be reproduced on a chassis dynamometer, as they were not recorded.

This strategy is the same for all the vehicles tested on the chassis dynamometer. It is named the "Record" strategy.

This strategy has been modified once as compared to the records. For a two sequence chaining, over two separate vehicles, the vehicle speed was steady around 80 km/h, but the 5^{th} gear was selected for the first vehicle, while the 3^{rd} gear was engaged for the second vehicle. It was thus required to shift from the 5^{th} to the 3^{rd} gear for the 80km/h speed stage. This operation appeared to be too risky (poor cycle monitoring and breakage risk for the tested vehicle). Therefore a 5 to

4 shift (instead of 5 to 3) at a sequence change was selected, followed 10 seconds later by a 4 to 3 shift.

3.5. The ‘free’ strategy

In this case, gearshifting depends on the choice of the laboratory driver. Since this strategy was the last tested, the driver had a good knowledge of the speed curve, thus enabling him to anticipate the gear changes in order to provide an appropriate cycle monitoring. The engine speeds recorded will enable to identify the gearshifts performed during the measurement. This is the so-called "Free" strategy.

4. Comparison of the gearshift strategies

4.1. Influence on the engine speed

The engine speed recorded on the chassis dynamometer is not accurate enough to enable to determine the time when gearshifts are operated, due to a frequent slipping of the clutch and thus an erratic engine speed when releasing the clutch. Only theoretical data for gearshifting can be used. Therefore, the free strategy, which does not include theoretical changes, cannot be studied in this section.

In Annex 3, average theoretical speeds at which gearshifts are performed are compared versus strategy. It should be noted that two strategies significantly differ:

- The NEDC strategy, in which gearshifts are performed at rather low speeds, but with frequent shifts.
  - Over 181 shifts throughout the 2 Artemis cycles (urban and rural) while the other strategies account for only 130 shifts on average
  - Over 214 shifts throughout the 3 VP motorization cycles (urban, rural and motorway) while the other strategies account for only 130 shifts on average
- The RPM strategy induces gearshifting (upshift) at very high speeds as compared to the other strategies. But under downshifting conditions it can be observed that the speeds at which gearshifts are performed are extremely low for the 5 to 4 and 4 to 3 shifts and very high for the 2 to 1 shift. This demonstrates that, in the real world, gearshifting under deceleration conditions is not performed according to the engine speed, but according to the vehicle speed.

The two NEDC and RPM strategies using set values account for a great number of gearshifts of the 3 to 2 and 2 to 1 types, as compared to the other strategies. This can be explained by the difficulty of anticipating sufficiently the speed curve when shifting: under real-world conditions, the driver often anticipates vehicle stopping by shifting from 3 to 0 or 2 to 0. This case is not contemplated in the RPM and NEDC strategies: a deceleration aiming at vehicle stopping is defined by a shift from 1 to 0. This demonstrates the difficulty of predicting gearshifts for deceleration conditions, leading either to a vehicle stop, or to a new vehicle acceleration. Such a choice, which corresponds to driver's anticipation, cannot be made with a strategy including set values. This problem is observed for acceleration conditions too, even if it is less marked. The driver shifts gears at highly variable speeds, which are strongly dependent on driving conditions. For example, the driver can choose to accelerate significantly holding a lower gear ratio to overtake. The main advantage of a strategy based on gearshifting statistics is to enable to take into account such cases as a function of their frequency of occurrence.

Finaly, it can be observed that the strategies adapted to the vehicle characteristics substantially differ: a 10 km/h deviation (resp. up to 15 km/h) can often be recorded for gearshifting speeds according to vehicle power (for instance comparing vehicles 1 and 6 for the ‘cycle (Artemis)’ strategy, or resp. vehicles 7 and 15 for the ‘cycle (VP motorization)’ strategy).

Gearshift strategy	Cycle (Artemis)		NEDC		RPM		Record		average
Artemis cycle	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	
Vehicle N°1	20	44	19	41	26	51	18	42	33
Vehicle N°2	20	39	19	39	26	51	18	39	31
Vehicle N°3	20	50	21	45	27	50	20	45	35
Vehicle N°4	19	47	22	49	27	53	22	49	36
Vehicle N°5	18	35	17	34	24	49	16	35	29
Vehicle N°6	22	46	26	48	28	52	25	49	37
average	20	43	21	43	27	51	20	43	34

Table 5: Relative engine speed (engine speed rated by engine speed at maximum power, in %) versus the studied vehicle and strategy for the 6 vehicles of the Artemis study[J3].

Gearshift strategy	Cycle (VP Motorization)			NEDC			RPM			average
VP motorization cycle	Urban	Rural	Mot.	Urban	Rural	Mot.	Urban	Rural	Mot.	
Vehicle N°7	19	43	61	19	38	58	27	52	61	42
Vehicle N°8	18	37	57	19	35	56	28	46	61	40
Vehicle N°9	19	43	60	19	38	58	27	53	60	42
Vehicle N°10	19	42	62	24	41	61	39	72	83	49
Vehicle N°11	18	43	63	22	41	62	33	59	72	46
Vehicle N°12	20	46	64	22	41	63	30	52	67	45
Vehicle N°13	26	60	86	33	57	85	42	73	90	61
Vehicle N°14	19	44	61	21	39	59	33	62	74	46
Vehicle N°15	20	45	66	25	43	65	36	60	76	48
average	20	45	64	23	41	63	33	59	71	47

Table 6: Relative engine speed (engine speed rated by engine speed at maximum power, in %) versus the studied vehicle and strategy for the 9 vehicles of the PNR-Ademe study.

Table 5 and Table 6 give the relative engine speed (i.e. engine speed rated by engine speed at maximum power) for each cycle (urban, rural and motorway), averaged over the whole cycle.

It should be first observed that the relative average engine speed is always higher in motorway than in road conditions, and in road than in urban conditions.

In addition, in the Table 5, it can be noted that for strategies that do not depend on vehicle parameters (NEDC, RPM, record), the average engine speed is higher for vehicles with a low-power engine than for high-power engined vehicles. For these latter vehicles, the power demand, as compared to vehicle capacities, is always lower than that of small vehicles. This demonstrates that a same speed curve leads to a higher relative power demand for small vehicles than for the others. This difference can be easily explained since speed discrepancies recorded between small and big vehicles under real-world traffic conditions are not really significant.

4.2. Strategy impact on emissions

It should be noted that, before the statistical analysis, instantaneous emissions averaged over each cycle are compared to the bag emissions in order to guarantee the measurement validity. The results are presented in Annex 4 and Annex 5 per vehicle, pollutant, driving cycle and gearshift strategy.

Then we compare the pollutant emissions on the same vehicles. The correct way to deal with the problem consists in making for each couple of gearshift strategy, the difference between the two emission averages, pollutant by pollutant. If the strategy has no influence, the difference in these averages should not differ significantly from 0. The results are significant if the propability is less than 5 %.

Gearshift strategy	Cycle (Artemis)	Cycle (VP mot.)	NEDC	RPM	Record
Cycle (VP mot.)	not tested				
NEDC	CO_2[1]	CO_2[3, 4, 5], HC[3]			
RPM	CO_2[2]	CO_2[4, 5]	CO_2[1, 2, 3], CO[4]		
Record				CO_2[2]	
Free			CO_2[3, 4], CO[4]	CO_2[1, 2]	

[1] Artemis data on rural cycles
[2] PNR-Ademe data on motorway cycles
[3] Artemis data on urban cycles
[4] PNR-Ademe data on urban cycles
[5] PNR-Ademe data on rural cycles

Table 7: The statistically significant differences in the T-test comparisons strategy by strategy.

This analyse shows that CO_2 is the pollutant the most sensitive to the gearshift strategy. Whatever the source of the data and the cycle type, CO_2 is always influenced by the gearshift strategy. This pollutant can have a 2 - 15 % variation when comparing the gearshift strategies.

The Table 8 recapitulates the results detailed in Annex 6. It shows the statistically significant results of the T-test analysis on the Artemis and PNR-Ademe data. As we can see, CO_2 is the pollutant the most sensitive to the gearshift strategy. The other pollutants are sometimes influenced by the strategy. NOx is never dependant of the strategy. The high influence on CO could become from the low accuracy of measurement, as CO emission is near to the analyser detection limit.

From the Table 8, we can make a classification of the strategies from the most polluting to the less polluting, for CO_2.

Study	Pollutant	Cycle name	Strategy A	Strategy B	difference (%)
Artemis	CO_2	Artemis urban	RPM	Cycle (Artemis)	12
				NEDC	15
				Free	11
				Record	11
		Artemis rural	Cycle (Artemis)	NEDC	5
			RPM	Cycle (Artemis)	9
				Free	11
				NEDC	13
				Record	11
PNR-Ademe	CO_2	VP faible/forte motorisation urbain	Free	NEDC	6
			Cycle (VP mot.)		4
			RPM		4
		VP faible/forte motorisation route	Free	NEDC	5
			Cycle (VP mot.)		10
				RPM	8
		VP faible/forte motorisation autotoute	Cycle (VP mot.)	NEDC	2
				RPM	2
	HC	VP faible/forte motorisation urbain	Cycle (VP mot.)	NEDC	27
	CO	VP faible/forte motorisation route	NEDC	Free	39
				RPM	25

Table 8: Synthesis of the T-Test analysis per pollutant and per driving cycle. The strategy A is more polluting than the strategy B with a probality of 95%..

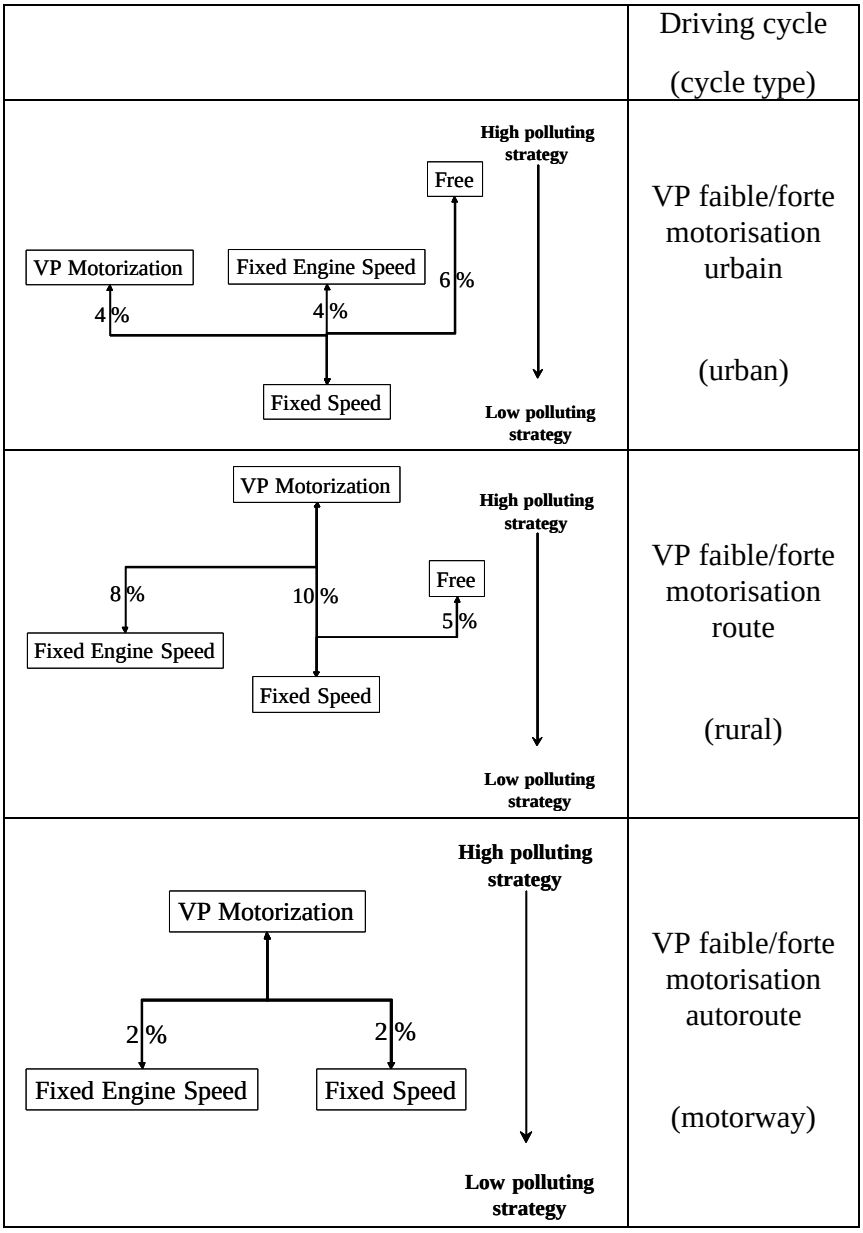


Figure 5: Classification of the gearshift strategies for CO_2 for the PNR-Ademe data. 'Fixed Engine Speed' and 'Fixed Speed' strategies are 'RPM' and 'NEDC' ones.

For the PNR-Ademe data, the Figure 5 shows that the most polluting strategy for CO_2 is the 'Cycle (VP Motorization)' one on road and motorway cycles. For the urban cycle, the 'free' strategy seems to be the most polluting one. In all the cases the 'NEDC' strategy is the less polluting strategy; it is less visible on motorway cycles because there are not a lot of gearshift changes. The ratio between the most and the less polluting strategies varies between 2 and 10 %.

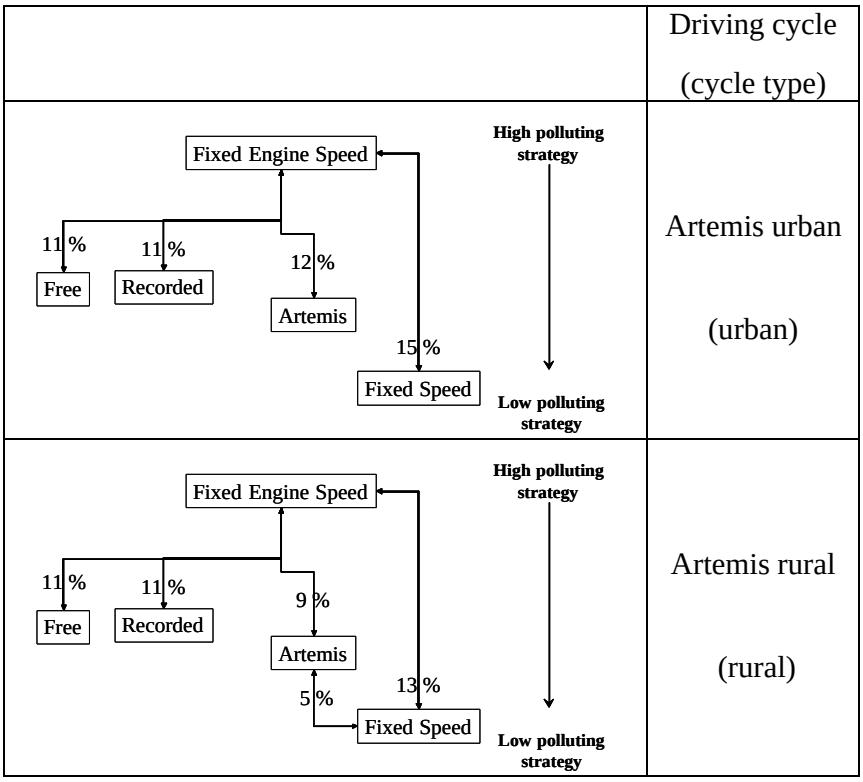


Figure 6: Classification of the strategies according to the CO_2 for the Artemis data.

For the Artemis data, the Figure 6 shows that the most polluting strategy for CO_2 is the 'RPM' one. The two graphs (Figure 5 and Figure 6) have the same look (the same strategies at the same place with the same values between the strategies). The ratio between the most and the less polluting strategies varies between 13 and 15 %.

Conclusion

Different gearshift strategies are developed in order to characterise the potential influence of such a parameter on emissions, meeting criteria of representativity, adaptation to the vehicle and comparability between the vehicles. We use 5 types of gearshift strategy: a 'cycle' strategy depending on the vehicle characteristics, a fixed speed strategy, a fixed engine speed strategy, a record strategy using gearshift as recorded in the data base, and a free strategy, up to the laboratory driver.

From driving behaviour point of view, the strategies defined from set values (RPM or fixed engine speed, NEDC or fixed speed) proved to be poorly adapted to actual cycles, as they did not enable to anticipate the speed curve as a driver does. In general, they involve a very high number of gearshifts and are far from real-world strategies, in particular in the deceleration phases. The fixed speed strategy corresponds to a gentle driving but with frequent gearshifts, and the fixed engine speed strategy corresponds to a very aggressive strategy. Nevertheless none of them is representative of a realistic behaviour. This led us to define a maximum range for the strategy impact on emissions

The data are from two different sources: the Artemis project, which uses 2 Artemis cycles and 5 different gearshift strategies, and the PNR-Ademe project, which uses new cycles (designed from the same data base than the Artemis cycles, but depending on the vehicle characteristics) and 4 strategies. All the driving cycles are real-world ones.

Using a T-test shows the statistically significant differences between the strategies. CO_2 is the pollutant the most sensitive to the strategy, with a systematic emission variation between strategies, going from 2 to 15 %. The other pollutants show sometimes significant differences. For CO, significant differences (25 - 39 %) are between the fixed speed stategy from one side, and the fixed engine speed and free strategies from other side. For HC the significant difference appears between the 'fixed speed' and the 'cycle (VP motorization)' strategies (27 %). NOx is never influenced by the gearshift strategy.

It is therefore possible to classify the gearshift strategies according to their CO_2 emission (the only pollutant always influenced by the strategy), for the different data sets. For the PNR-Ademe data set the most polluting strategy is the 'cycle (VP motorization)' strategy on rural and motorway driving cycles and the 'free' strategy on the urban cycle. For the Artemis data set the most polluting strategy is the 'fixed engine speed' (so-called 'RPM') whatever the cycle. For the two data sets the less polluting strategy seems to be the 'fixed speed' (so-called 'NEDC') one.

Such a classification is not possible for the other pollutants. A first reason is the too low size of the vehicle sample, as the sample size is a higher significant parameter than the gearshift strategy. A second reason is the emission level, which is often near the detection limit of the analysers.

The strategy impact remains nevertheless relatively low as soon as realistic patterns are selected.

Annex 1 – List of tested vehicles

Artemis study	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4	Vehicle 5	Vehicle 6
Model	Renault Mégane Coupé	Peugeot 406 SL	Citroën ZX	Renault Clio 1.9D	Suzuki Swift 1.3 GLX	Ford Mondeo 1.8 TD SW
Weight (kg)	1060	1275	895	995	830	1345
Engine speed at maximum power (rpm)	5730	5500	5800	4500	6000	4500
Power (kW)	79	81	55	47	99	65
Power to mass ratio (W/kg)	47.5	63.5	61.4	47.2	119.3	48.3
Speed at 1000 rpm in 3rd gear (km/h)	21.06	22.37	18.8	22.68	22.87	21.11
Engine capacity (cm^3)	1597	1762	1361	1870	1298	1753
Year of first registration	2000	1995	1996	1999	2001	1996
Fuel	gasoline	gasoline	gasoline	diesel	gasoline	diesel
Standard Emission	Euro 2	Euro 1	Euro 1	Euro 2	Euro 2	Euro 2
Laboratory	INRETS	INRETS	INRETS	INRETS	KTI	KTI
Laboratory chronological number	390	389	392	391	501/0387/A	501/0387/C
Study	Artemis	Artemis	Artemis	Artemis	Artemis	Artemis
Artemis cycles used	yes	yes	yes	yes	yes	yes
VP motorization cycles used	no	no	no	no	no	no
'Cycle' gearshift strategy	Artemis 1	Artemis 2	Artemis 3	Artemis 4	Artemis 2	Artemis 4

PNR-Ademe study	Vehicle 7	Vehicle 8	Vehicle 9	Vehicle 10	Vehicle 11	Vehicle 12
Model	Rover 414 I	Renault Clio 1.2L	Renault Scenic 1.6 16s	Peugeot 307 HDI	Ford Fiesta 1.8 L	Peugeot 206 XR
Weight (kg)	1100	845	1250	1260	925	910
Engine speed at maximum power (rpm)	6000	6000	5750	4000	4800	5500
Power (kW)	76	43	79	66	44	44
Power to mass ratio (W/kg)	69.1	50.9	63.2	52.4	47.6	48.3
Speed at 1000 rpm in 3rd gear (km/h)	20,45	20,7	21,06	25,6	21,58	18,95
Engine capacity (cm^3)	1396	1171	1598	1997	1753	1124
Year of first registration	1997	1995	2001	2001	1995	2001
Fuel	gasoline	gasoline	gasoline	Diesel	Diesel	gasoline
Standard Emission	Euro 2	Euro 1	Euro 3	Euro 3	Euro 1	Euro 3
Laboratory	INRETS	INRETS	INRETS	INRETS	INRETS	INRETS
Laboratory chronological number	417	418	420	421	422	423
Study	PNR-Ademe	PNR-Ademe	PNR-Ademe	PNR-Ademe	PNR-Ademe	PNR-Ademe
Artemis cycles used	no	no	no	no	no	no
VP motorization cycles used	VP forte motorisation	VP faible motorisation	VP forte motorisation	VP faible motorisation	VP faible motorisation	VP faible motorisation
'Cycle' gearshift strategy	VP motorization 2	VP motorization 3	VP motorization 2	VP motorization 4	VP motorization 4	VP motorization 3

PNR-Ademe study	Vehicle 13	Vehicle 14	Vehicle 15
Model	Volkswagen Passat TDI	Peugeot 206 D	Fiat Brava 1.9L D
Weight (kg)	1437	1009	1130
Engine speed at maximum power (rpm)	4000	4600	4600
Power (kW)	85	51	48
Power to mass ratio (W/kg)	59.1	50.5	42.5
Speed at 1000 rpm in 3rd gear (km/h)	18,15	23,44	20,78
Engine capacity (cm^3)	1896	1868	1929
Year of first registration	2000	1999	1996
Fuel	Diesel	Diesel	Diesel
Standard Emission	Euro 2	Euro 2	Euro 1
Laboratory	INRETS	INRETS	INRETS
Laboratory chronological number	425	426	427
Study	PNR-Ademe	PNR-Ademe	PNR-Ademe
Artemis cycles used	no	no	no
VP motorization cycles used	VP faible motorisation	VP faible motorisation	VP faible motorisation
'Cycle' gearshift strategy	VP motorization 4	VP motorization 3	VP motorization 4

Annex 2 – Rule of determination of the vehicle category in the 'cycle' strategy

Before testing a car with an *Artemis*, *VP faible motorisation* or *VP forte motorisation* cycle, it is necessary to determine the vehicle category to identify the cycle gearshift strategy to be applied. Therefore, from the following variables :

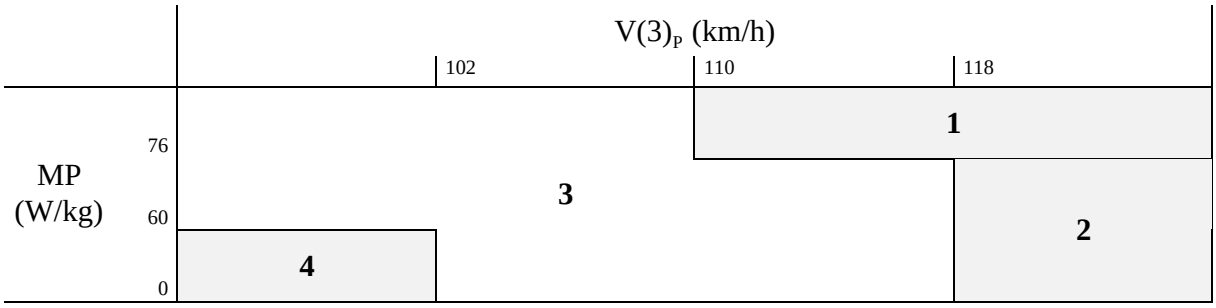
- P : maximal power of the car (kW).
- M : empty mass (kg)
- $V(3)_{1000}$: vehicle speed at 1000 rpm in the 3rd ratio (km/h)
- rpm : engine speed at the maximal power.

the 2 following parameters are calculated (with the right units):

- $MP = P/M$ — the vehicle massic power, in (W/kg)
- $V(3)_P = V(3)_{1000} * rpm / 1000$ — the vehicle speed at the maximum power, in 3rd ratio, in (km/h)

The strategy determination is done as follows :

If:	And:	Then choose strategy:
MP > 76 W/kg	$V(3)_P$ > 110 km/h	1
MP < 76	$V(3)_P$ > 118	2
MP < 60	$V(3)_P$ < 102	4
In all other cases,		3



For the different driving cycles, the 'cycle' strategies are called:

- "Artemis" cycles: strategies Artemis 1, Artemis 2, Artemis 3 and Artemis 4.
- "VP faible motorisation" cycles: strategies VP faible motorisation 1, VP faible motorisation 2, VP faible motorisation 3 and VP faible motorisation 4.
- "VP forte motorisation" cycles: strategies VP forte motorisation 1, VP forte motorisation 2, VP forte motorisation 3 and VP forte motorisation 4.

Annex 3 – Gearshifts statistics

Stategy	Cycle (Artemis)						NEDC	Record	RPM					
Vehicle Nb	1	2	3	4	5	6	1 to 6	1 to 6	1	2	3	4	5	6
Shifting from Neutral to 1st gear														
Nb of Shifts	27	26	28	27	26	27	27	26	44	45	44	47	45	43
Av. Speed	0,3	0,6	0,6	0,4	0,6	0,4	0,9	1,4	2,2	2,8	2,2	3,1	2,8	2,2
Shifting from 1st to 2nd gear														
Nb of Shifts	19	18	19	18	18	18	26	18	16	18	21	24	16	22
Av. Speed	23,9	19,6	20,5	17,8	19,6	17,8	14,6	17,40	33,5	32,8	28,8	27,6	37,4	22,4
Shifting from 2nd to 3rd gear														
Nb of Shifts	14	11	16	19	11	19	27	19	3	3	3	5	4	16
Av. Speed	45,4	39,2	44,6	37,5	39,2	37,5	36,1	37,2	61,4	61,4	57,0	52,8	68,1	42,0
Shifting from 3rd to 4th gear														
Nb of Shifts	8	8	6	9	8	9	11	10	1	1	2	4	1	4
Av. Speed	61,8	61,2	59,8	55,7	61,2	55,7	55,9	58,0	90,3	90,3	81,1	74,8	100,9	70,0
Shifting from 4th to 5th gear														
Nb of Shifts	1	1	0	2	1	2	3	3	0	0	1	1	0	1
Av. Speed	98,2	104,4		95,7	104,4	95,7	93,9	92,9			106,2	96,4		103,2
Shifting from 5th to 4th gear														
Nb of Shifts	1	1	0	2	1	2	3	3	0	0	1	1	0	1
Av. Speed	88,4	80,1		77,0	80,1	77,0	79,5	75,4			56,9	56,9		63,4
Shifting from 4th to 3rd gear														
Nb of Shifts	8	8	6	8	8	8	10	8	1	1	2	4	1	4
Av. Speed	52,6	50,3	57,5	56,2	50,3	56,2	51,5	51,6	41,0	46,8	40,0	45,8	56,9	50,8
Shifting from 3rd to 2nd gear														
Nb of Shifts	11	7	12	12	7	12	24	11	3	3	3	5	4	16
Av. Speed	33,4	32,2	32,3	27,6	32,2	27,6	38,9	34,9	33,9	37,1	29,5	35,1	37,5	34,7
Shifting from 2nd to 1st gear														
Nb of Shifts	7	5	5	2	5	2	23	3	15	17	20	23	15	20
Av. Speed	13,1	12,7	12,7	8,6	12,7	8,6	13,6	15,1	24,6	25,8	23,1	26,6	27,0	22,2
Shifting from 1st to Neutral gear														
Nb of Shifts	15	14	14	12	14	12	24	14	43	44	43	46	44	41
Av. Speed	5,8	6,1	6,5	5,5	6,1	5,5	2,03	5,4	10,1	10,5	9,3	11,6	11,5	9,4
Shifting from 2nd to Neutral gear														
Nb of Shifts	9	9	10	9	9	9	1	8	1	1	1	1	1	2
Av. Speed	27,1	24,4	22,1	19,0	24,4	19,0	18,7	21,5	13,9	13,9	1,5	13,9	13,9	14,9
Shifting from 3rd to Neutral gear														
Nb of Shifts	3	3	4	5	3	5	2	3	0	0	0	0	0	0
Av. Speed	42,0	39,3	40,5	40,2	39,3	40,2	35,3	29,9						
Total Nb of Shifts	**123**	**111**	**120**	**125**	**111**	**125**	**181**	**126**	**127**	**133**	**141**	**161**	**131**	**170**

Table 9: Average speed (km/h) and number of shifts for each gearshift type versus various strategies for urban + road Artemis cycles.

Stategy	Cycle (VP Motorization)									NEDC									RPM								
Vehicle Nb	7	8	9	10	11	12	13	14	15	7	8	9	10	11	12	13	14	15	7	8	9	10	11	12	13	14	15
Shifting from Neutral to 1st gear																											
Nb of Shifts	25	27	25	28	28	27	28	27	28	25	22	25	22	22	22	22	22	22	33	37	32	37	38	37	37	38	37
Av. Speed	0	0,80	0,45	0,94	0,94	0,80	0,94	0,80	0,94	0	0	0	0	0	0	0	0	0	1,40	1,48	0,63	1,48	1,62	1,48	1,50	1,62	1,48
Shifting from 1st to 2nd gear																											
Nb of Shifts	21	21	21	22	22	21	22	21	22	25	26	25	26	26	26	26	26	26	16	21	16	20	18	21	19	19	20
Av. Speed	22,9	18,1	21,8	18,5	18,5	18,1	18,5	18,1	18,5	11,8	12,0	11,8	12,0	12,0	12,0	12,0	12,0	12,0	34,3	30,2	35,1	36,4	38,0	29,9	26,2	36,8	32,8
Shifting from 2nd to 3rd gear																											
Nb of Shifts	16	21	16	19	19	21	19	21	19	23	28	23	28	28	28	28	28	28	5	6	5	6	6	5	11	6	6
Av. Speed	49,3	40,5	47,5	34,5	34,5	40,5	34,5	40,5	34,5	32,8	33,6	32,8	33,6	33,6	33,6	33,6	33,6	33,6	60,9	58,4	64,8	69,7	63,3	58,9	50,3	70,3	58,6
Shifting from 3rd to 4th gear																											
Nb of Shifts	8	13	8	15	15	13	15	13	15	21	24	21	24	24	24	24	24	24	2	3	2	2	3	3	3	3	3
Av. Speed	80,1	65,9	71,1	56,8	56,8	65,9	56,8	65,9	56,8	48,7	48,8	48,7	48,8	48,8	48,8	48,8	48,8	48,8	90,2	92,2	94,0	115,2	96,4	83,9	80,8	105,0	92,2
Shifting from 4th to 5th gear																											
Nb of Shifts	2	2	2	3	3	2	3	2	3	13	10	13	10	10	10	10	10	10	1	1	1	0	2	3	2	1	2
Av. Speed	109,4	102,2	109,4	95,7	95,7	102,2	95,7	102,2	95,7	69,0	69,5	69,0	69,5	69,5	69,5	69,5	69,5	69,5	115,6	134,1	121,2		130,0	110,7	112,8	142,1	130,0
Shifting from 5th to 4th gear																											
Nb of Shifts	2	2	2	3	3	2	3	2	3	13	10	13	10	10	10	10	10	10	1	1	1	0	2	3	2	1	2
Av. Speed	81,7	67,3	81,7	71,3	71,3	67,3	71,3	67,3	71,3	70,7	70,9	70,7	70,9	70,9	70,9	70,9	70,9	70,9	49,4	49,8	54,9		55,6	49,3	50,2	60,1	57,1
Shifting from 4th to 3rd gear																											
Nb of Shifts	7	12	7	11	11	12	11	12	11	21	24	21	24	24	24	24	24	24	2	3	2	2	3	3	3	3	3
Av. Speed	62,4	50,6	55,6	46,9	46,9	50,6	46,9	50,6	46,9	51,2	51,6	51,2	51,6	51,6	51,6	51,6	51,6	51,6	40,1	45,4	43,7	55,6	44,5	40,1	40,1	49,3	44,5

Stategy	VP Motorization									NEDC									RPM								
Vehicle Nb	7	8	9	10	11	12	13	14	15	7	8	9	10	11	12	13	14	15	7	8	9	10	11	12	13	14	15
Shifting from 3rd to 2nd gear																											
Nb of Shifts	8	11	8	5	5	11	5	11	5	23	28	23	28	28	28	28	28	28	4	6	5	6	6	5	11	6	6
Av. Speed	36,02	35,42	33,50	34,27	34,27	35,42	34,27	35,42	34,27	38,2	37,2	38,2	37,2	37,2	37,2	37,2	37,2	37,2	33,5	34,7	33,6	41,9	34,8	28,8	29,6	38,6	34,7
Shifting from 2nd to 1st gear																											
Nb of Shifts	2	1	2	0	0	1	0	1	0	25	26	25	26	26	26	26	26	26	15	21	16	20	18	21	19	19	20
Av. Speed	12,3	13,5	12,2			13,5		13,5		18,4	17,1	18,4	17,1	17,1	17,1	17,1	17,1	17,1	22,8	21,2	24,9	25,9	24,8	22,5	19,1	26,4	22,8
Shifting from 1st to Neutral gear																											
Nb of Shifts	7	6	7	6	6	6	6	6	6	25	22	25	22	22	22	22	22	22	33	37	32	37	38	37	37	38	37
Av. Speed	4,7	4,4	4,2	4,5	4,5	4,4	4,5	4,4	4,5	1,7	1,3	1,7	1,3	1,3	1,3	1,3	1,3	1,3	10,4	8,9	11,7	11,7	11,6	9,3	8,2	12,0	9,3
Shifting from 2nd to Neutral gear																											
Nb of Shifts	11	10	11	8	8	10	8	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Av. Speed	25,5	17,4	26,4	14,6	14,6	17,4	14,6	17,4	14,6																		
Shifting from 3rd to Neutral gear																											
Nb of Shifts	6	10	6	10	10	10	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Av. Speed	41,9	34,8	38,6	32,6	32,6	34,8	32,6	34,8	32,6																		
Total Nb of Shift	**115**	**136**	**115**	**130**	**130**	**136**	**130**	**136**	**130**	**214**	**220**	**214**	**220**	**220**	**220**	**220**	**220**	**220**	**112**	**136**	**112**	**130**	**134**	**138**	**144**	**134**	**136**

Table 10: Average speed (km/h) and number of shifts for each gearshift type versus various strategies for urban + road + motorway VP motorization cycles (VP faible/forte motorisation urbain, route, autoroute).

Annex 4 – Measurement results: emission factors (g/km)

Vehicle			1: Renault Mégane Coupé 1.6		2: Peugeot 406 1.8l		3: Citroen ZX 1.4i		4: Renault Clio 1.9D		5: Suzuki Swift 1.3 GLX		6: Ford Mondeo 1.8 TD SW	
Pollutant	Gearbox strategy	Artemis driving cycle	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
CO	Cycle (Artemis)		0.004	0.032	5.520	9.380	0.210	0.846	0.039	0.172	5.990	4.060	0.040	0.100
	NEDC (fixed speed)		0.009	0.029	4.410	11.300	0.265	1.590	0.043	0.258	10.500	7.720	0.040	0.240
	RPM (fixed engine speed)		0.002	0.007	5.410	10.400	0.417	1.430	0.144	0.700	4.270	2.710	0.050	0.260
	Record		0.005	0.007	4.370	10.800	0.516	1.620	0.060	0.418	6.910	5.680	0.040	0.230
	Free		0.009	0.007	5.580	9.890	0.372	1.500	0.017	0.313	5.320	2.270	0.040	0.200
	Average		0.006	0.016	5.060	10.350	0.356	1.400	0.061	0.372	6.600	4.490	0.042	0.206
	Standard deviation		0.003	0.013	0.611	0.760	0.122	0.317	0.049	0.204	2.390	2.240	0.004	0.063
CO_2	Cycle (Artemis)		137	249	150	274	145	227	134	219	113	163	138	182
	NEDC (fixed speed)		138	246	138	270	131	234	134	204	106	158	131	217
	RPM (fixed engine speed)		161	267	163	296	156	267	146	239	130	173	145	257
	Record		142	244	142	269	142	226	122	212	110	154	146	233
	Free		151	235	144	261	136	229	130	207	112	159	133	185
	Average		146	248	147	274	142	237	133	216	114	161	138	215
	Standard deviation		10	12	9	13	9	17	9	14	9	7	7	32
HC	Cycle (Artemis)		0.003	0.006	1.300	2.430	0.024	0.058	0.015	0.021	0.050	0.135	0.005	0.010
	NEDC (fixed speed)		0.003	0.006	1.030	2.870	0.025	0.088	0.009	0.022	0.160	0.450	0.004	0.021
	RPM (fixed engine speed)		0.004	0.011	1.340	3.190	0.037	0.124	0.026	0.080	0.045	0.066	0.006	0.054
	Record		0.003	0.012	1.110	2.920	0.030	0.076	0.012	0.038	0.078	0.252	0.007	0.037
	Free		0.004	0.009	1.170	2.960	0.032	0.074	0.009	0.028	0.090	0.060	0.006	0.035
	Average		0.003	0.009	1.190	2.870	0.030	0.084	0.014	0.038	0.084	0.193	0.006	0.031
	Standard deviation		0.001	0.003	0.128	0.276	0.005	0.025	0.007	0.025	0.046	0.163	0.001	0.017
NOx	Cycle (Artemis)		0.29	0.53	2.66	2.53	0.08	0.16	0.47	0.90	0.03	0.04	0.51	0.45
	NEDC (fixed speed)		0.46	0.80	2.14	2.37	0.10	0.17	0.44	0.82	0.03	0.04	0.48	0.66
	RPM (fixed engine speed)		0.26	0.60	2.72	3.38	0.09	0.11	0.71	1.15	0.03	0.05	0.56	0.80
	Record		0.36	0.78	2.27	2.56	0.15	0.25	0.58	0.89	0.03	0.04	0.55	0.68
	Free		0.46	0.80	2.15	2.58	0.17	0.25	0.55	0.80	0.03	0.03	0.48	0.57
	Average		0.37	0.70	2.39	2.68	0.12	0.19	0.55	0.91	0.03	0.04	0.52	0.63
	Standard deviation		0.09	0.13	0.28	0.40	0.04	0.06	0.10	0.14	0.00	0.01	0.04	0.13

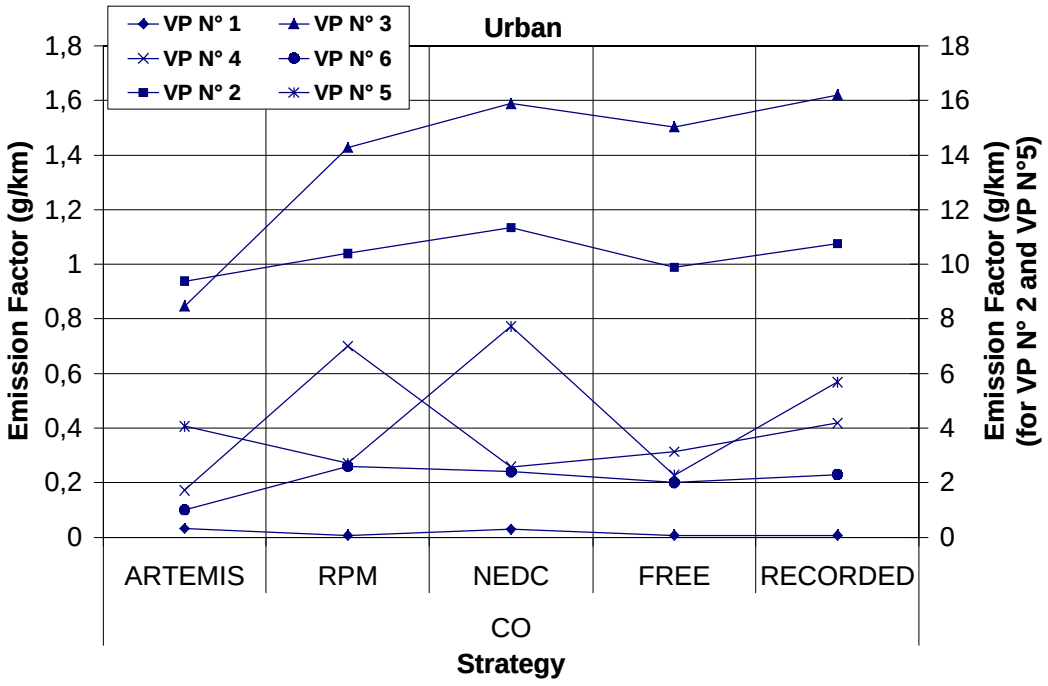
Vehicle			7: Rover 414 I			8; Renault Clio 1.2L			9: Renault Scenic 1.6 16s		
Pollutant	Gearbox strategy	VP faible/forte motorisation cycle	Motorway	Rural	Urban	Motorway	Rural	Urban	Motorway	Rural	Urban
CO	Cycle (VP motorization)		0.39	0.22	0.16	4.05	3.85	4.91	0.58	0.52	0.02
	NEDC (fixed speed)		0.37	1.03	0.89	3.11	4.31	6.80	1.97	0.74	0.02
	RPM (fixed engine speed)		0.83	0.13	0.26	2.50	3.99	4.95	0.76	0.21	0.00
	Free		0.51	0.22	0.37	3.15	3.38	4.20	0.92	0.18	0.01
	Average		0.52	0.40	0.42	3.20	3.88	5.21	1.06	0.41	0.01
	Standard deviation		0.21	0.42	0.32	0.64	0.39	1.11	0.62	0.27	0.01
CO_2	Cycle (VP motorization)		189	154	233	158	121	187	207	164	238
	NEDC (fixed speed)		187	145	218	159	115	180	207	155	237
	RPM (fixed engine speed)		190	151	239	160	120	192	195	155	243
	Free		185	149	239	167	124	192	203	151	228
	Average		187	150	232	161	120	188	203	156	236
	Standard deviation		2	4	10	4	4	6	6	6	6
HC	Cycle (VP motorization)		0.027	0.020	0.037	0.097	0.136	0.278	0.008	0.029	0.012
	NEDC (fixed speed)		0.021	0.015	0.036	0.073	0.143	0.207	0.017	0.031	0.002
	RPM (fixed engine speed)		0.028	0.007	0.021	0.070	0.154	0.179	0.010	0.010	0.003
	Free		0.030	0.027	0.051	0.080	0.112	0.179	0.011	0.009	0.003
	Average		0.027	0.017	0.036	0.080	0.136	0.211	0.012	0.020	0.005
	Standard deviation		0.004	0.008	0.012	0.012	0.018	0.047	0.004	0.012	0.005
NOx	Cycle (VP motorization)		0.04	0.08	0.08	0.61	0.25	0.21	0.07	0.14	0.27
	NEDC (fixed speed)		0.05	0.03	0.09	0.42	0.27	0.18	0.08	0.23	0.36
	RPM (fixed engine speed)		0.04	0.07	0.08	0.56	0.31	0.17	0.08	0.11	0.11
	Free		0.04	0.10	0.12	0.63	0.25	0.12	0.09	0.09	0.12
	Average		0.04	0.07	0.09	0.56	0.27	0.17	0.08	0.14	0.22
	Standard deviation		0.00	0.03	0.02	0.10	0.03	0.04	0.01	0.06	0.12

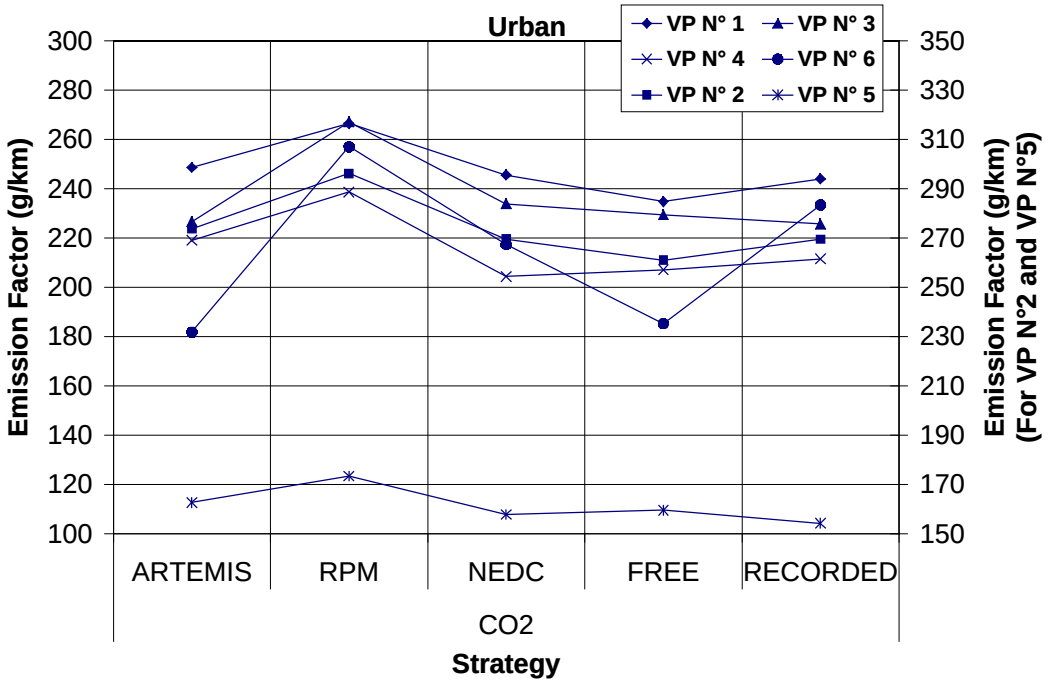
Vehicle			10: Peugeot 307 HDI			11: Ford Fiesta 1.8 L			12 : Peugeot 206 XR		
Pollutant	Gearbox strategy	VP faible/forte motorisation cycle	Motorway	Rural	Urban	Motorway	Rural	Urban	Motorway	Rural	Urban
CO	Cycle (VP motorization)		0.01	0.00	0.01	0.19	0.24	0.34	4.15	1.49	0.29
	NEDC (fixed speed)		0.01	0.00	0.01	0.18	0.23	0.36	1.89	3.04	0.36
	RPM (fixed engine speed)		0.01	0.02	0.06	0.18	0.20	0.48	2.10	2.55	0.13
	Free		0.01	0.01	0.09	0.18	0.25	0.44	3.96	1.57	0.03
	Average		0.01	0.01	0.04	0.18	0.23	0.41	3.02	2.16	0.20
	Standard deviation		0.00	0.01	0.04	0.00	0.02	0.07	1.19	0.76	0.15
CO_2	Cycle (VP motorization)		184	137	189	162	122	175	185	158	215
	NEDC (fixed speed)		182	127	179	161	120	176	178	146	219
	RPM (fixed engine speed)		178	125	185	158	117	173	184	147	220
	Free		179	135	200	159	121	187	184	157	224
	Average		181	131	188	160	120	178	183	152	220
	Standard deviation		3	6	9	2	2	6	3	6	4
HC	Cycle (VP motorization)		0.006	0.012	0.032	0.013	0.018	0.035	0.110	0.033	0.039
	NEDC (fixed speed)		0.004	0.006	0.013	0.011	0.018	0.029	0.039	0.058	0.029
	RPM (fixed engine speed)		0.007	0.006	0.024	0.014	0.020	0.040	0.045	0.074	0.024
	Free		0.005	0.011	0.048	0.010	0.015	0.030	0.079	0.044	0.016
	Average		0.006	0.009	0.029	0.012	0.018	0.034	0.068	0.052	0.027
	Standard deviation		0.001	0.003	0.015	0.002	0.002	0.005	0.033	0.018	0.010
NOx	Cycle (VP motorization)		1.29	0.65	0.85	0.72	0.54	0.90	0.39	0.28	0.18
	NEDC (fixed speed)		1.31	0.75	0.91	0.74	0.51	0.86	0.39	0.22	0.15
	RPM (fixed engine speed)		1.21	0.70	0.87	0.73	0.52	0.85	0.31	0.28	0.21
	Free		1.26	0.66	0.78	0.71	0.53	0.95	0.41	0.32	0.13
	Average		1.27	0.69	0.85	0.73	0.52	0.89	0.38	0.27	0.17
	Standard deviation		0.04	0.04	0.06	0.01	0.01	0.04	0.04	0.04	0.03

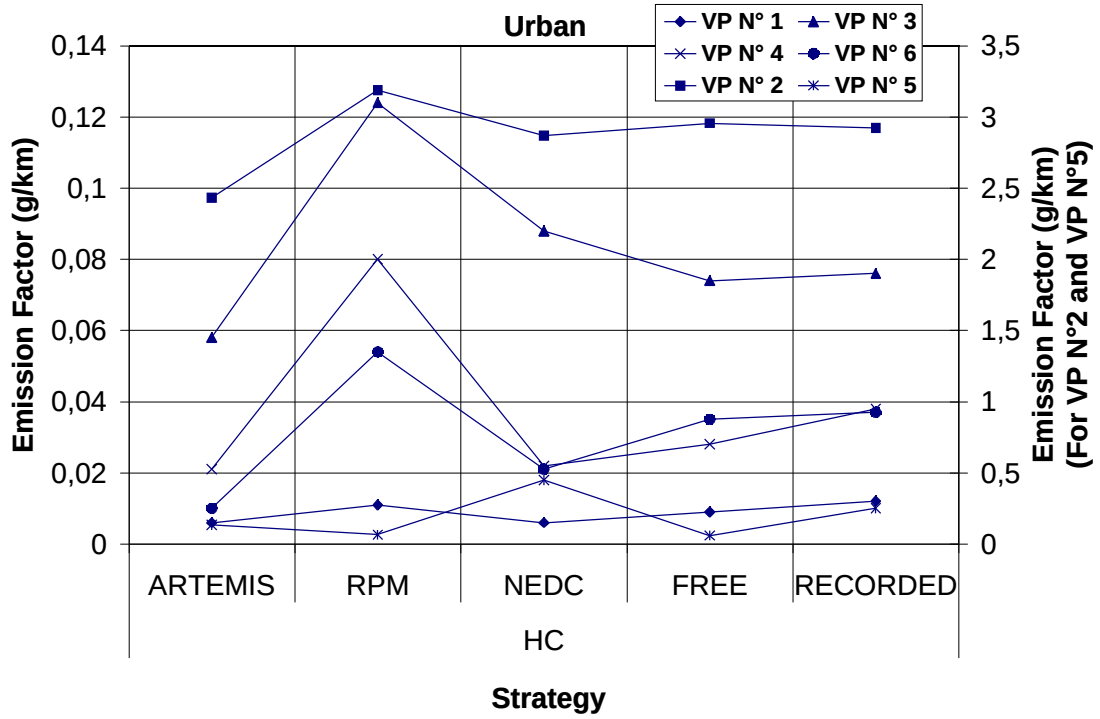
Vehicle			13: Volkswagen Passat TDI			14: Peugeot 206 D			15: Fiat Brava 1.9L D		
Pollutant	Gearbox strategy	VP faible/forte motorisation cycle	Motorway	Rural	Urban	Motorway	Rural	Urban	Motorway	Rural	Urban
CO	Cycle (VP motorization)		0.06	0.06	0.24	0.27	0.27	0.27	0.08	0.08	0.08
	NEDC (fixed speed)		0.07	0.15	0.30	0.27	0.27	0.27	0.08	0.08	0.08
	RPM (fixed engine speed)		0.07	0.10	0.07	0.08	0.08	0.08	0.08	0.08	0.08
	Free		0.05	0.08	0.25	0.08	0.08	0.08	0.08	0.08	0.08
	Average		0.06	0.10	0.22	0.17	0.17	0.17	0.08	0.08	0.08
	Standard deviation		0.01	0.04	0.10	0.11	0.11	0.11	0.00	0.00	0.00
CO_2	Cycle (VP motorization)		169	140	205	185	156	224	203	203	240
	NEDC (fixed speed)		165	133	198	177	131	198	189	156	242
	RPM (fixed engine speed)		169	136	197	181	138	217	198	162	236
	Free		168	147	228	185	150	211	200	156	248
	Average		168	139	207	182	144	213	198	169	242
	Standard deviation		2	6	14	4	11	11	6	23	5
HC	Cycle (VP motorization)		0.010	0.024	0.047	0.004	0.004	0.016	0.027	0.027	0.068
	NEDC (fixed speed)		0.008	0.014	0.029	0.003	0.013	0.007	0.019	0.025	0.078
	RPM (fixed engine speed)		0.010	0.009	0.024	0.003	0.006	0.026	0.023	0.034	0.060
	Free		0.008	0.010	0.045	0.002	0.007	0.010	0.022	0.030	0.062
	Average		0.009	0.014	0.036	0.003	0.008	0.015	0.023	0.029	0.067
	Standard deviation		0.001	0.007	0.012	0.001	0.004	0.008	0.003	0.004	0.008
NOx	Cycle (VP motorization)		1.19	0.65	0.87	0.81	0.59	0.95	0.90	0.90	0.83
	NEDC (fixed speed)		1.25	0.83	0.92	0.80	0.45	0.83	0.79	0.50	0.83
	RPM (fixed engine speed)		1.24	0.73	0.84	0.81	0.45	0.90	0.83	0.61	0.92
	Free		1.08	0.67	0.74	0.84	0.57	0.89	0.89	0.56	0.87
	Average		1.19	0.72	0.84	0.81	0.52	0.89	0.86	0.65	0.86
	Standard deviation		0.08	0.08	0.07	0.02	0.08	0.05	0.05	0.18	0.04

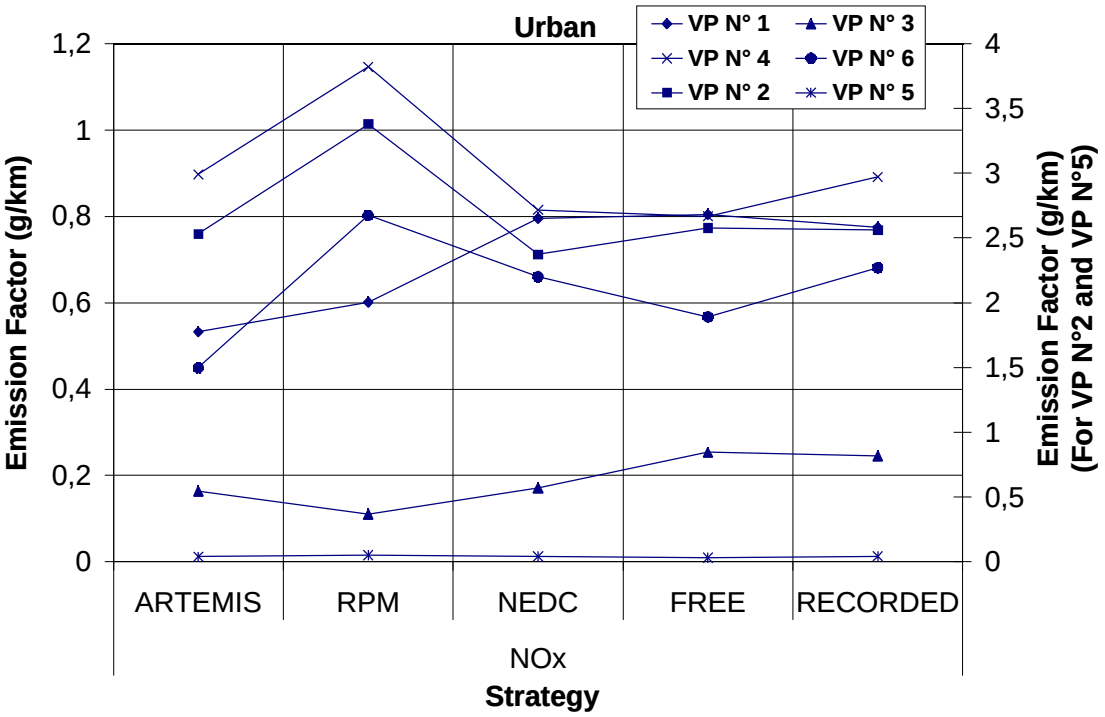
Annex 5 – Drawing of measurement results

Artemis study, 'Artemis urban' cycle

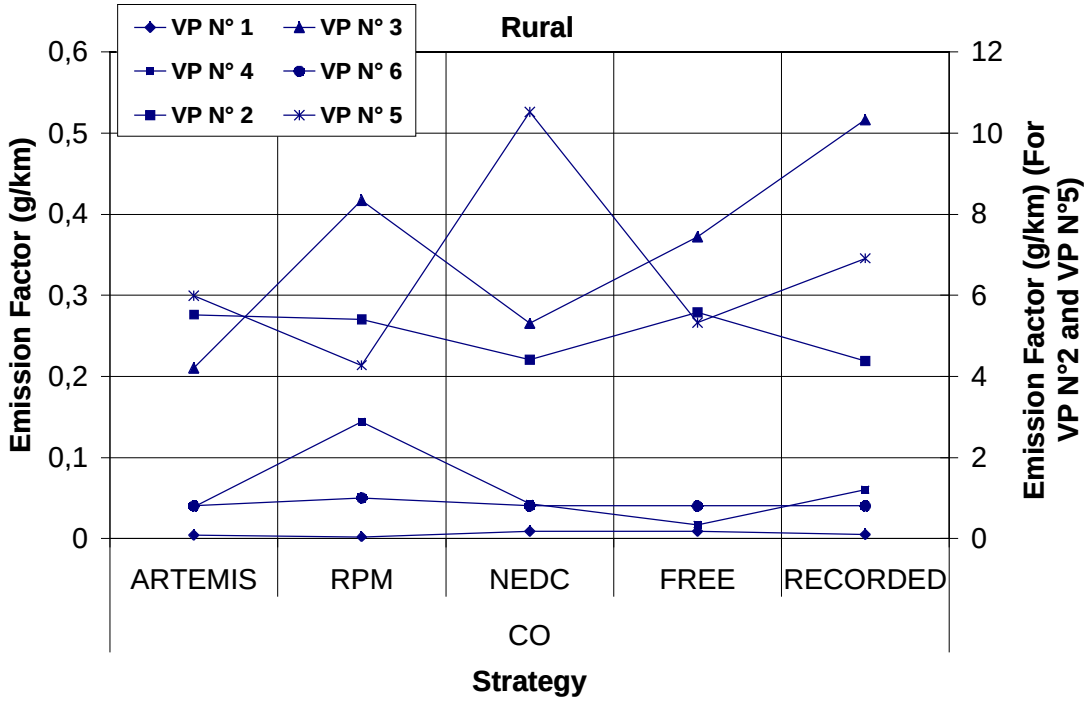


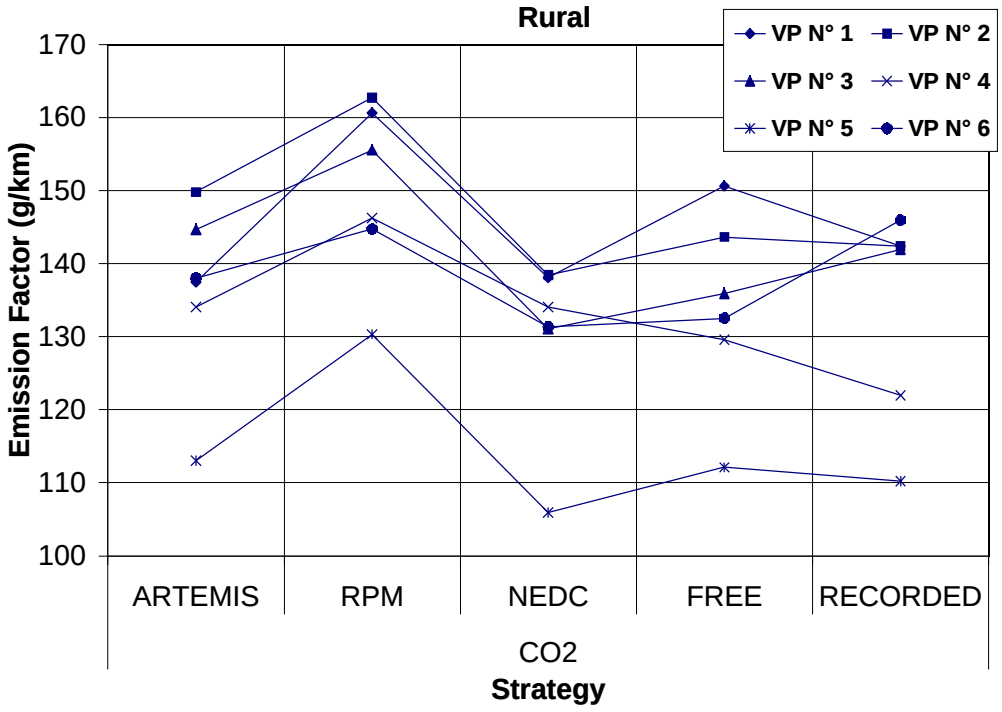


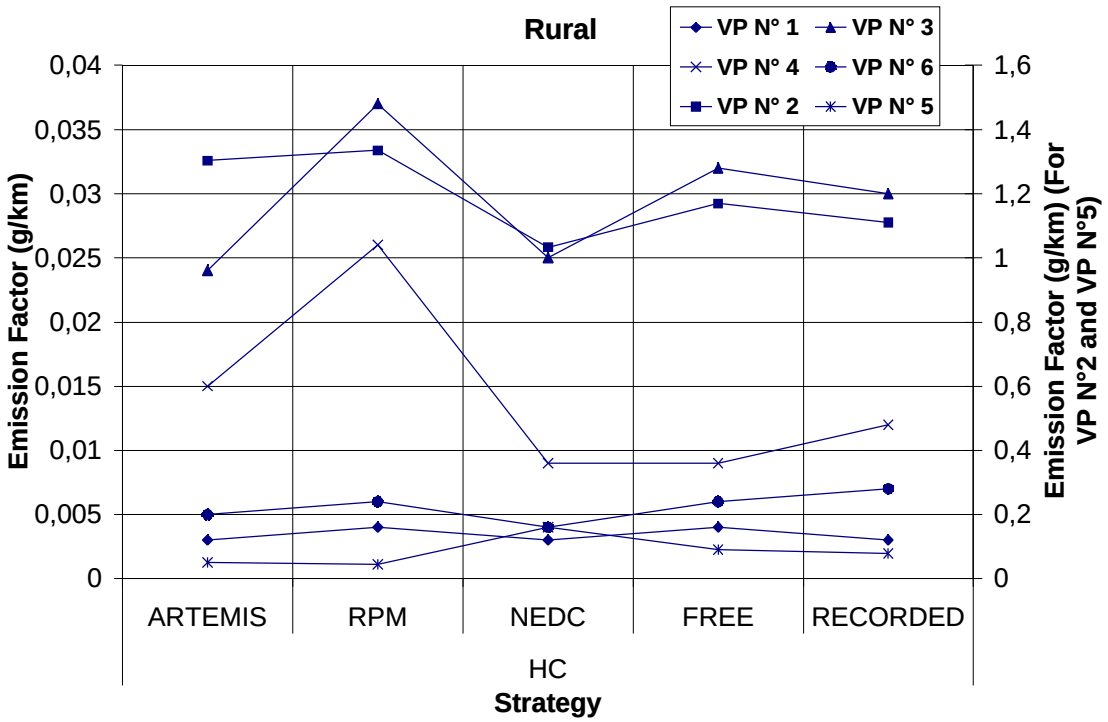


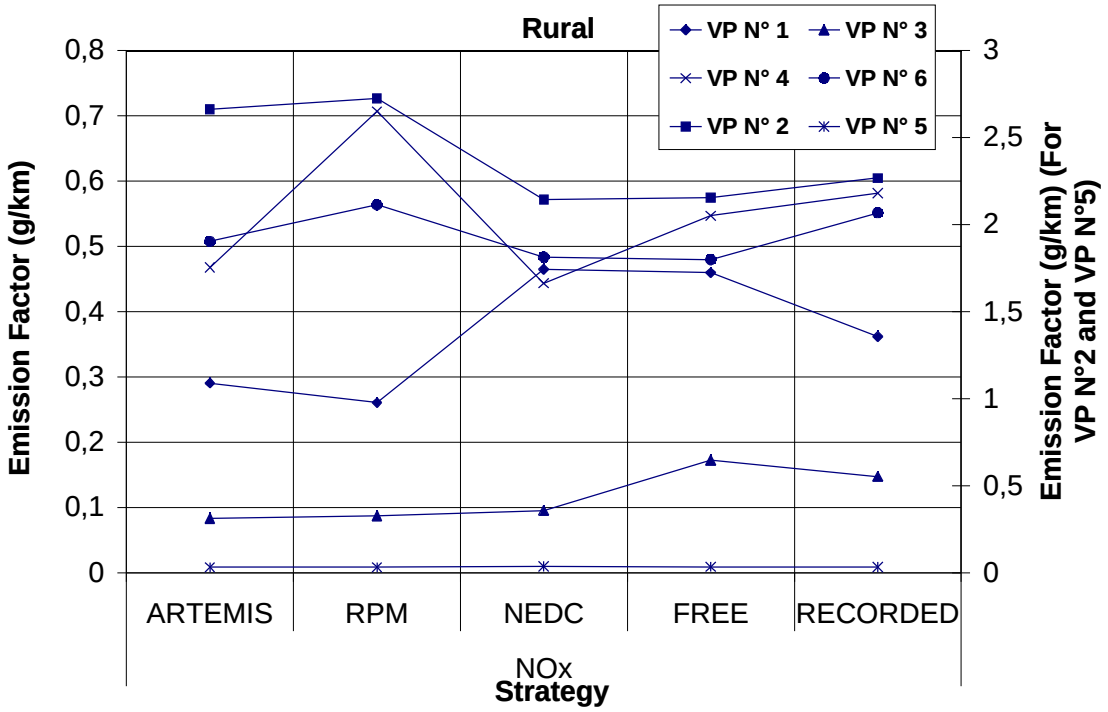


Artemis study, 'Artemis rural' cycle

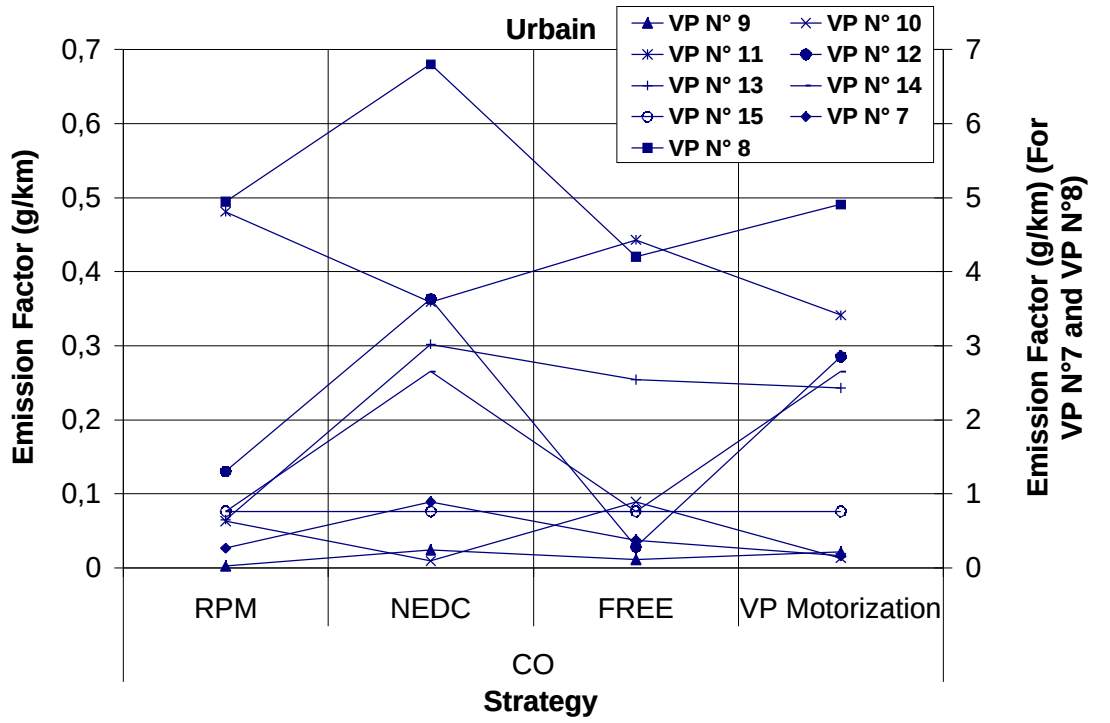


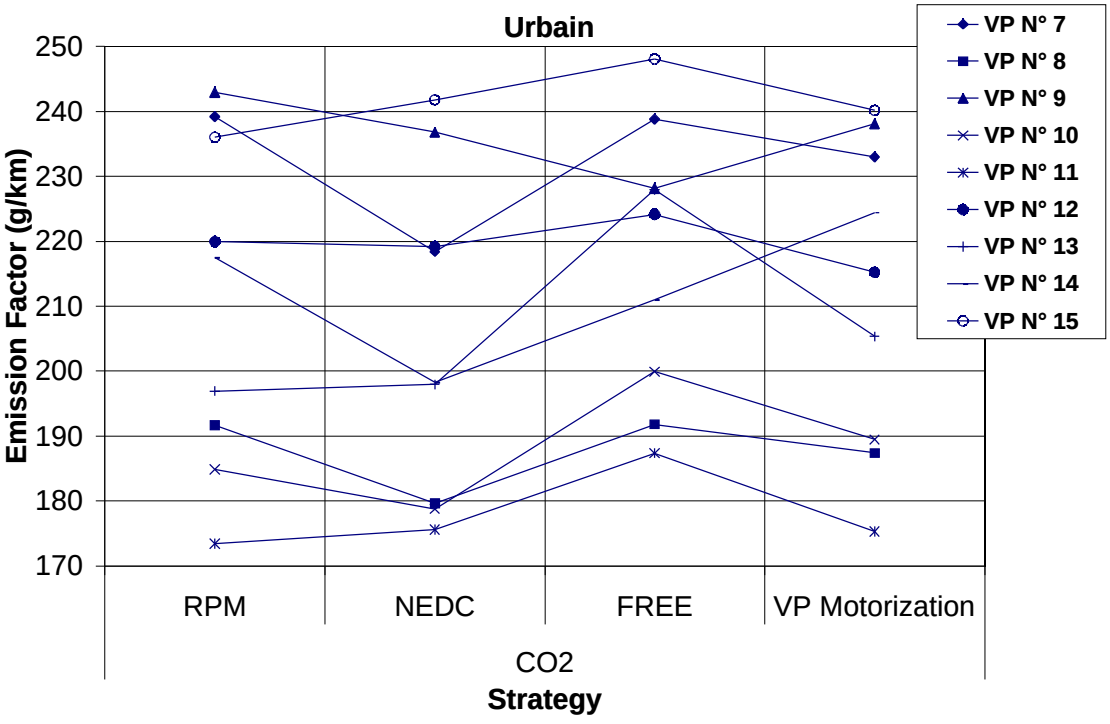


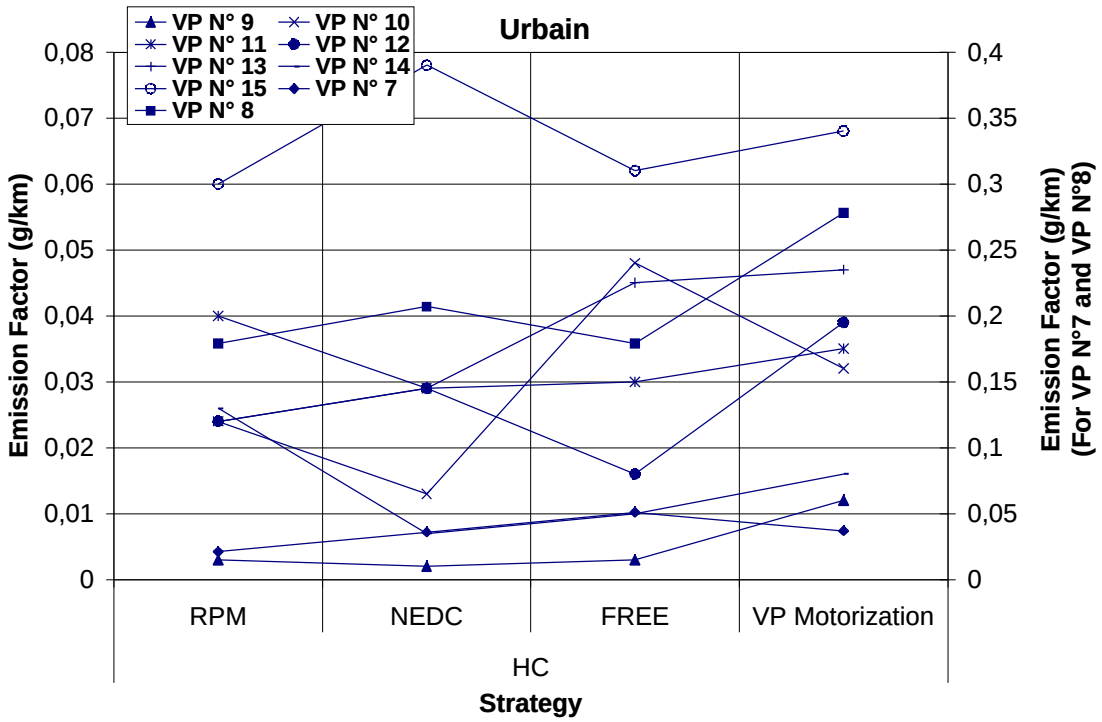


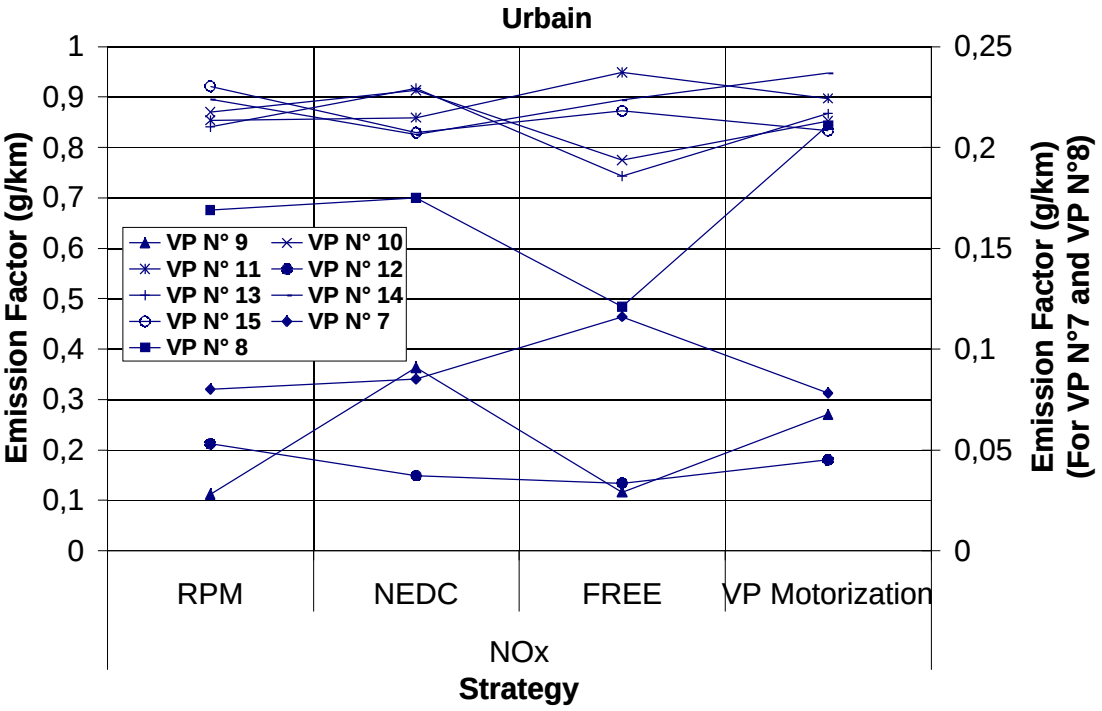


PNR-Ademe study, 'VP faible/forte motorisation urbain' cycle

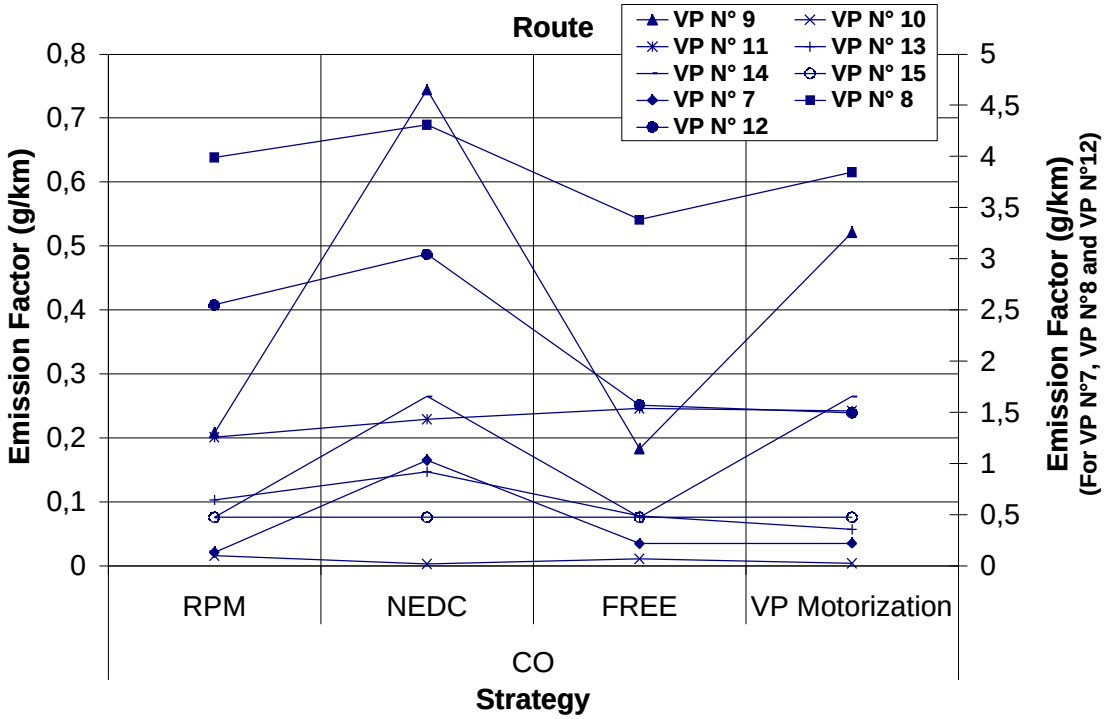


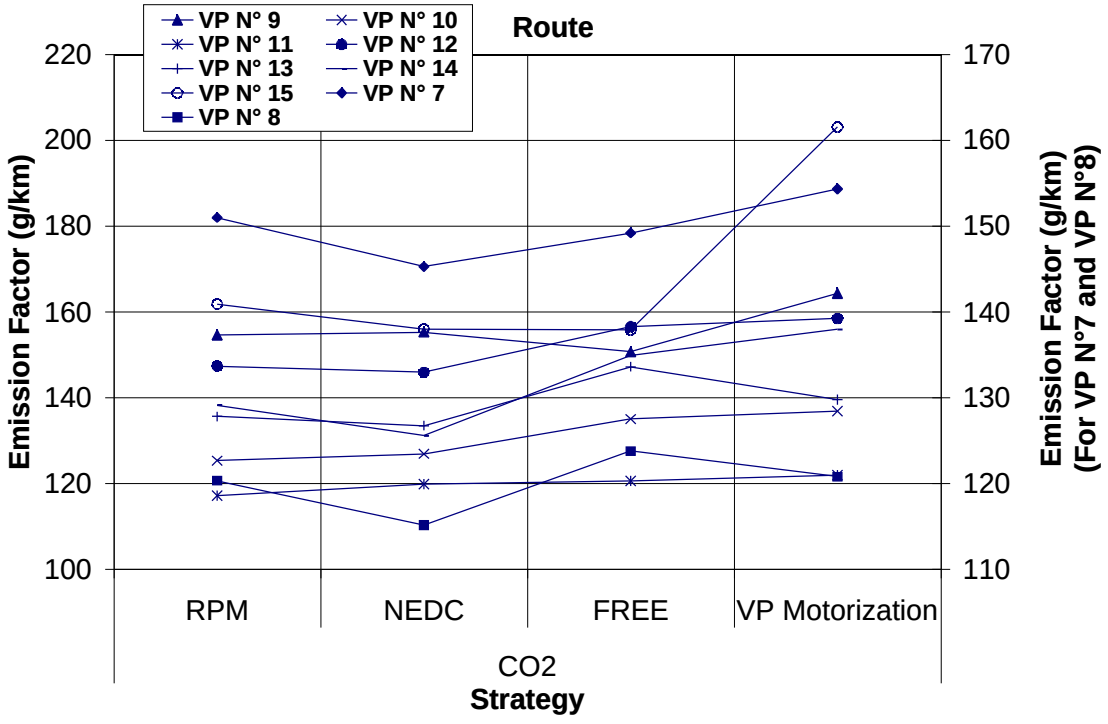


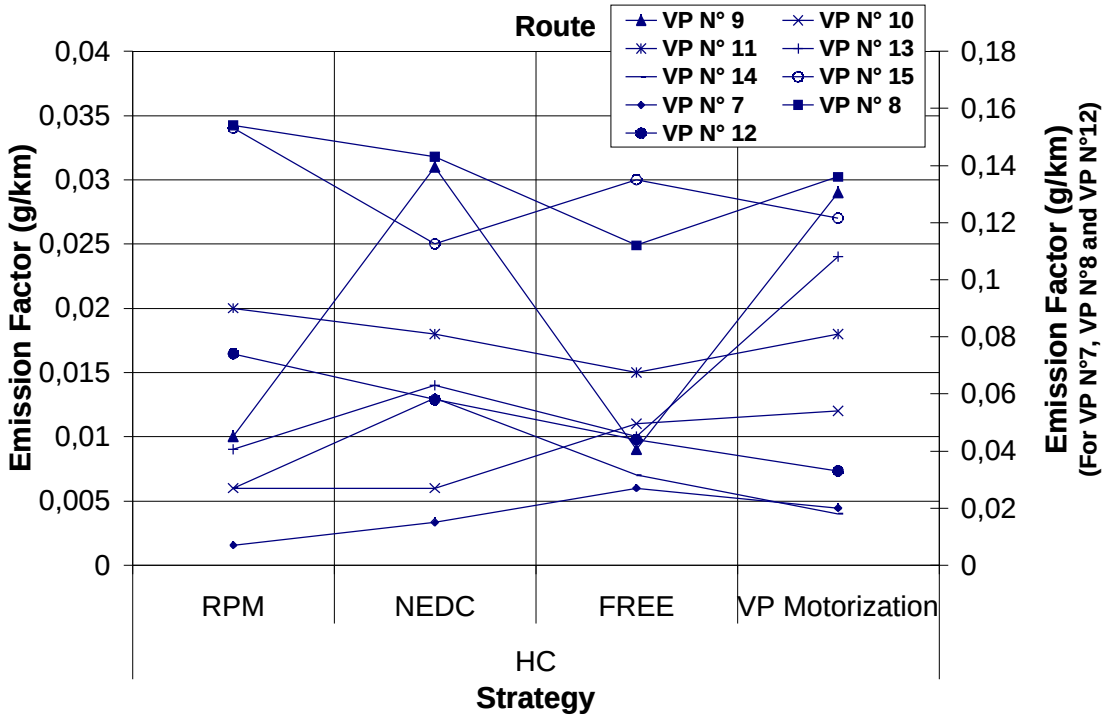


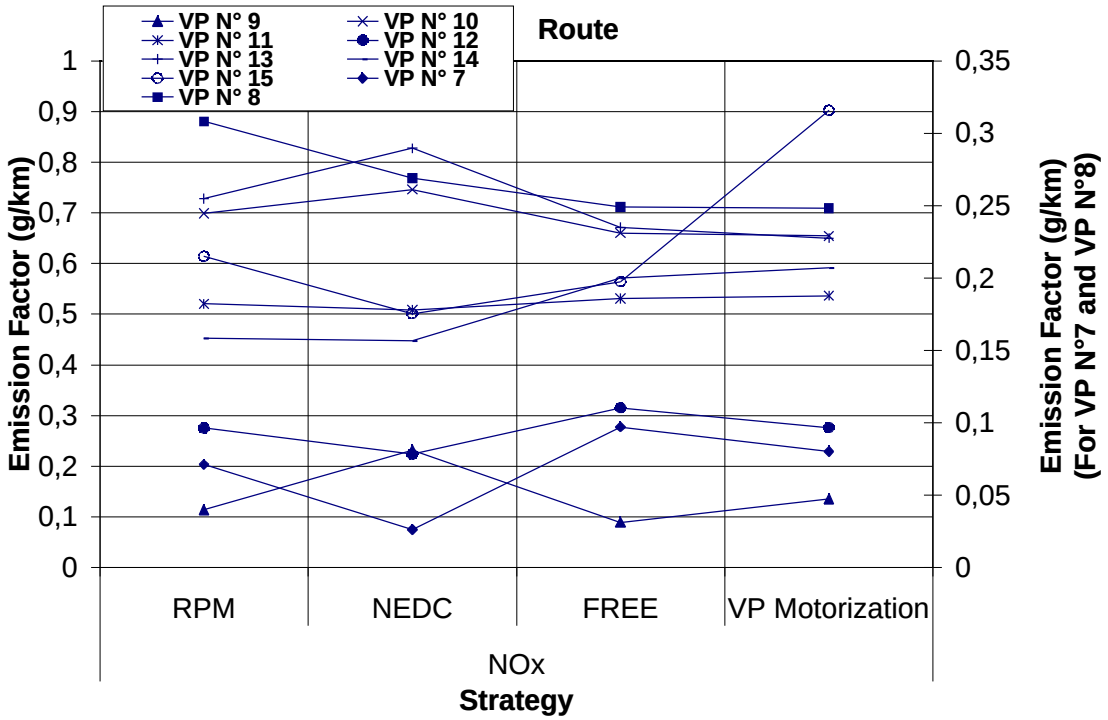


PNR-Ademe study, 'VP faible/forte motorisation route' cycle

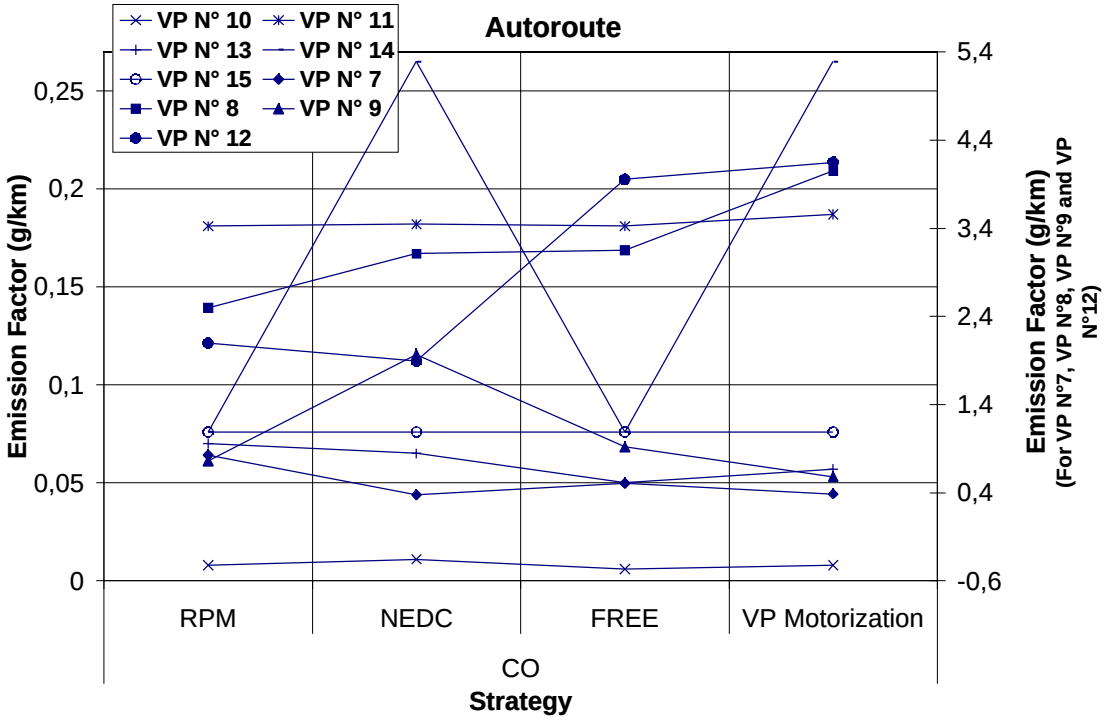


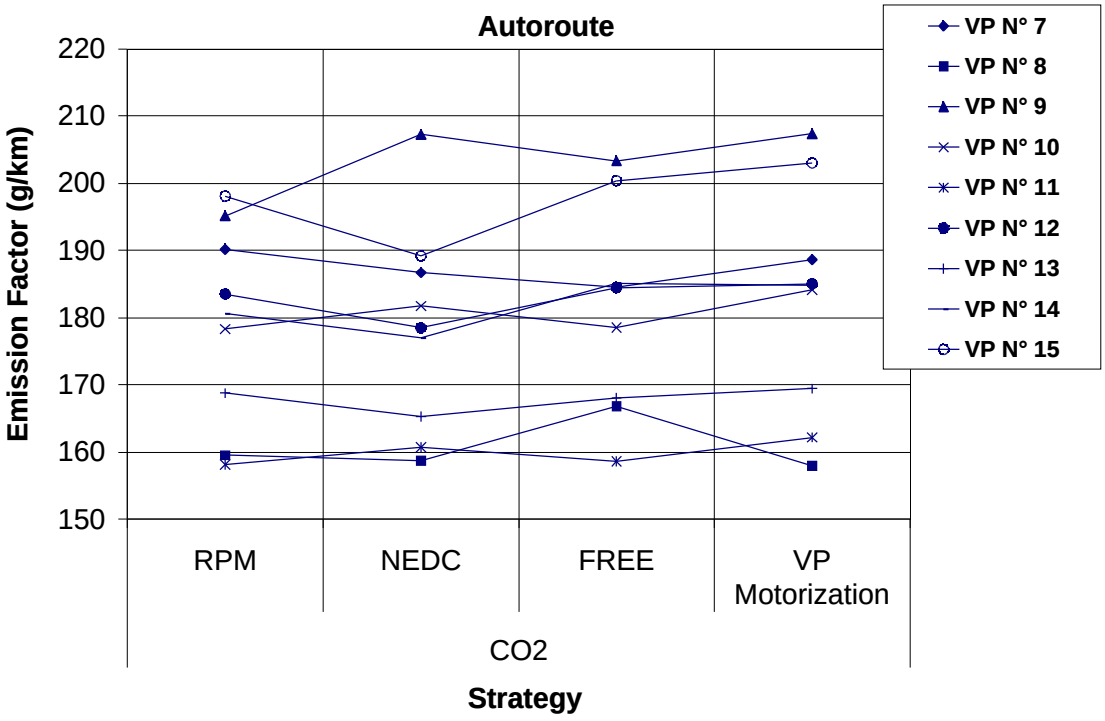


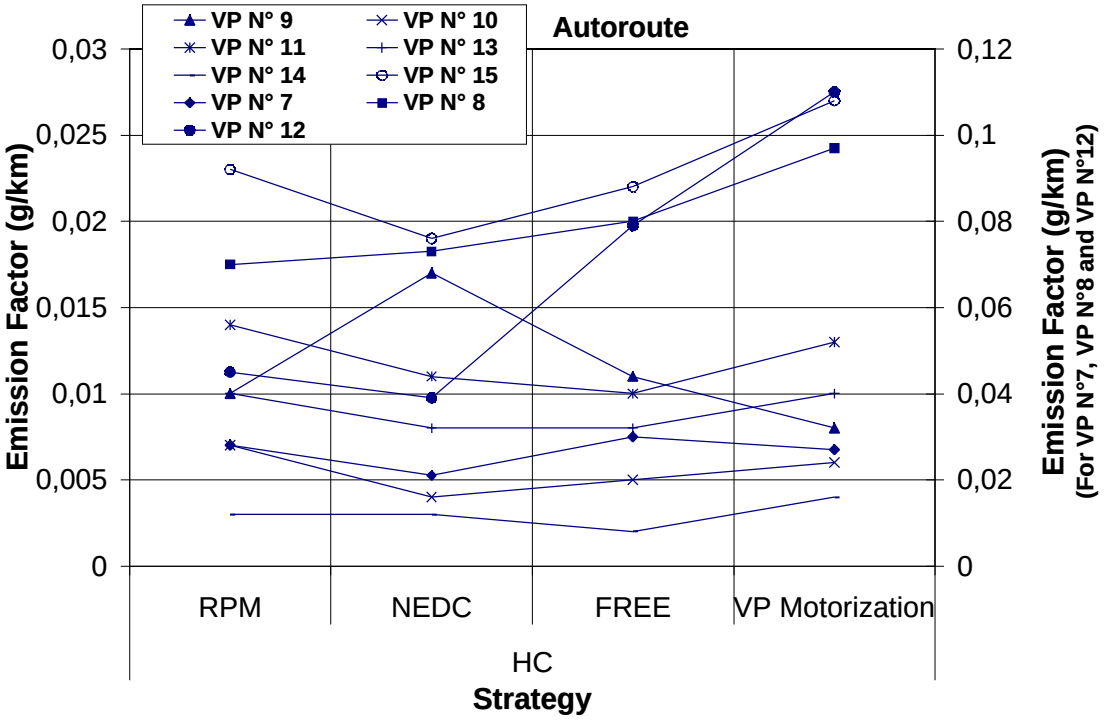


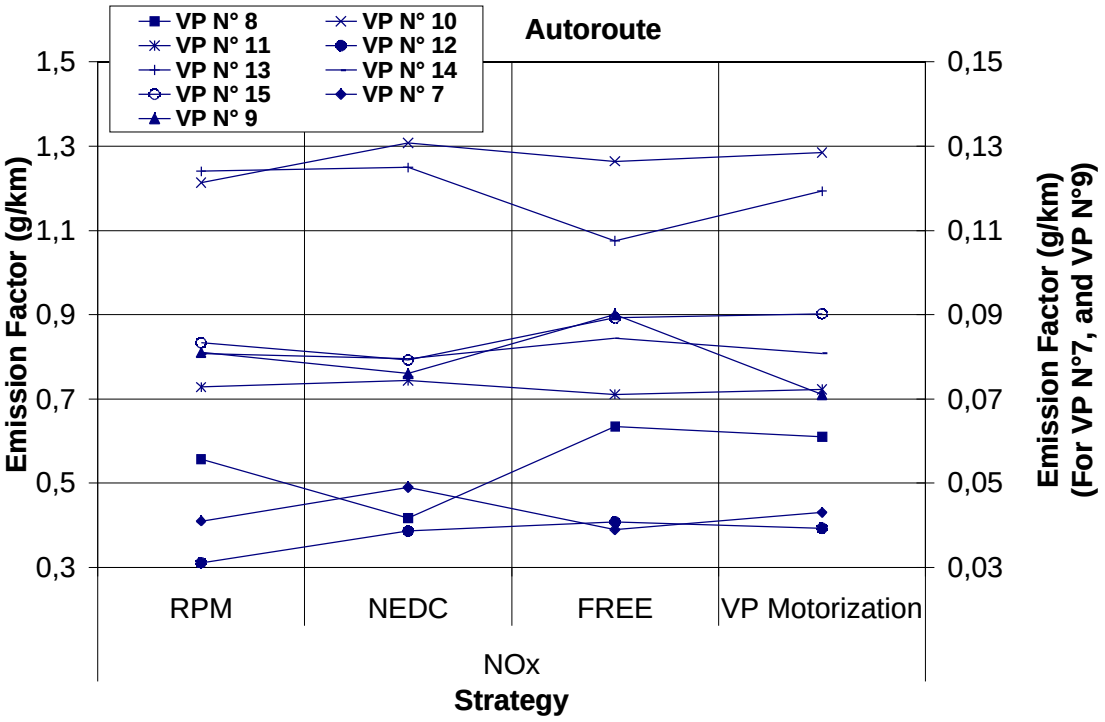


PNR-Ademe study, 'VP faible/forte motorisation autoroute' cycle









Annex 6 – T-test results

T means the results of the T-Test and is defined by $T = \frac{\text{Mean Difference}}{\text{Std. Dev.}}\sqrt{\text{Nb Cases}}$.

'Cycle (Artemis)', 'Cycle (VP Motorization)', 'NEDC', 'RPM', 'Record' and 'Free' are gearshift strategies.

Artemis study

CO **Cycle 'Artemis urban'**			Free	NEDC	RPM	Record
			2.363	3.530	2.583	3.118
Cycle (Artemis)	2.431	Mean Difference	0.068	-1.098	-0.152	-0.687
		95.00% CI	-0.858 to 0.995	-2.626 to 0.429	-1.013 to 0.709	-1.409 to 0.035
		SD Difference	0.883	1.456	0.820	0.688
		t	0.190	-1.848	-0.454	-2.446
		df	5	5	5	5
		Prob	0.857	0.124	0.669	0.058
Free	2.363	Mean Difference		-1.167	-0.221	-0.755
		95.00% CI		-3.450 to 1.117	-0.487 to 0.046	-2.162 to 0.652
		SD Difference		2.176	0.254	1.341
		t		-1.313	-2.124	-1.380
		df		5	5	5
		Prob		0.246	0.087	0.226
NEDC	3.530	Mean Difference			0.946	0.411
		95.00% CI			-1.197 to 3.089	-0.469 to 1.292
		SD Difference			2.042	0.839
		t			1.135	1.201
		df			5	5
		Prob			0.308	0.284
RPM	2.583	Mean Difference				-0.535
		95.00% CI				-1.807 to 0.738
		SD Difference				1.212
		t				-1.080
		df				5
		Prob				0.329

CO_2 cycle 'Artemis urban'			Free	NEDC	RPM	Record
			212.804	221.419	249.829	223.031
Cycle (Artemis)	218.753	Mean Difference	5.949	-2.666	***-31.076***	-4.278
		95.00% CI	-2.384 to 14.282	-21.124 to 15.791	***-56.089 to -6.063***	-28.768 to 20.212
		SD Difference	7.941	17.588	***23.835***	23.336
		t	1.835	-0.371	***-3.194***	-0.449
		df	5	5	***5***	5
		Prob	0.126	0.726	***0.024***	0.672
Free	212.804	Mean Difference		-8.615	***-37.025***	-10.227
		95.00% CI		-21.999 to 4.769	***-57.006 to -17.044***	-30.761 to 10.307
		SD Difference		12.754	***19.040***	19.567
		t		-1.655	***-4.763***	-1.280
		df		5	***5***	5
		Prob		0.159	***0.005***	0.257
NEDC	221.419	Mean Difference			***-28.410***	-1.612
		95.00% CI			***-37.900 to -18.920***	-10.709 to 7.485
		SD Difference			***9.043***	8.669
		t			***-7.696***	-0.455
		df			***5***	5
		Prob			***0.001***	0.668
RPM	249.829	Mean Difference				***26.798***
		95.00% CI				***18.643 to 34.953***
		SD Difference				***7.770***
		t				***8.448***
		df				***5***
		Prob				***0.000***

HC cycle 'Artemis urban'			Free	NEDC	RPM	Record
			0.527	0.576	0.587	0.556
Cycle (Artemis)	0.444	Mean Difference	-0.083	-0.133	-0.144	-0.113
		95.00% CI	-0.313 to 0.146	-0.335 to 0.070	-0.463 to 0.176	-0.312 to 0.086
		SD Difference	0.219	0.193	0.305	0.190
		t	-0.933	-1.679	-1.155	-1.455
		df	5	5	5	5
		Prob	0.394	0.154	0.300	0.206
Free	0.527	Mean Difference		-0.049	-0.060	-0.029
		95.00% CI		-0.228 to 0.130	-0.152 to 0.031	-0.114 to 0.056
		SD Difference		0.171	0.087	0.081
		t		-0.706	-1.694	-0.886
		df		5	5	5
		Prob		0.512	0.151	0.416
NEDC	0.576	Mean Difference			-0.011	0.020
		95.00% CI			-0.248 to 0.225	-0.074 to 0.114
		SD Difference			0.225	0.090
		t			-0.121	0.541
		df			5	5
		Prob			0.908	0.612
RPM	0.587	Mean Difference				0.031
		95.00% CI				-0.120 to 0.182
		SD Difference				0.144
		t				0.527
		df				5
		Prob				0.621

NOx cycle 'Artemis urban'			Free	NEDC	RPM	Record
			0.839	0.809	1.015	0.866
Cycle (Artemis)	0.768	Mean Difference	-0.070	-0.041	-0.247	-0.097
		95.00% CI	-0.201 to 0.060	-0.214 to 0.132	-0.595 to 0.101	-0.216 to 0.021
		SD Difference	0.125	0.165	0.332	0.113
		t	-1.384	-0.604	-1.822	-2.113
		df	5	5	5	5
		Prob	0.225	0.572	0.128	0.088
Free	0.839	Mean Difference		0.030	-0.176	-0.027
		95.00% CI		-0.078 to 0.138	-0.567 to 0.215	-0.090 to 0.037
		SD Difference		0.103	0.373	0.061
		t		0.711	-1.158	-1.086
		df		5	5	5
		Prob		0.509	0.299	0.327
NEDC	0.809	Mean Difference			-0.206	-0.057
		95.00% CI			-0.659 to 0.247	-0.135 to 0.022
		SD Difference			0.432	0.075
		t			-1.168	-1.849
		df			5	5
		Prob			0.295	0.124
RPM	1.015	Mean Difference				0.149
		95.00% CI				-0.234 to 0.533
		SD Difference				0.365
		t				1.002
		df				5
		Prob				0.363

CO Cycle 'Artemis rural'			Free	NEDC	RPM	Record
			1.889	2.547	1.715	1.984
Cycle (Artemis)	1.967	Mean Difference	0.078	-0.581	0.252	-0.017
		95.00% CI	-0.234 to 0.390	-2.665 to 1.504	-0.511 to 1.015	-0.721 to 0.687
		SD Difference	0.298	1.987	0.727	0.671
		t	0.641	-0.716	0.849	-0.062
		df	5	5	5	5
		Prob	0.550	0.506	0.435	0.953
Free	1.889	Mean Difference		-0.658	0.174	-0.095
		95.00% CI		-3.043 to 1.726	-0.288 to 0.636	-1.027 to 0.837
		SD Difference		2.272	0.440	0.888
		t		-0.710	0.970	-0.261
		df		5	5	5
		Prob		0.510	0.377	0.804
NEDC	2.547	Mean Difference			0.833	0.563
		95.00% CI			-1.981 to 3.646	-1.007 to 2.134
		SD Difference			2.681	1.496
		t			0.761	0.923
		df			5	5
		Prob			0.481	0.399
RPM	1.715	Mean Difference				-0.269
		95.00% CI				-1.565 to 1.027
		SD Difference				1.235
		t				-0.534
		df				5
		Prob				0.616

CO_2 Cycle 'Artemis rural'			Free	NEDC	RPM	Record
			134.043	129.791	150.003	134.100
Cycle (Artemis)	136.144	Mean Difference	2.100	***6.353***	***-13.859***	2.044
		95.00% CI	-6.181 to 10.381	***0.305 to 12.401***	***-19.832 to -7.886***	-5.766 to 9.854
		SD Difference	7.891	***5.763***	***5.692***	7.442
		t	0.652	***2.700***	***-5.964***	0.673
		df	5	***5***	***5***	5
		Prob	0.543	***0.043***	***0.002***	0.531
Free	134.043	Mean Difference		4.253	***-15.959***	-0.057
		95.00% CI		-1.665 to 10.171	***-20.109 to -11.810***	-8.810 to 8.697
		SD Difference		5.639	***3.954***	8.341
		t		1.847	***-9.886***	-0.017
		df		5	***5***	5
		Prob		0.124	***0.000***	0.987
NEDC	129.791	Mean Difference			***-20.212***	-4.309
		95.00% CI			***-26.308 to -14.116***	-13.898 to 5.279
		SD Difference			***5.809***	9.137
		t			***-8.523***	-1.155
		df			***5***	5
		Prob			***0.000***	0.300
RPM	150.003	Mean Difference				***15.903***
		95.00% CI				***6.397 to 25.408***
		SD Difference				***9.058***
		t				***4.301***
		df				***5***
		Prob				***0.008***

HC Cycle 'Artemis rural'			Free	NEDC	RPM	Record
			0.218	0.206	0.242	0.207
Cycle (Artemis)	0.233	Mean Difference	0.015	0.028	-0.009	0.027
		95.00% CI	-0.049 to 0.079	-0.105 to 0.161	-0.023 to 0.005	-0.060 to 0.113
		SD Difference	0.061	0.127	0.013	0.082
		t	0.607	0.534	-1.638	0.794
		df	5	5	5	5
		Prob	0.570	0.616	0.162	0.463
Free	0.218	Mean Difference		0.013	-0.024	0.012
		95.00% CI		-0.058 to 0.083	-0.100 to 0.053	-0.013 to 0.037
		SD Difference		0.067	0.073	0.024
		t		0.463	-0.802	1.203
		df		5	5	5
		Prob		0.663	0.459	0.283
NEDC	0.206	Mean Difference			-0.037	-0.001
		95.00% CI			-0.183 to 0.110	-0.054 to 0.052
		SD Difference			0.139	0.050
		t			-0.642	-0.049
		df			5	5
		Prob			0.549	0.963
RPM	0.242	Mean Difference				0.035
		95.00% CI				-0.063 to 0.134
		SD Difference				0.094
		t				0.923
		df				5
		Prob				0.398

NOx **Cycle 'Artemis rural'**			Free	NEDC	RPM	Record
			0.640	0.610	0.728	0.656
Cycle (Artemis)	0.673	Mean Difference	0.032	0.062	-0.055	0.016
		95.00% CI	-0.222 to 0.286	-0.184 to 0.309	-0.157 to 0.046	-0.181 to 0.214
		SD Difference	0.242	0.235	0.097	0.189
		t	0.327	0.652	-1.405	0.214
		df	5	5	5	5
		Prob	0.757	0.543	0.219	0.839
Free	0.640	Mean Difference		0.030	-0.088	-0.016
		95.00% CI		-0.020 to 0.080	-0.369 to 0.193	-0.094 to 0.062
		SD Difference		0.047	0.268	0.074
		t		1.558	-0.804	-0.521
		df		5	5	5
		Prob		0.180	0.458	0.624
NEDC	0.610	Mean Difference			-0.118	-0.046
		95.00% CI			-0.404 to 0.168	-0.139 to 0.047
		SD Difference			0.273	0.089
		t			-1.061	-1.269
		df			5	5
		Prob			0.337	0.260
RPM	0.728	Mean Difference				0.072
		95.00% CI				-0.142 to 0.286
		SD Difference				0.204
		t				0.864
		df				5
		Prob				0.427

PNR-Ademe study

CO **Cycle 'VP faible/forte motorisation urbain'**			Cycle (VP Motorization)	NEDC	RPM
			0.733	1.101	0.741
Free	0.695	Mean Difference	-0.039	-0.406	-0.046
		95.00% CI	-0.200 to 0.123	-1.045 to 0.232	-0.202 to 0.109
		SD Difference	0.210	0.831	0.203
		t	-0.551	-1.467	-0.688
		df	8	8	8
		Prob	0.596	0.180	0.511
Cycle (VP Motorization)	0.733	Mean Difference		-0.368	-0.008
		95.00% CI		-0.914 to 0.178	-0.127 to 0.111
		SD Difference		0.710	0.154
		t		-1.553	-0.153
		df		8	8
		Prob		0.159	0.882
NEDC	1.101	Mean Difference			0.360
		95.00% CI			-0.152 to 0.872
		SD Difference			0.666
		t			1.621
		df			8
		Prob			0.144

CO_2 **Cycle 'VP faible/forte motorisation urbain'**			Cycle (VP Motorization)	NEDC	RPM
			235.097	225.104	233.848
Free	238.539	Mean Difference	3.442	***13.435***	4.691
		95.00% CI	-4.639 to 11.523	***6.582 to 20.289***	-4.943 to 14.325
		SD Difference	10.513	***8.916***	12.534
		t	0.982	***4.521***	1.123
		df	8	***8***	8
		Prob	0.355	***0.002***	0.294
Cycle (VP Motorization)	235.097	Mean Difference		***9.993***	1.249
		95.00% CI		***2.543 to 17.443***	-3.321 to 5.819
		SD Difference		***9.692***	5.945
		t		***3.093***	0.630
		df		***8***	8
		Prob		***0.015***	0.546
NEDC	225.104	Mean Difference			***-8.744***
		95.00% CI			***-15.828 to -1.661***
		SD Difference			***9.215***
		t			***-2.847***
		df			***8***
		Prob			***0.022***

HC **Cycle 'VP faible/forte motorisation urbain'**			Cycle (VP Motorization)	NEDC	RPM
			0.073	0.053	0.050
Free	0.058	Mean Difference	-0.015	0.004	0.008
		95.00% CI	-0.037 to 0.007	-0.011 to 0.019	-0.007 to 0.023
		SD Difference	0.029	0.020	0.020
		t	-1.570	0.675	1.165
		df	8	8	8
		Prob	0.155	0.518	0.278
Cycle (VP Motorization)	0.073	Mean Difference		***0.020***	0.023
		95.00% CI		***-0.001 to 0.040***	-0.003 to 0.048
		SD Difference		***0.026***	0.033
		t		***2.225***	2.077
		df		***8***	8
		Prob		***0.057***	0.071
NEDC	0.053	Mean Difference			0.003
		95.00% CI			-0.008 to 0.014
		SD Difference			0.014
		t			0.683
		df			8
		Prob			0.514

NOx **Cycle 'VP faible/forte motorisation urbain'**			Cycle (VP Motorization)	NEDC	RPM
			0.657	0.053	0.050
Free	0.618	Mean Difference	-0.039	-0.029	-0.014
		95.00% CI	-0.098 to 0.019	-0.131 to 0.073	-0.064 to 0.036
		SD Difference	0.076	0.133	0.065
		t	-1.542	-0.655	-0.645
		df	8	8	8
		Prob	0.162	0.531	0.537
Cycle (VP Motorization)	0.657	Mean Difference		0.010	0.025
		95.00% CI		-0.049 to 0.070	-0.036 to 0.087
		SD Difference		0.077	0.080
		t		0.394	0.946
		df		8	8
		Prob		0.704	0.372
NEDC	0.053	Mean Difference			0.015
		95.00% CI			-0.082 to 0.112
		SD Difference			0.126
		t			0.359
		df			8
		Prob			0.729

CO **Cycle 'VP faible/forte motorisation route'**			Cycle (VP Motorization)	NEDC	RPM
			0.648	0.935	0.701
Free	0.569	Mean Difference	-0.079	***-0.366***	-0.131
		95.00% CI	-0.187 to0.029	***-0.703 to -0.028***	-0.371 to 0.108
		SD Difference	0.140	***0.439***	0.312
		t	-1.691	***-2.501***	-1.266
		df	8	***8***	8
		Prob	0.129	***0.037***	0.241
Cycle (VP Motorization)	0.648	Mean Difference		-0.286	-0.052
		95.00% CI		-0.619 to 0.046	-0.306 to 0.202
		SD Difference		0.432	0.331
		t		-1.988	-0.475
		df		8	8
		Prob		0.082	0.648
NEDC	0.935	Mean Difference			***0.234***
		95.00% CI			***0.044 to 0.424***
		SD Difference			***0.247***
		t			***2.844***
		df			***8***
		Prob			***0.022***

CO_2 **Cycle 'VP faible/forte motorisation route'**			Cycle (VP Motorization)	NEDC	RPM
			150.005	135.548	138.294
Free	142.198	Mean Difference	-7.807	***6.650***	3.905
		95.00% CI	-20.672 to 5.059	***1.270 to 12.030***	-1.386 to9.196
		SD Difference	16.738	***6.999***	6.884
		t	-1.399	***2.851***	1.702
		df	8	***8***	8
		Prob	0.199	***0.021***	0.127
Cycle (VP Motorization)	150.005	Mean Difference		***14.457***	***11.712***
		95.00% CI		***2.877 to 26.036***	***1.716 to 21.707***
		SD Difference		***15.064***	***13.004***
		t		***2.879***	***2.702***
		df		***8***	***8***
		Prob		***0.021***	***0.027***
NEDC	135.548	Mean Difference			-2.745
		95.00% CI			-6.047 to0.557
		SD Difference			4.296
		t			-1.917
		df			8
		Prob			0.092

HC **Cycle 'VP faible/forte motorisation route'**			Cycle (VP Motorization)	NEDC	RPM
			0.034	0.035	0.034
Free	0.029	Mean Difference	-0.005	-0.006	-0.005
		95.00% CI	-0.014 to 0.004	-0.017 to 0.005	-0.018 to 0.009
		SD Difference	0.012	0.014	0.018
		t	-1.197	-1.260	-0.775
		df	8	8	8
		Prob	0.266	0.243	0.461
Cycle (VP Motorization)	0.034	Mean Difference		-0.001	0.000
		95.00% CI		-0.010 to0.007	-0.014 to0.014
		SD Difference		0.011	0.018
		t		-0.361	0.024
		df		8	8
		Prob		0.728	0.981
NEDC	0.035	Mean Difference			0.001
		95.00% CI			-0.006 to0.009
		SD Difference			0.010
		t			0.450
		df			8
		Prob			0.665

NOx **Cycle 'VP faible/forte motorisation route'**			Cycle (VP Motorization)	NEDC	RPM
			0.462	0.426	0.423
Free	0.422	Mean Difference	-0.040	-0.004	-0.001
		95.00% CI	-0.123 to 0.044	-0.076 to 0.069	-0.046 to 0.045
		SD Difference	0.109	0.095	0.059
		t	-1.086	-0.115	-0.043
		df	8	8	8
		Prob	0.309	0.911	0.967
Cycle (VP Motorization)	0.462	Mean Difference		0.036	0.039
		95.00% CI		-0.084 to 0.156	-0.043 to 0.121
		SD Difference		0.156	0.106
		t		0.691	1.089
		df		8	8
		Prob		0.509	0.308
NEDC	0.426	Mean Difference			0.003
		95.00% CI			-0.052 to 0.058
		SD Difference			0.072
		t			0.116
		df			8
		Prob			0.910

CO **Cycle 'VP faible/forte motorisation autoroute'**			Cycle (VP Motorization)	NEDC	RPM
			1.256	1.009	0.874
Free	1.075	Mean Difference	-0.180	0.066	0.201
		95.00% CI	-0.493 to 0.132	-0.487 to 0.620	-0.194 to 0.597
		SD Difference	0.407	0.720	0.514
		t	-1.329	0.277	1.173
		df	8	8	8
		Prob	0.220	0.789	0.274
Cycle (VP Motorization)	1.256	Mean Difference		0.247	0.381
		95.00% CI		-0.538 to 1.031	-0.301 to 1.064
		SD Difference		1.020	0.888
		t		0.725	1.289
		df		8	8
		Prob		0.489	0.234
NEDC	1.009	Mean Difference			0.135
		95.00% CI			-0.236 to 0.506
		SD Difference			0.482
		t			0.839
		df			8
		Prob			0.426

CO_2 **Cycle 'VP faible/forte motorisation autoroute'**			Cycle (VP Motorization)	NEDC	RPM
			183.316	179.831	179.862
Free	182.505	Mean Difference	-0.811	2.674	2.643
		95.00% CI	-3.896 to 2.274	-0.981 to 6.329	-0.930 to 6.216
		SD Difference	4.013	4.755	4.648
		t	-0.606	1.687	1.706
		df	8	8	8
		Prob	0.561	0.130	0.126
Cycle (VP Motorization)	183.316	Mean Difference		***3.485***	***3.454***
		95.00% CI		***0.750 to 6.220***	***0.276 to 6.632***
		SD Difference		***3.558***	***4.135***
		t		***2.939***	***2.506***
		df		***8***	***8***
		Prob		***0.019***	***0.037***
NEDC	179.831	Mean Difference			-0.031
		95.00% CI			-4.117 to 4.055
		SD Difference			5.316
		t			-0.018
		df			8
		Prob			0.986

HC **Cycle 'VP faible/forte motorisation autoroute'**			Cycle (VP Motorization)	NEDC	RPM
			0.039	0.027	0.028
Free	0.031	Mean Difference	-0.008	0.004	0.004
		95.00% CI	-0.020 to 0.004	-0.005 to 0.013	-0.003 to 0.011
		SD Difference	0.015	0.012	0.009
		t	-1.512	1.037	1.213
		df	8	8	8
		Prob	0.169	0.330	0.260
Cycle (VP Motorization)	0.039	Mean Difference		0.012	0.011
		95.00% CI		-0.008 to 0.032	-0.007 to 0.030
		SD Difference		0.026	0.024
		t		1.359	1.417
		df		8	8
		Prob		0.211	0.194
NEDC	0.027	Mean Difference			-0.000
		95.00% CI			-0.005 to 0.005
		SD Difference			0.007
		t			-0.194
		df			8
		Prob			0.851

NOx **Cycle 'VP faible/forte motorisation autoroute'**			Cycle (VP Motorization)	NEDC	RPM
			0.709	0.692	0.693
Free	0.706	Mean Difference	-0.003	0.014	0.013
		95.00% CI	-0.038 to 0.032	-0.070 to 0.099	-0.046 to 0.073
		SD Difference	0.045	0.110	0.078
		t	-0.198	0.393	0.512
		df	8	8	8
		Prob	0.848	0.705	0.623
Cycle (VP Motorization)	0.709	Mean Difference		0.017	0.016
		95.00% CI		-0.046 to 0.081	-0.013 to 0.046
		SD Difference		0.083	0.038
		t		0.629	1.267
		df		8	8
		Prob		0.547	0.241
NEDC	0.692	Mean Difference			-0.001
		95.00% CI			-0.058 to 0.056
		SD Difference			0.074
		t			-0.047
		df			8
		Prob			0.964

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