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Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

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***INSTITUT NATIONAL DE RECHERCHE
SUR LES TRANSPORTS ET LEUR SECURITE***

Michel ANDRÉ, Mario RAPONE, Robert JOUMARD

*Analysis of the cars pollutant
emissions as regards driving cycles
and kinematic parameters*

*ARTEMIS - Assessment and reliability of transport
emission models and inventory systems
WP3141 research task*

*Report INRETS-LTE 0607
March 2006*



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Michel ANDRÉ, Mario RAPONE, Robert JOUMARD

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

ARTEMIS - Assessment and reliability of transport emission models and inventory systems

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*Report INRETS-LTE 0607
March 2006*

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- *the availability of emission data, by TUG (Technical University of Graz, Austria), KTI (Institute for Transport Science, Budapest, Hungary), TNO (Delft, The Netherlands) and INRETS (France), in the frame of the Artemis project, as well as the numerous partners who contributed to the elaboration of the Artemis emission database.*
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13 Summary <p>Consequent works have been undertaken within the ARTEMIS project to analyse the influence of the driving cycles as regards the estimation of the emissions. A large number of cycles was reviewed, and their characterization enabled the building-up of a set of contrasted cycles to assess this influence.</p> <p>The emission analyses have demonstrated the significant and even preponderant influence of the driving cycles on the emissions. Quite contrasted emission behaviours were observed for Diesel (rather sensitive to speed and stop parameters) and Petrol cars (rather sensitive to accelerations) The most significant kinematic parameters have been identified.</p> <p>A partial least square hierarchical approach was developed to analyse and estimate the emissions;, which led to a good fit for CO₂ but was less or not satisfying for the other pollutants due to a variability between the vehicles and to "high emitting" cars. It was also observed that a model based on the only average speed is unable to predict the emission behaviour induced by the dynamic of the cycles.</p> <p>The question of using dedicated driving cycles for the high- and low-powered cars respectively rather than a unique common set of cycles for all the cars was also raised-up as this procedure aspect induced strong differences in the estimation.</p> <p>The harmonization of the Artemis cars emission database, through a "cartography" of the cycles has enabled the definition of reference emissions which should enable a better taking into account of the traffic dynamic on the emissions. These results were also implemented for the development of a specific method to compute the emissions at a low spatial scale, i.e. the so-called traffic situation approach.</p>					
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13 Résumé <p>Des travaux conséquents ont été entrepris dans le cadre du projet de recherche ARTEMIS, pour analyser l'incidence des cycles de conduite sur les émissions de polluants des voitures particulières. A grand nombre de cycles a été analysé et leur caractérisation a permis la construction d'un jeu de cycles contrastés permettant d'analyser cette influence.</p> <p>L'analyse des émissions démontre l'influence significative et même prépondérante du cycle de conduite sur les émissions. Des comportements contrastés sont observés entre véhicules Diesel (sensibles aux vitesses et arrêts) et voitures essence (plutôt sensibles aux accélérations). Les paramètres cinématiques les plus significatifs ont été identifiés.</p> <p>Une approche hiérarchique basée sur la régression partielle a été développée pour analyser et estimer les émissions. Cette approche est satisfaisante pour le CO2 mais moins pour les autres polluants en raison de la forte variabilité entre les véhicules et en particulier de véhicules « fortement » polluants. Un modèle basé sur la vitesse moyenne se révèle insuffisant à prédire les émissions en raison de la dynamique des cycles.</p> <p>La question de l'utilisation de cycles de conduite spécifiques, selon les capacités de motorisation des véhicules plutôt que d'utiliser des cycles communs pour tous les véhicules a été soulevée également, compte tenu des distorsions importantes d'estimation des émissions induites par cet aspect purement méthodologique.</p> <p>L'harmonisation des données d'émissions de la base de données Artemis (voitures particulières), au travers d'une cartographie des cycles d'essai, a permis l'élaboration d'émissions de référence qui doivent permettre une meilleure prise en compte de la dynamique du trafic sur les émissions. Ces résultats ont été également mis en œuvre pour la construction d'une approche spécifique permettant d'estimer les émissions à une échelle « locale » (approche dite de situations de trafic).</p>					
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Introduction

These works (task WP3141: influence of the driving cycle of the ARTEMIS¹ research project) were initially and roughly designed to :

- review and compare the existing driving cycles as regards their kinematics, representativity and method of determination,
- analyse the sensitivity of emissions as regards test cycles and compare emissions data measured with different cycles,
- assess the quality of the emissions modelling according to the number and quality of measurement cycles.

In this aim, emissions measurements were foreseen on 11 cars using about 16 driving cycles, to be selected amongst the already existing test cycles, or to be adapted or developed. Six laboratories were involved in these tests.

In fact, the works conducted around this topic have deviated to a large extent from this very simple experimental design due to the complexity of the question and to the importance of the issues. Indeed:

- The driving cycle is the basic “material” of the emissions measurements and therefore its qualities (representativity, exhaustivity, reproducibility, reliability, etc.) are crucial as regards the quality of the emissions data, factors and modelling. Unfortunately, due to the experimentation costs, the driving cycles are often limited in number (2-3) and in duration (some tenths of minutes), and that probably limits their representativity. In Europe, there are plenty of driving cycles and that should be seen as an advantage. But these cycles were developed in various countries with different methods and assumptions, without coherency between them. Furthermore, there is generally no reliable mean or dataset that would enable the necessary comparisons and getting then the advantage of this cycles multiplicity, and of the large quantity of related emission measurements.
- The driving cycle is the only link with the driving conditions or behaviour, i.e. with the actual on-the-road condition. The necessity in ARTEMIS to estimate the emissions as a detailed level (i.e. in one street for a given traffic condition) increased dramatically the need to understand and even to model the link between emissions and kinematic parameters. Although the present task had not such aim, it appeared to be the good framework and at least a good starting point to deal with such a question.
- The collection in ARTEMIS of a very large amount of ancient and new emissions data, coming from various laboratories and measured using a large range of driving cycles raised up the question of harmonizing these data and in particular as regards the test cycles. This necessary harmonization should obviously be based on the analyses of these

¹ ARTEMIS: Assessment and reliability of transport emission models and inventory systems. Project funded by the European Commission within the 5th Framework Research Programme, DG TREN.

driving cycles as regards their kinematic content, and on the understanding of the link between driving profiles and emissions. Indeed the very large heterogeneity of the emission data is certainly due to a large extent to the variability between the cycles. Once again and although not foreseen in its frame, the WP3141 task appeared to be a good framework to approach this question.

- Although the experimental dataset foreseen in this task enabled to draw significant conclusions as regards the impact of driving cycles on the emissions, it appeared to be generally insufficient to derive practical functions or corrections such as the ones mentioned in the previous point. Complementary emissions dataset were thus considered and analysed. These dataset were much more consequent in size, but unfortunately not so well conceived to measure in a simple way the effect of one or several parameters. Complex data analyses were then required.

For these reasons, the scope of this task was strongly enlarged to cover complementary questions such as emissions modelling aspects, emissions data corrections, and by the need of sophisticated analyses of complementary dataset.

Finally the works described in that report includes the following main topics:

1. The review and collection of a large range of cycles, their characterisation, and the building-up of a set of contrasted and typical cycles,
2. The tests on chassis dynamometer and measurement of the pollutants emissions of 9 out of 11 cars foreseen (for 2 cars the data was not made available),
3. The analysis of the previous data and of a complementary dataset of 30 vehicles tested using both the Artemis cycles and specific cycles corresponding to their motorization (cycles for the high and low motorization cars), to characterize the influence of the cycles on the emissions,
4. The review of diverse approaches to model emissions as regards the kinematic parameters, and the elaboration of a hierarchical statistic modelling approach using Partial Least Square regression and based on the Artemis database,
5. The analysis of the whole set of hot emissions data for passenger cars collected in the Artemis database and the development of an approach that enabled the harmonization according to the test cycles and the computation of the emissions,
6. The development of a specific method to compute the emissions at a low spatial scale, i.e. the so-called traffic situation approach.

Remark: These works led us to deal with a large number of driving cycles, sometimes used or known by other institutions with differing names. The induced confusion led us to a fastidious task in order to harmonize and define clearly each cycle. By convention, in that report a cycle will be named by its “family name” (giving information on its origin or its context), followed by a cycle name, which attempts to be as explicit as possible.

1. Review, characterization and selection of driving cycles

The first aim of this chapter is the review and collection of a large range of driving cycles. Their description and characterization enable then the selection of a pertinent sample of test cycles, in order to study the cycle influence on emissions. We develop hereafter the methodological aspects of this selection.

1.1. Methodological aspects

1.1.1. Objectives

These works do not intend to compare different driving cycles as regards their emission level or their quality (which objective would be of quite low interest) but aimed firstly at :

1. analysing the influence of the driving cycle and its "kinematic content" on the pollutant emissions,
2. enlarging the coverage of the emissions test, to driving conditions that are not covered by the cycles used in the others tasks of the Artemis project,
3. possibly, studying the methods and principles used to derive driving cycles.

We examine these points as regards their implication on the experimental design and the works to be conducted.

1.1.2. Influence of the driving cycles and their kinematic characteristics

This objective should contribute to a better knowledge of emissions as a function of the driving conditions, and in particular to the improvement of the instantaneous (or microscopic) emissions modelling. The underlying questions are:

- **How to characterise the driving cycles ?** - Synthetic parameters can be envisaged, such as stop number and duration, maximum and average speeds, acceleration number and level, power or energy of the speed profile. More detailed or complex parameters can also be considered, such as the speed – acceleration crossed distribution.
- **Which cycles do we consider ?** – the calculation of the above parameters for each of the available cycles should enable their ranking and the selection of cycles that would be contrasted as regards their kinematic contents (i.e. maximising the variation of the kinematic content for different speed levels).

1.1.3. Enlarging the coverage of the usual driving cycles

The selection of cycles should allow getting emission data in ranges that are not covered by the driving cycles used in Artemis (i.e. Artemis cycles, NEDC, FTP), while addressing also the question the influence of driving cycles on emissions. In the following of (De Haan et al., 2001) the following situations are suggested to increase the coverage of the Artemis cycles:

- the very congested urban, or stop and go,
- stop and go on motorway,
- the range of about 100 km/h (motorway with 100 km/h limit),
- high (and low) accelerations.

1.1.4. Method and principles to derive driving cycles

Although useful, such a review (as regards the database, the statistical principles and method used, the basis or induced assumptions) is quite difficult as it implies a good documentation on the works, which is not always available. However, several works in that area can already be found (see André 1996, André 2004b, Watson 1995, etc.).

On the other hand, it would be useful to analyse the incidence of principles induced by the approaches, and to consider for instance the following aspects:

- the "central trend approach" (i.e. cycles are derived to reproduce average or median parameters, etc.), which leads to cover the average driving instead of describing its diversity,
- the appropriateness of a unique cycle, independent of the cars performances (high or low motorization, etc.) and of vehicle categories (private or commercial cars, light duty vehicles, etc.),
- the homogeneity of driving conditions within a cycle, rather than the heterogeneity observed within real trips,
- the design of short sub-cycles within the test cycles, which enrich the accuracy of the measurements and analyses (through more detailed situations) but also decrease the representativity through short measurements (at the sub-cycle scale),
- the taking into account of the gear strategy, of the starting conditions, etc., which are certainly important criteria characterizing the cycles.

1.2. Driving cycles considered

A large range of driving cycles for passenger cars is available in Europe. A compilation of some of these works can be found in (André, 1996, 2004a and 2004b, Joumard et al. 2000). The list of these cycles, their main characteristics and classification according to the following analyses are provided in Annex 1 (which includes also the other cycles considered in Chapter 6). We provide hereafter a brief description of these cycles, considering first the existing cycles and then those developed in the frame of the Artemis project.

1.2.1. Existing cycles

The following driving cycles have been considered in this framework:

- Standard (or legislative) driving cycles such as the European NEDC cycles (urban, suburban), the US FTP cycle, the US Highway.
- The Inrets cycles: derived from French experimentation on the actual driving, these 10 driving cycles (5 urban, 3 rural, 2 motorway) describe in detail the driving conditions, with an intrinsic homogeneity in speed levels (Joumard et al. 1987).
- The Inrets short cycles: derived from the previous ones to measure the cold start effect, they consist in urban and rural short cycles that are repeated numerous times.
- The modem cycles: these 14 urban cycles were derived from the monitoring of 60 European cars in actual use (DRIVE-modem research project, André et al. 1994)). Compared to the Inrets cycles and apart from their international character, they introduce the heterogeneity and chronology of the driving conditions within the cycles.
- The modem-IM cycles and short-cycle: based on the same database and principles than the modem cycles, 4 cycles cover the congested urban driving, the free-urban driving, the rural and motorway driving (André et al. 1998).
- The modem-Hyzem driving cycles for cars: derived from the DRIVE-modem and BRITE/EURAM-Hyzem research projects, they consist in 2 imbricate sets of 3 (urban, rural, motorway) and 8 cycles (3 urban, 3 rural, 2 motorway), providing two levels of description of the driving conditions (André, 1997). Compared to the modem and modem-IM cycles, they are based on a larger dataset (80 European cars) and on totally revised statistical principles improving their representativity.
- The PVU or LDV cycles for 4 categories of light duty vehicles (cars professionally used, light vans, 2.5 and 3.5 tons vans): these four sets of cycles account for 6 to 9 cycles and include urban, rural and motorway empty and loaded driving, as well as specific conditions such as delivery. These cycles were based on a French experimentation with 40 LDV monitored in real-world driving conditions (Joumard et al. 2003).
- Short test cycles: 3 short test cycles were considered: the US IM240, the modem-IM short-cycle and one short test cycle derived from the European standard cycles (André et al. 1998).
- Various other test cycles: New-York City Cycle (NYCC), the non-FTP cycles (US SC03, US06).
- The Swiss Handbook driving cycles, developed to cover the Swiss driving conditions in a detailed way (3 cycles, 12 sub-cycles, de Haan et al. 2001).
- 23 Neapolitan driving patterns recorded in urban and congested contexts.

1.2.2. The Artemis cycles

Based on a large database (called modem-Hyzem) on the actual driving in Europe, the Artemis driving cycles have been designed to describe the “space” of the actual driving conditions in their diversity. Twelve typical driving patterns were identified from the

analysis of the detailed speed and acceleration, and 14 representative sub-cycles were built-up within 3 driving cycles (André, 2004a and b, Figure 1). These test cycles enabled then the measurement of the emissions according to 12 patterns characterizing the European driving, allowing then a detailed analysis of the emissions as regards kinematic parameters. This accuracy in the emissions description was searched for to enable accurate emissions estimation approaches (street level, see Chapter 0).

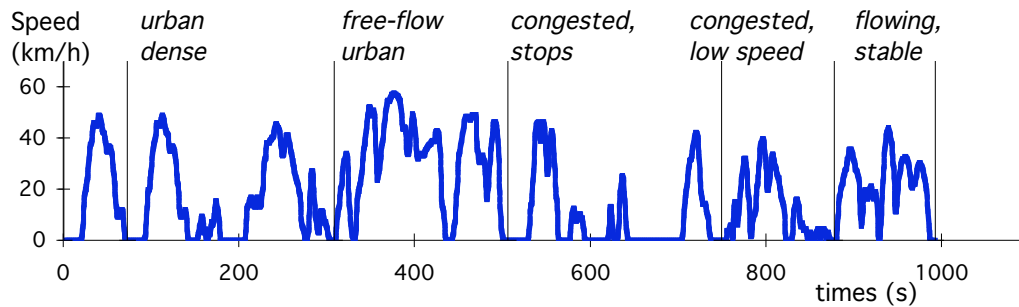


Figure 1: The ARTEMIS urban driving cycle and its structure in driving conditions

1.2.3. Driving cycles designed for high and low powered cars

These cycles were built-up using the same data and principles than the Artemis cycles, but considering two sub-samples of cars differentiated according to their motorization (power to mass rate). Compared to the Artemis cycles, they introduce then a refinement in the representativity as they are more appropriated to the cars according to their performances (see Andre et al. 2005a), and correspond in a better way to the driving conditions really observed by these two categories of vehicles.

Two sets of 5 cycles dedicated to high and low motorized cars (each car being tested according to its characteristics using the one or the other cycles set) have then been developed. The urban, rural, motorway cycles are totally compatible with the Artemis cycles in their structure and method of elaboration. A dense and a free-flow urban cycles are added.

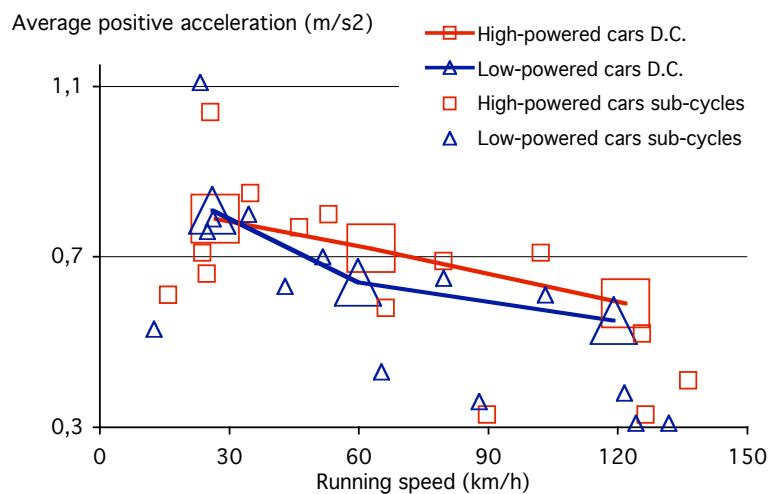


Figure 2: Difference in the driving patterns reproduced in the cycles and sub-cycles for high and low powered cars, as regards speed and acceleration.

These driving cycles (respectively Artemis.HighMot_motorway, _rural, _urban, _urbdense

and freeurban, and Artemis.LowMot_motorway, _rural, _urban, _urbdense and freeurban) are used respectively by the vehicles with high / low power to mass rate. Diesel vehicles appear to be all in the low category.

Due to the similarity between the cycles sets (equivalence in the traffic situation but difference in the driving patterns as highlighted in Figure 2), these cycles constitute a good basis to analyse the influence of the driving patterns on the emissions, even if the differences are very limited (compared to those observed between the large range of cycles). This cycles should also enable to assess the influence of considering a single set of cycles common to all the cars, rather than developing specific cycles according to the vehicle characteristics.

1.3. Methods

Considering the above list of cycles and objectives, we attempt to select contrasted cycles for different speed levels, congested cycles (Neapolitan driving, Swiss urban and motorway stop-and go cycles), cycles derived according to contrasted approaches (cycles derived according to vehicle performances, homogeneous versus heterogeneous cycles, single cycle compared to a set of contrasted cycles, etc.).

Two approaches have been used to characterize and select driving cycles. The first one, a simple approach, is mainly based on the visualization of the driving cycles as a function of 2 kinematic parameters. The second approach is based on the analysis of the kinematical content of the cycles, through the 2-dimensional distribution of the instantaneous speed and acceleration. This approach (which is obviously more rich due to the detailed description of the kinematic) aims at establishing a typology of the test conditions, this typology being then used to select contrasted cycles. In the following analyses, both approaches are presented in parallel and the charts show the combined results (i.e. the typology can be shown on the speed x acceleration charts). This should highlight the interest of the approach and reinforce the conclusions.

The driving cycles for light duty vehicles (light vans and vans) were not used for selection as the corresponding driving patterns would not have been appropriated for passenger cars. They are however considered in the analyses for their positioning as regards the other cycles.

Some driving cycles are structured in sub-cycles for the emissions analysis. Thus, they can be analysed at the 2 levels: as main cycle and per sub-cycle. Each sub-cycle is then named by the label of the driving cycle followed by the number of the sub-cycle. This is the case for the Swiss Handbook and Neapolitan driving patterns, for the Artemis driving cycles as well as other ones.

Some cycles include also pre-conditioning, transitions or post-parts that are generally not considered in the analyses.

When the sub-cycle is the appropriate “entity” to describe a driving condition, only the sub-cycle is considered as “an active” observation (i.e. which contribute elaborating the typology), while the whole cycle is considered afterwards as regards this typology (illustrative observation).

1.3.1. Simple approach

The first approach is mainly based on a simple positioning of the driving cycles as regards

variables that can be considered as relevant for emissions.

A high number of variables can be considered:

- the average speed (including the stop phase) and the running speed (stop excluded), the first one being less representative of the movement phase,
- the speed variation (through the standard deviation, the number of fluctuations, etc.),
- the acceleration variation (through the standard deviation of the acceleration, the average positive acceleration, deceleration, the number of accelerations, etc.),
- stops number and durations, etc.

The correlations between more than 51 of these parameters (calculated for the available driving cycles) are shown in Annex 2. This demonstrates that we should consider several categories of parameters, and within these categories, the parameters are quite well correlated together:

- those linked to the size of the cycle (i.e. duration, distance, duration within a certain driving condition, speed range, etc., number of stops, accelerations, etc.),
- those describing the speed (average, running, maximum, etc.),
- those describing the acceleration (average values, frequencies, etc.).

One should also remark that the stop frequency (stop/km) is not correlated to other parameters.

The running speed (stops excluded) and the average positive acceleration have been selected for these analyses. Indeed, correlation analyses have shown that these 2 parameters enable a quite satisfying description of the vehicle movement. The average acceleration is quite strongly correlated with other kinematic parameters representing the variability (stops parameters included), while being not too much correlated with the speed parameters.

Considering then the field of the driving conditions as regards speed and acceleration, we can select driving cycles allowing a good coverage, and choose cycles that would be well contrasted as regards acceleration for a given level of speed.

1.3.2. Speed and acceleration distribution approach

The second approach is based on the analysis of the 2-dimensionnal distribution of the instantaneous speed and acceleration. This distribution is calculated during the running phases (the stop phases are excluded). Stop duration is taken as supplementary variable. Respectively, 8 and 7 classes have been considered for speed and acceleration. In all, we define then 57 variables (frequencies in % of time) which constitutes an very accurate description of the speed profile.

Cycles and sub-cycles are then analysed using the Binary Correspondences Analysis. This enables identification of the principal axes and determining variables. An automatic clustering (classification), allows then the identification of typical and contrasted classes. We have thus an optimal description in classes, enabling a good coverage of the driving conditions.

We can then select representative driving cycles in these typical classes. These cycles are obviously contrasted as regards their kinematical content due to the method. This analysis is quite similar to the approach used to derive the Artemis cycles (André 2004a).

A slight refinement was however introduced, which concerns the 2-dimensionnal

distribution of the speed and acceleration. Indeed, such matrix includes generally a high number of cases with very low or null figures, the time spent at high speed and high acceleration being very rare. These “empty cells” are generally a source of trouble with the factorial analysis. The solution adopted for the building-up of the Artemis driving cycles, was to group the situations with low time frequencies (i.e. to reduce the number of acceleration classes at high speed and even to regroup high speed classes). This resulted in a lower accuracy of the description of the driving at high speed. We have here solved this problem through a distortion of the acceleration according to the speed (highlighted in Figure 3). We apply for that a multiplying rate on the acceleration, which is 1 at low speed and increase linearly up to 2 at 140 km/h. This enables artificially an improvement of the description of the high speed driving.

Normal 2-dimimensional distribution of speed and acceleration

Acceleration (m/s ²)	duration in 1/1000, stops excluded								total
	Speed (km/h)								
	<20	20-40	40-60	60-80	80-100	100-120	120-140	>140	
<-1.4	7	12	4	1	1	0	0	0	25
-1.4 ~ -0.6	43	32	16	6	3	2	1	0	104
-0.6 ~ -0.2	68	35	30	15	11	12	5	2	178
-0.2 ~ +0.2	83	52	63	45	40	55	34	11	383
+0.2 ~ +0.6	53	43	35	20	13	14	6	2	184
+0.6 ~ +1.0	31	28	13	4	3	1	0	0	79
> +1.0	26	16	4	1	0	0	0	0	47
total	310	216	166	92	71	84	46	15	1000

Distribution with a distortion of the acceleration

Acceleration (m/s ²)	duration in 1/1000, stops excluded								total
	Speed (km/h)								
	<20	20-40	40-60	60-80	80-100	100-120	120-140	>140	
<-1.4	8	18	9	4	2	1	1	0	42
-1.4 ~ -0.6	37	29	20	10	7	9	4	1	119
-0.6 ~ -0.2	54	31	27	18	17	15	8	3	172
-0.2 ~ +0.2	68	44	53	37	31	45	27	9	314
+0.2 ~ +0.6	44	36	34	22	18	22	12	3	193
+0.6 ~ +1.0	27	26	17	9	5	5	2	0	90
> +1.0	26	24	10	4	3	1	0	0	70
total	265	208	170	104	83	99	55	18	1000

Figure 3: Two-dimensional distribution of the speed and acceleration obtained with the set of driving cycles (top) and distortion introduced to improve the description of the driving at high speed (down – the acceleration classes are only indicative in that case)

1.3.3. Driving cycles and sub-cycles selection

The selection of cycles / sub-cycles will be firstly based on the second approach, because this one is the most statistically significant and it offers also criteria of ranking and representativity of the cycles. The first approach - more arbitrary – will be considered to validate the choices. Furthermore, to simplify the experimental procedure, an optimization of the selection should:

- favour entire set of sub-cycles (within a cycle) and of cycles (belonging to the same family),
- select in particular the Artemis sub-cycles as they constitute a reference for most of the emissions measurements done in the Artemis project and in other related national projects.

1.4. Preliminary classification

The 2 above approaches cannot be conducted considering directly the whole set of driving cycles, because of the too large field covered. Furthermore, preliminary analyses have demonstrated that considering the whole range of driving doesn't enable a pertinent description

of the different driving types (at least urban and motorway) and lead to trivial conclusions such as opposing high to low speeds. It is therefore pertinent and useful to get a first classification, allowing analyses by rough classes of cycles.

There are several possibilities for this preliminary classification:

- to consider urban, rural and motorway cycles according to their definition or “official status”; this approach appeared as not appropriate as definitions are not always coherent. The following analyses will demonstrate it.
- to define large classes according to the speed level (for instance, 0 - 40 km/h for urban driving cycles, 35 - 80 km/h for road driving, 70 - 100 km/h for main road driving, 90 - 140 km/h for motorway driving). Although quite arbitrary, such a breakdown enables the identification of quite homogeneous groups of cycles.

The analysis of the speed and acceleration distribution (as described above) was used here. This method identifies the factorial axes as follows: the Axis 1 is typically a speed axis, which opposes high speeds to low acceleration rates and frequency. The Axes 2 and 3 represents well the frequency of the accelerations, and differ as regards their speed range. The classification (full list in Annex 3) enables easily the identification 4 homogeneous sets of driving cycles:

- 14 motorway cycles (or sub-cycles) driven at an average speed of 121 km/h, with very low occurrence of stops. The most representative of this group are the Artemis motorway sub-cycles and their equivalent within the High- Low-powered cycles, the Handbook.R1_I.
- 21 cycles corresponding to the driving on main roads, at a quite stabilized speed of 92 km/h on average, with one stop every 14 km. The Artemis rural_4 sub-cycles and equivalent, LDV-PVU.CommercialCars.motorway_1, Handbook.R1_II, Inrets.autoroute1 and 2, US06, modemHyzem.road2 and motorway1 belong to this group. It is interesting to note that numerous motorway and rural cycles are part of this group.
- 42 cycles corresponding to a driving on rural roads, possibly also in sub-urban or extra-urban conditions (as suggested by the affectation in this class of one Artemis urban sub-cycle, several free-flow urban cycles or sub-cycles, the European standard extra-urban cycle, and even several Neapolitan driving patterns). These cycles have together an average speed of 50 km/h, and record about one stop every 2 kilometres (which gives a rough idea of length between intersections). The most significant cycles of this group are Inrets.route2, modemHyzem.road and road1, modemIM.Road, as well as Napoli.17 and 20 patterns, US.SC03, modemIM.Short. We note that the FTP first phase and whole cycle, the US_Highway, IM240, and European EUDC belong also to this group.
- 74 urban cycles / sub-cycles, with an average speed of 15 km/h, 30% of the duration at stop, and about one stop every 200 meters, which typically corresponds to an urban area. The most representative cycles of this category are respectively Artemis.urban1 and 4, US.NYCC, modem.urban1 and 8, modemHyzem.urban2, Inrets.urbainfluide1, modemIM.Urban_Slow. The FTP second phase, US. NYCC, European ECE belong to this category, which includes most of the free-flow and congested cycles and sub-cycles and most of the Neapolitan patterns.

. The classification process as well as the high variability of the cycles are well illustrated in Figure 5 and Figure 6. The average characteristics (computed per group of cycles) are provided in Table 1.

Class	Number of cycles or sub-cycles	Average speed (km/h)	Running speed (km/h)	Average positive acceleration (m/s ²)	Number of accelerations /km	Stop duration (%)	Number of stops /km
1 – motorway cycles	14	121	122	0,41	0,4	0,3	0,02
2 – main roads (highways) cycles	21	92	94	0,60	1,1	1,5	0,07
3 – rural (and suburban) cycles	42	50	53	0,68	2,7	6,9	0,5
4 – urban cycles	74	15	21	0,73	8,1	29,8	5,8
All together	151	45	53	0,67	2,6	16,1	1,1

Table 1: Average characteristics of the clusters of driving cycles, determined through analysis and automatic classification of the driving cycles described by their crossed distribution of the instantaneous speed and acceleration (average values calculated for the samples)

As the motorway and highways groups are quite comparable and relatively limited in number, they will be analysed together in the following.

Average positive acceleration
(m/s²)

WP3141 - Selection of driving cycles

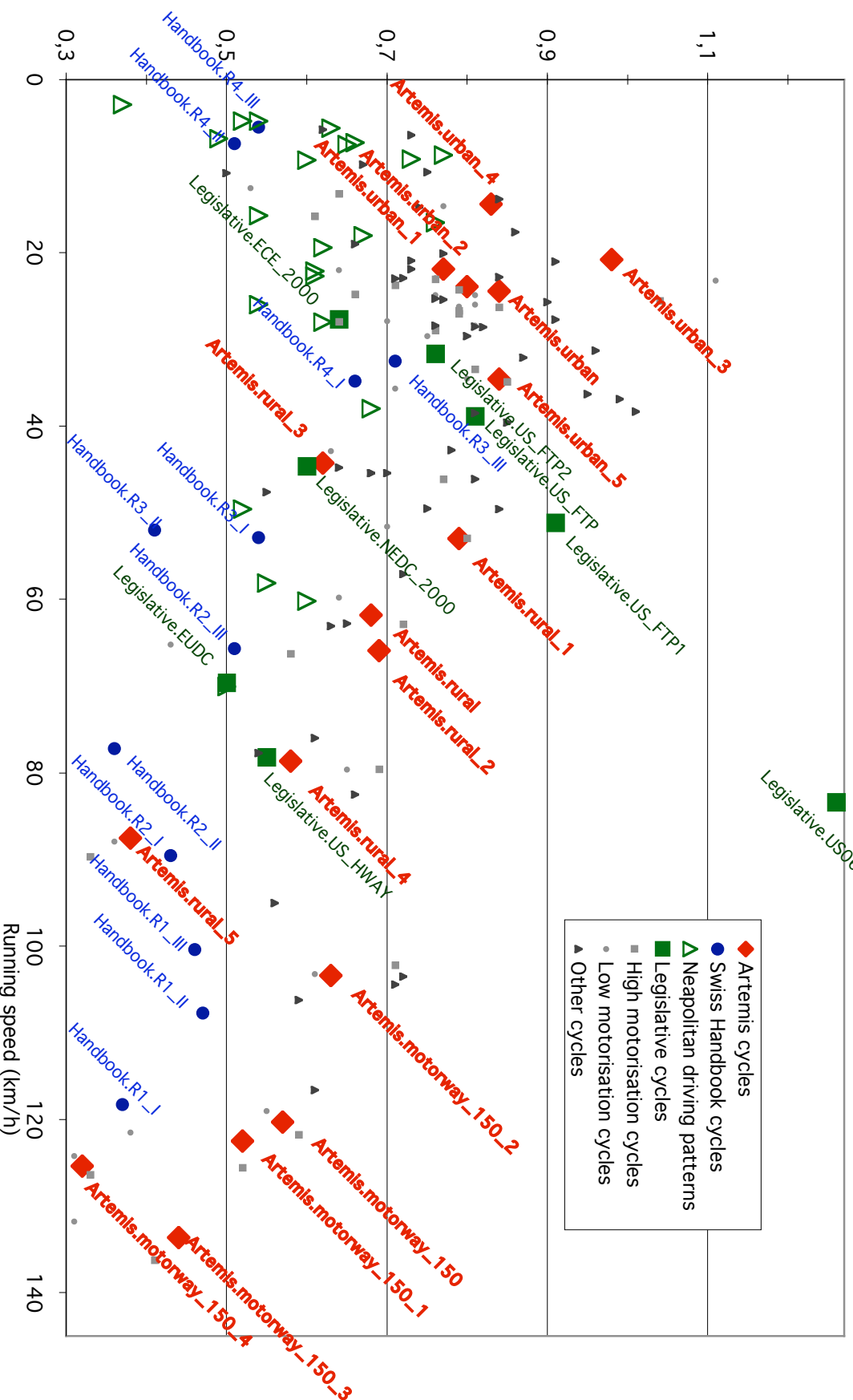


Figure 4: Visualization of the main cycles as regards speed and acceleration

Average positive acceleration
(m/s²)

WP3141 - Urban driving cycles

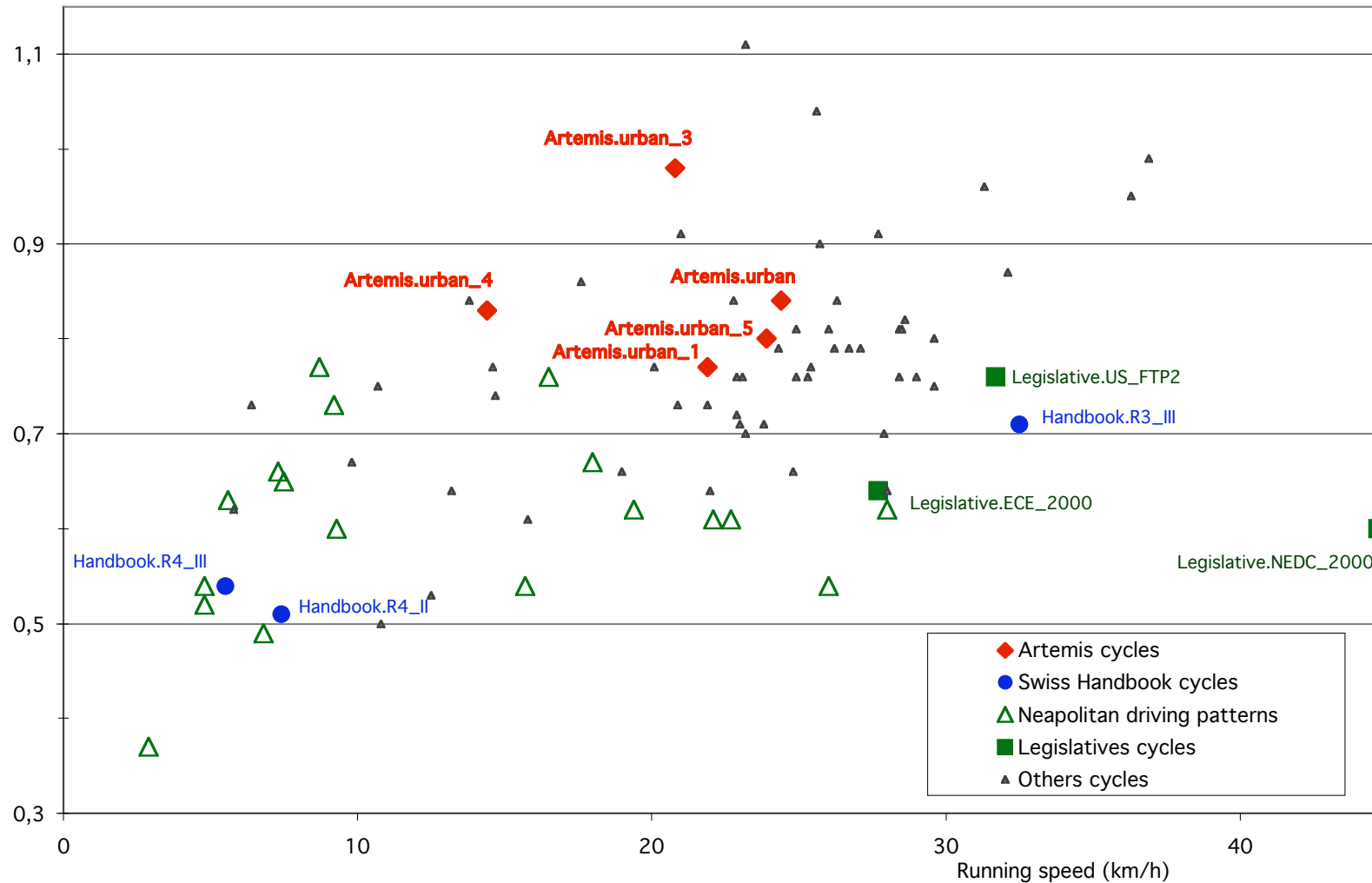


Figure 5: Visualization of the urban cycles as regards speed and acceleration – the urban class results from the automatic classification according to the 2-dimensional distribution of the instantaneous speed and acceleration

Average positive acceleration
(m/s²)

WP3141 - Suburban/rural, main road and motorway driving cycles

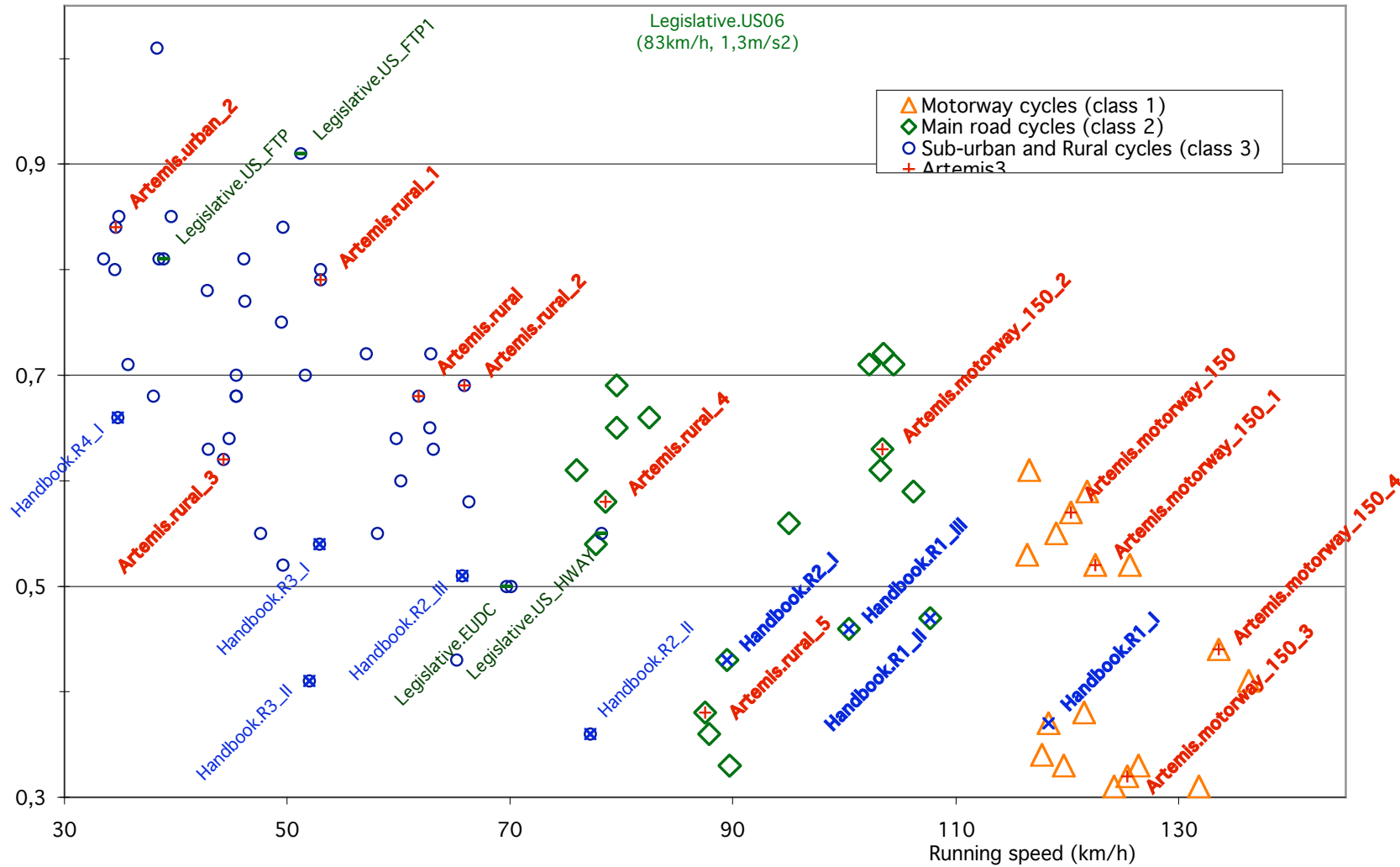


Figure 6: Visualization of the rural / suburban, main road and motorway cycles as regards speed and acceleration – the 3 classes result from the automatic classification according to the 2-dimensional distribution of the instantaneous speed and acceleration

1.5. Motorway /main road driving cycles

1.5.1. Simple Analysis of the motorway driving cycles

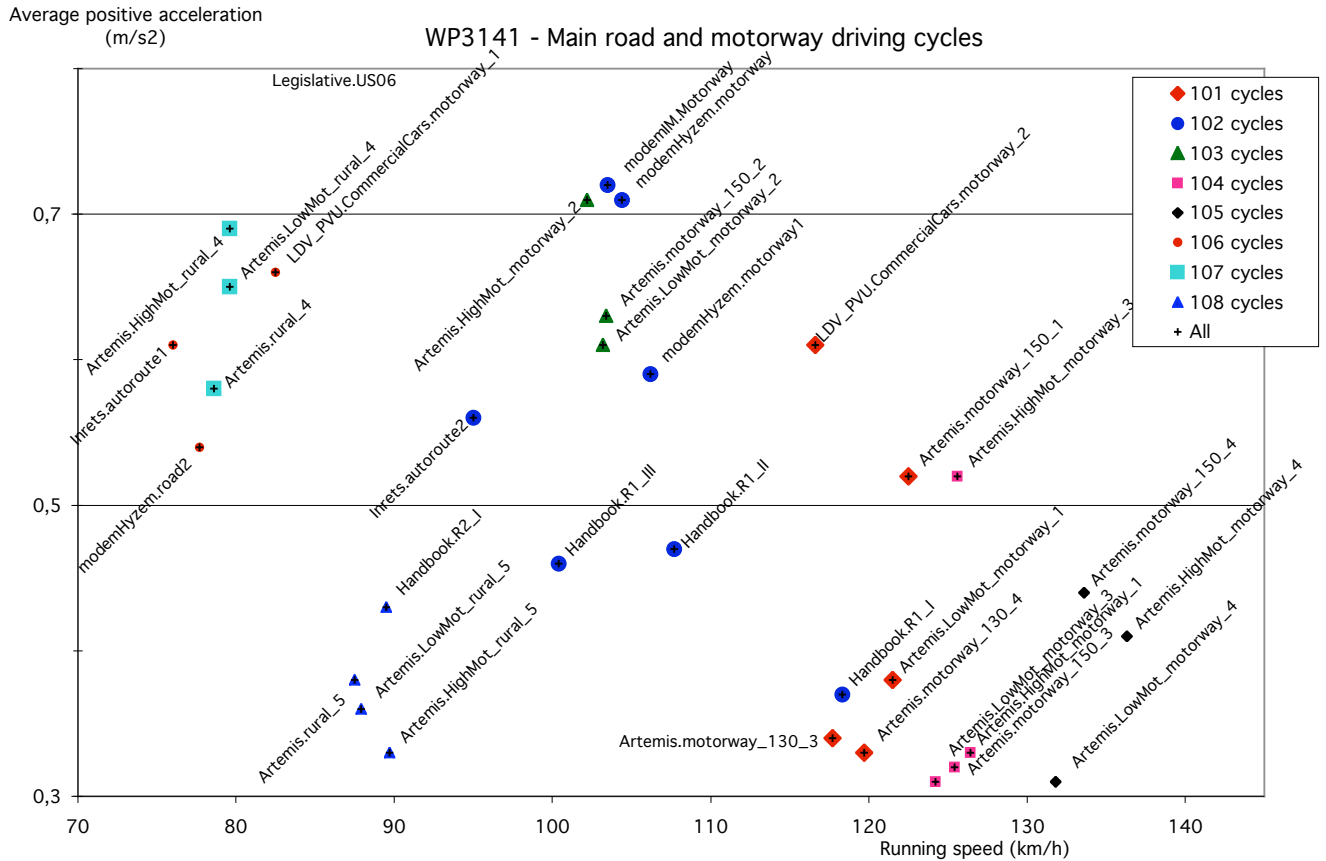


Figure 7: visualization of the motorway and highway cycles as regards the running speed (in x) and the average positive acceleration (in y) – the classes 1-8 results from the automatic classification based on the 2-dimensional distribution of the speed and acceleration (see next section)

The simple analysis of the driving cycles as a function of running speed and acceleration (Figure 7) suggests:

- the Artemis.motorway cycle enables a good coverage for high speeds (sub-cycles 1, 3, 4) and high acceleration (sub-cycles 1, 4). The Artemis.motorway130 cycle (limited to 130 km/h) does not offer such a contrast (except for sub-cycle 1)
- the two sub-cycles with high acceleration can be opposed to the corresponding sub-cycles from the motorway cycles dedicated to vehicles with low power-to-mass rates (Artemis.LowMot_cycles).
- Generally and for high speeds, both Artemis.motorway and Artemis.motorway130 cycles show a high contrast with Handbook.R1_I (which has lower acceleration rate). LDV-PVU.CommercialCars.motorway_1 (dedicated to vehicles with professional use) is also well and directly opposed to Handbook.R1_I.
- Handbook driving patterns R1_I, II, III and R2_I have relatively low acceleration rates.

It is then interesting to use these cycles as representative of driving patterns with low acceleration, opposed to the Artemis motorway sub-cycles.

Considering the lowest speed levels, we observe :

- at about 105 km/h, a strong contrast between Handbook.R1_I and II on one side and modemHyzem.motorway1 or modemIM.motorway (high acceleration).
- at about 90 km/h, a contrast in acceleration between Artemis.rural_5 and Handbook.R2_I on one side (with quite low acceleration level) and Artemis.rural_4, or worse Artemis.HighMot_rural_4 (vehicles with high power-to-mass rate) or LDV-PVU.CommercialCars.motorway_1 (dedicated to vehicles with professional use) that presents high acceleration rate.

We should also note the very high level of acceleration of the US cycle US06 (dedicated to cover high speed and acceleration not covered in FTP75). This cycle is not represented because it is out of the scale. It won't be used in the following as we are not well aware about its context.

This simple analysis suggests then the use of the following cycles to get a contrasted coverage of the driving conditions:

- Artemis.motorway (alternatively Artemis.motorway130), Artemis.LowMot_motorway (reaching also 150 km/h) when possible, Handbook R1 (sub-cycles 1 to 3) and R2 (sub-cycle 1) for high speeds,
- modem-HyZem.motorway or modemIM.motorway, Artemis.rural at about 105 km/h,
- Artemis.HighMot_rural, LDV-PVU.CommercialCars.motorway_1 at about 90 km/h.

1.5.2. Speed - acceleration Analysis for the motorway driving cycles

The classification of the driving cycles enables the identification of 8 contrasted classes described in Table 2, and shown in the principal axes in Figure 8.

Roughly, the axis 1 is linked to the speed level, the second axis is linked to the stop occurrence, and the third one is linked to the acceleration level. We observe a quite large contrast for high speeds.

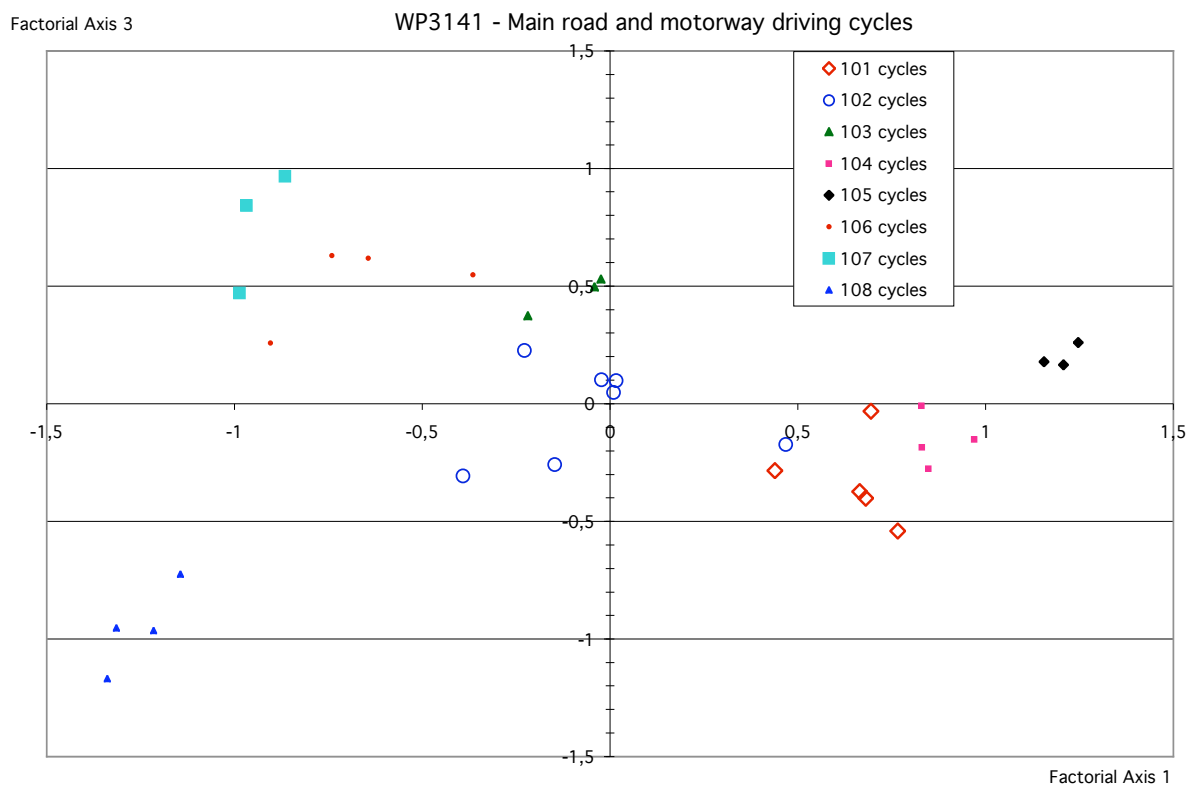
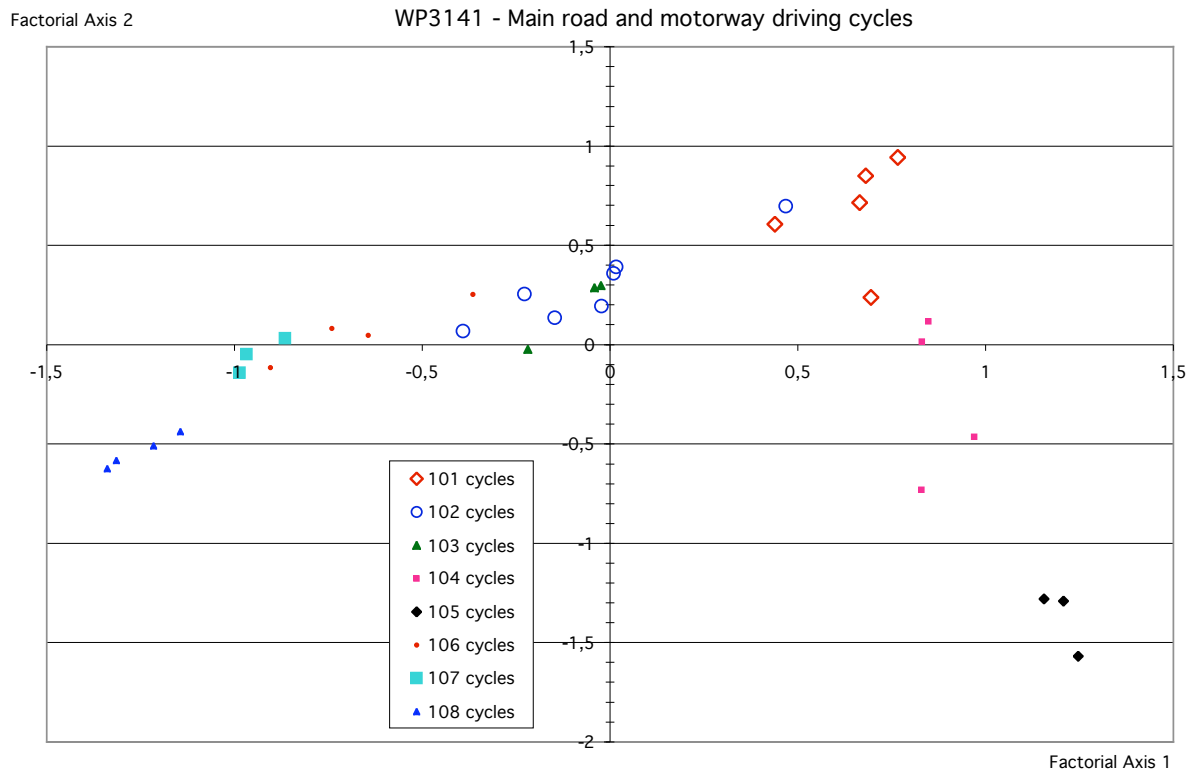


Figure 8: Partition of the motorway and highway cycles as regards the 3 main axes (Axis 1 \approx speed, Axis 2 \approx stop number, Axis 3 \approx acceleration)

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

Class and characteristics of the cycles	Number of cycles sub-cycles	Average speed (km/h)	Running speed (km/h)	Average positive acceleration (m/s ²)	Number of accelerations /km	Stop duration (%)	Number of stops /km
1. high speed 140 km/h – low accelerations	6	118,5	119,3	0,45	0,42	0,6	0,03
2. long stable cycles, speeds 120 km/h, stop	7	103,4	104,5	0,55	0,71	1,1	0,04
3. speeds 120 km/h with strong accelerations	4	103,0	103,0	0,64	1,48	0,0	0,00
4. very high speed	4	125,5	125,5	0,37	0,39	0,0	0,00
5. very high but unstable speeds	3	134,0	134,0	0,39	0,42	0,0	0,00
6. low speeds (20-80 km/h) and stop	4	77,3	79,6	0,77	1,48	2,9	0,17
7. low speed (60 – 100 km/h) and high number of accelerations	3	79,2	79,2	0,64	2,21	0,0	0,00
8. low stables speeds (80 – 100 km/h)	4	88,9	88,9	0,38	0,87	0,0	0,00
All together	35	99,8	101,1	0,52	0,86	1,2	0,06

Table 2: Average characteristics of the clusters of motorway and highway driving cycles, determined through analysis and automatic classification of the driving cycles described by their crossed distribution of the instantaneous speed and acceleration

Class	Ranked representative cycles
1. high speed 140 km/h – low accelerations	Artemis.motorway_130_3; <u>Artemis.LowMot_motorway_1</u> ; LDV_PVU.CommercialCars.motorway_2; <u>Artemis.motorway_150_1</u> ; Artemis.motorway_150_1; Artemis.motorway_130_4;
2. long stable cycles, speeds 120 km/h, stop	modemIM.Motorway; modemHyzem.motorway; <u>Handbook.R1_II</u> ; modemHyzem.motorway1; Inrets.autoroute2; <u>Handbook.R1_III</u> ; <u>Handbook.R1_I</u>
3. speeds 120 km/h with strong accelerations	<u>Artemis.LowMot_motorway_2</u> ; <u>Artemis.motorway_150_2</u> ; Artemis.motorway_150_2; Artemis.HighMot_motorway_2; ; ;
4. very high speed	Artemis.HighMot_motorway_1; <u>Artemis.motorway_150_3</u> ; Artemis.HighMot_motorway_3; <u>Artemis.LowMot_motorway_3</u> ; ; ;
5. very high but unstable speeds	<u>Artemis.LowMot_motorway_4</u> ; <u>Artemis.motorway_150_4</u> ; Artemis.HighMot_motorway_4; ; ; ;
6. low speeds (20-80 km/h) and stop	Inrets.autoroute1; <u>LDV_PVU.CommercialCars.motorway_1</u> ; modemHyzem.road2; Legislative.US06; ; ;
7. low speed (60 – 100 km/h) and high number of accelerations.	<u>Artemis.rural_4</u> ; Artemis.LowMot_rural_4; Artemis.HighMot_rural_4; ; ; ;
8. low stables speeds (80 – 100 km/h)	<u>Artemis.rural_5</u> ; Artemis.HighMot_rural_5; Artemis.LowMot_rural_5; <u>Handbook.R2_I</u> ; ; ;

Table 3: Composition of the driving cycles classes determined through the analysis and automatic classification of the motorway driving cycles. In yellow underlined, the interesting candidate cycles/sub-cycles

The analysis of the classes suggests that:

- Classes 2 and 3 have similar speed (103 km/h) but differ in acceleration level,
- Class 1 has a higher speed level (119 km/h),
- Classes 4 and 5 have very high level of speed and differ in acceleration (level and number),
- Classes 6 to 8 have a low speed (77 to 90 km/h) but differ in acceleration level and numbers.

We can then select representative or typical cycles / sub-cycles to cover this typology:

- Handbook.R1_I, II and III (driving cycle R1) represent well the class 2, (together with modemIM.motorway and modem-HyZem.motorway and motorway1).
- Artemis.motorway enables the coverage of the clusters 1, 3, 4, 5. However, Artemis.motorway130 represents only class 1 and 3. One should note that these high speed classes (1,4) and high speed – high acceleration classes (3,5) are only covered by the Artemis

cycles and by the dedicated cycles (Artemis.LowMot_ and Artemis.HighMot_motorway).

- Artemis.rural_5 and Handbook.R2_I belong to class 8.
- Artemis.rural_4 represents class 7.
- Class 6 can be represented by LDV_PVU.CommercialCars.motorway_1 (stronger accelerations), INRETS.autoroute1, modem.HyZem.road2, or US06.

This leads to (in a good accordance with the simple analysis) the following selection:

- Artemis.motorway (alternatively Artemis.motorway130) sub-cycles 1 to 4, Artemis.LowMot_motorway sub-cycles 1 to 4, Handbook.R1 (sub-cycles I, II, III),
- Artemis.rural (sub-cycles 4 and 5), LDV_PVU.CommercialCars.motorway and Handbook R2 (sub-cycle I).

1.6. Urban driving cycles

1.6.1. Simple analysis of the urban driving cycles

The visualisation of the urban driving as regards speed and acceleration (Figure 5) suggests an analysis by speed ranges.

The range 0-12 km/h : is not covered by the Artemis cycles. Handbook.R4_II and III are part of this range. Naples Driving patterns N° 2, 3, 5, 7, 8, 12, 13, 18, 19, 23 are very slow. The first 4 are however too short to be used as driving cycles. 8 and 13 are very long (about 1500 s). A combination of 18 (or 12), 19, 23 should be interesting in duration (1119 s) and coverage. The others cycles in this range are: modem.urban6 and 9, Inrets.urbainlent2 and Inrets.lentcourt.

This suggests the selection of Handbook.R4 and Neapolitan driving patterns 18 (or 12), 19 and 23 combined in a single cycle.

Range 12-38 km/h : the Artemis.urban sub-cycles 3, 4 and 5 cover a middle range of speed, with rather high accelerations. Naples DP 4, 9 to 11, 15, 21 present low acceleration rates, over the same speed range (some are very short). 9 and 15 are relatively short. A combination of 10, 11, 15, 21 should enable a good range of speed.

Handbook.R3_III has also low acceleration rate at relatively high speed (32-35 km/h). The modem.urban cycles 2, 5, 7, 10, 13 draw a line of cycles at high level of acceleration over a large range of speeds. It could be then very interesting to use modem 5-6-7 (in one modem cycle) and 4-10-13 recombined in a single cycle.

We can note also that the NEDC urban driving cycle (i.e. Legislative.NEDC_2000) has a relatively high level of speed and a low level of acceleration, compared to the cloud of the other urban cycles (Figure 5).

This suggests then the use of Artemis.urban, a Neapolitan cycle based on DP 10, 11, 15, 21, modem cycles 5-6-7 and 4-10-13, and possibly Handbook driving pattern III in R3 cycle.

1.6.2. Speed - acceleration Analysis for the urban driving cycles

The analysis of the speed x acceleration distribution and the classification identify 8 classes as

described in Table 4 and shown in Figure 9.

Class and characteristics of the cycles	Number of cycles or sub-cycles	Average speed (km/h)	Running speed (km/h)	Average positive acceleration (m/s ²)	Number of accelerations /km	Stop duration (%)	Number of stops /km
1. speeds 60-80 km/h, high accelerations, high number of accelerations and strong accelerations	14	21,2	28,2	0,82	6,2	24,8	2,8
2. speeds 40-60 km/h, low accelerations, few stops	7	25,5	29,3	0,68	4,7	13,2	2,0
3. speeds 40 km/h, few stops, strong accelerations	14	18,2	23,6	0,75	7,4	22,9	3,3
4. speeds 20-40 km/h, high number of accelerations and strong accelerations	13	14,8	19,0	0,72	11,5	22,2	5,3
5. speeds 80-100 km/h and 40, strong accelerations, high speed and maximum speed	1	30,2	36,9	0,99	4,8	18,0	3,6
6. high stop duration and number, low speed, average accelerations	10	4,6	12,5	0,73	8,7	63,6	30,0
7. speeds 20 km/h, high number of low accelerations, low speed	2	5,2	6,2	0,52	14,5	16,1	7,7
8. speeds 20 km/h, high stop duration and number, high number of accelerations and strong accelerations	13	5,6	8,6	0,65	21,5	35,5	26,5
All together	74	14,9	21,2	0,73	8,1	29,8	5,8

Table 4: Average characteristics of the clusters of urban driving cycles, determined through analysis and automatic classification

Class	Ranked representative cycles
1. speeds 60-80 km/h, high accelerations, high number of accelerations and strong accelerations	Artemis.HighMot_urbdense_1; modemHyzem.urban1; <u>modem.urban13</u> ; modem.urban1; modemHyzem.urban; Artemis.HighMot_urban_1; Artemis.HighMot_freurban_1; LDV_PVU.CommercialCars.urban_1; modemiM.Urban_Free_Flow; Inrets.urbainfluide3
2. speeds 40-60 km/h, low accelerations, few stops	modem.urban12; <u>Handbook.R3_III</u> ; Napoli.4; Legislative.US_FTP2; Artemis.LowMot_freurban_3; Artemis.HighMot_freurban_3; <u>Napoli.15</u> ;
3. speeds 40 km/h, few stops, strong accelerations	Inrets.urbainfluidecourt; Inrets.urbainfluide2; modem.urban8; modem.urban10; Artemis.LowMot_urban_1; modemiM.Urban_Slow; Artemis.LowMot_urban_5; Legislative.ECE_2000; modem.urban3; Artemis.HighMot_urban_5; <u>Artemis.urban_5</u> ; <u>Napoli.21</u>
4. speeds 20-40 km/h, high number of accelerations and strong accelerations	modem.urban4; Artemis.HighMot_urban_4; Napoli.1; LDV_PVU.CommercialCars.urban_3; Napoli.11; Inrets.urbainfluide1; Napoli.14; <u>Artemis.urban_4</u> ; <u>Napoli.10</u> ; Napoli.9; <u>Artemis.urban_1</u>
5. speeds 80-100 km/h and 40, strong accelerations, high speed and maximum speed	<u>modem.urban7</u> ;
6. high stop duration and number, low speed, average accelerations	Artemis.LowMot_urbdense_2; <u>Artemis.urban_3</u> ; Artemis.HighMot_urbdense_2; Napoli.13; Napoli.12; Napoli.7; <u>Napoli.23</u> ; Artemis.LowMot_urban_3; Napoli.3; Artemis.HighMot_urban_3
7. speeds 20 km/h, high number of low accelerations, low speed	<u>Handbook.R4_II</u> ; <u>Handbook.R4_III</u> ; ; ; ; ; ; ;
8. speeds 20 km/h, high stop duration and number, high number of accelerations and strong accelerations	Inrets.lentcourt; <u>Napoli.19</u> ; Napoli.5; modem.urban9; Inrets.urbainlent1; Inrets.urbainlent2; Artemis.LowMot_urban_4; Napoli.2; Artemis.LowMot_urbdense_3; Napoli.8; modem.urban6; <u>Napoli.18</u>

Table 5: Composition of the driving cycles classes determined through the analysis and automatic classification of the urban driving cycles. In yellow underlined, the interesting candidate cycles/sub-cycles

The analysis of these clusters suggests that:

- Classes 1 to 4 cover an intermediate range of speeds (15 – 25 km/h) and differ in accelerations (level and number) and in stops,
- Class 5 (one cycle) is very particular, with high speeds and acceleration,
- Class 6, 7, 8 are quite similar in speed but differ either in stop or in accelerations.

We could then select representative cycles or sub-cycles in these classes :

- Artemis.urban_1 and 4 belong to class 4, Artemis.urban_3 and 5 belong respectively to classes 6 and 3. We have then a quite large coverage of these classes through the Artemis cycles,
- modem.urban13 and 5 offer a good coverage of the class 1,
- Handbook.R3_III and Napoli.15 are 2 contrasted points of the class 2,
- modem.urban10 (or 8), Napoli.21 and Artemis.urban_5 present a large coverage of class 3,
- modem.urban4, Artemis.urban_1 and 4, Napoli.10 and 11 represent well class 4,
- modem.urban7 is the only representative of class 5,
- Artemis.urban_3, Napoli.12 and 23 allow a good coverage of class 6,
- Handbook.R4_II and III are the class 7,
- Napoli.19, 18 and modem.urban6 is a quite good selection for class 8.

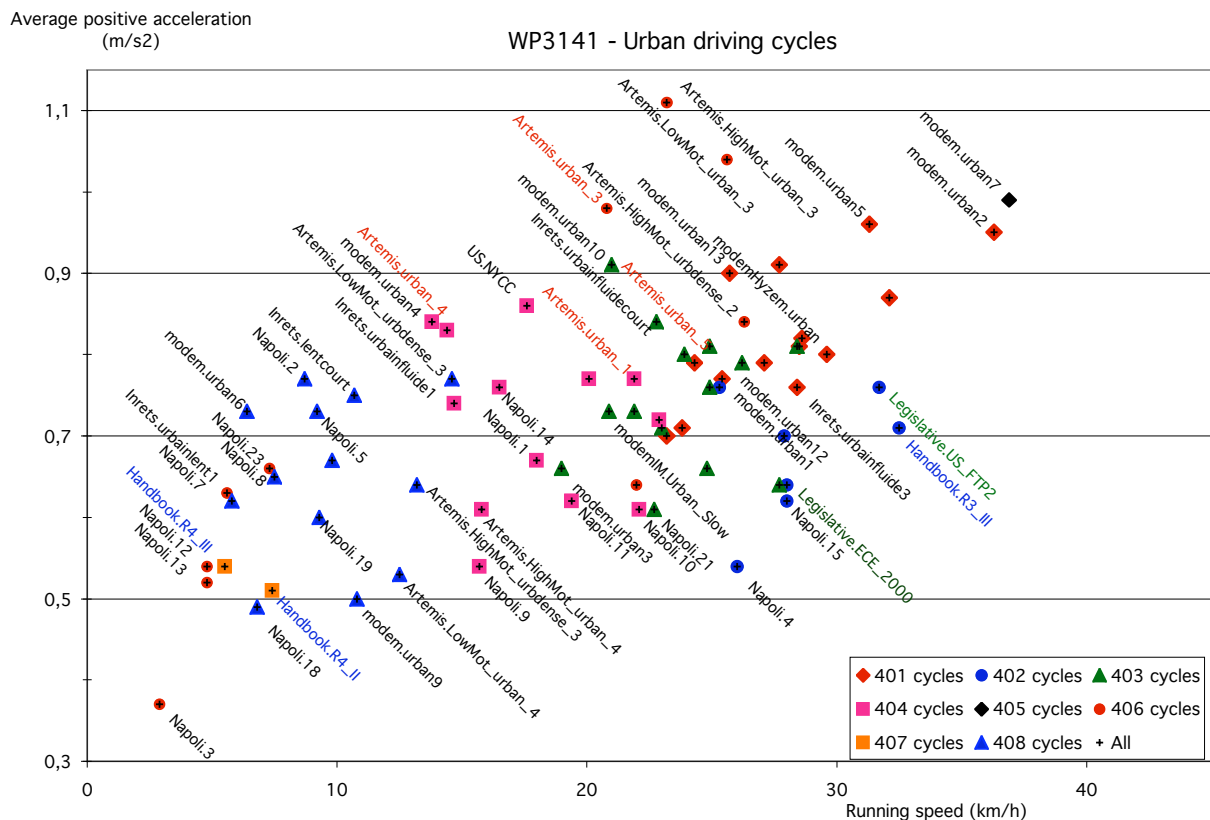


Figure 9: Partition of the urban cycles into 8 classes, according to the running speed and acceleration

We have then a relatively satisfying coverage of the classes, by using the cycles that were already identified by the simple analysis. The similarities and contrasts are however not always the same in the both approaches.

This leads finally to the following selection: the Artemis.urban sub-cycles 1, 3, 4, and 5, a Neapolitan cycle based on driving patterns 10, (possibly 11), 15, 21, the modem.urban sub-cycles 5-6-7, or 4-10-13, or in an optimal way a modem cycle based on 5-7-13 (the other sub-cycles being of less interest), possibly Handbook.R3_III,

and for the low speeds: Handbook.R4_II and III (stop and go) and a Neapolitan cycle based on driving patterns 18, 19, 23.

1.7. Rural-road and sub-urban driving cycles

1.7.1. Simple Analysis of the road driving cycles

The “de-visu” analysis of the rural-road driving cycles (cf. Figure 10) suggests that:

- The Artemis.urban_2 and rural sub-cycles cover a relatively large range of speeds (from 35 to 65 km/h) with a rather high level of acceleration (except for Artemis.rural_3),
- The Handbook.R2_II and III, R3_I and II, and R4_I sub-cycles cover the whole range of speeds (35 to 75 km/h) with a low level of acceleration,
- Naples driving patterns 20, 17 and 22 are also in this low level of acceleration),
- On the opposite side (higher level of acceleration), we can find the cycles: Inrets.route1, the FTP75 first part (Legislative.US_FTP_1, while the second part is considered as urban), modemHyzem.road and road1, and the US Highway for the highest speeds,
- Finally, Artemis.LowMot_Rural sub-cycles offer good contrasts in acceleration with the Artemis.rural (sub-cycles 1 and 2).

This suggests then the use of: Artemis.rural and eventually Artemis.LowMot_Rural, Artemis.urban for sub-cycle 2, Handbook.R2 (I,II,III), R3 (I,II,III) and R4 (I) already considered for urban, Inrets.route1, modemHyzem.road and.road1, and the US FTP and Highway.

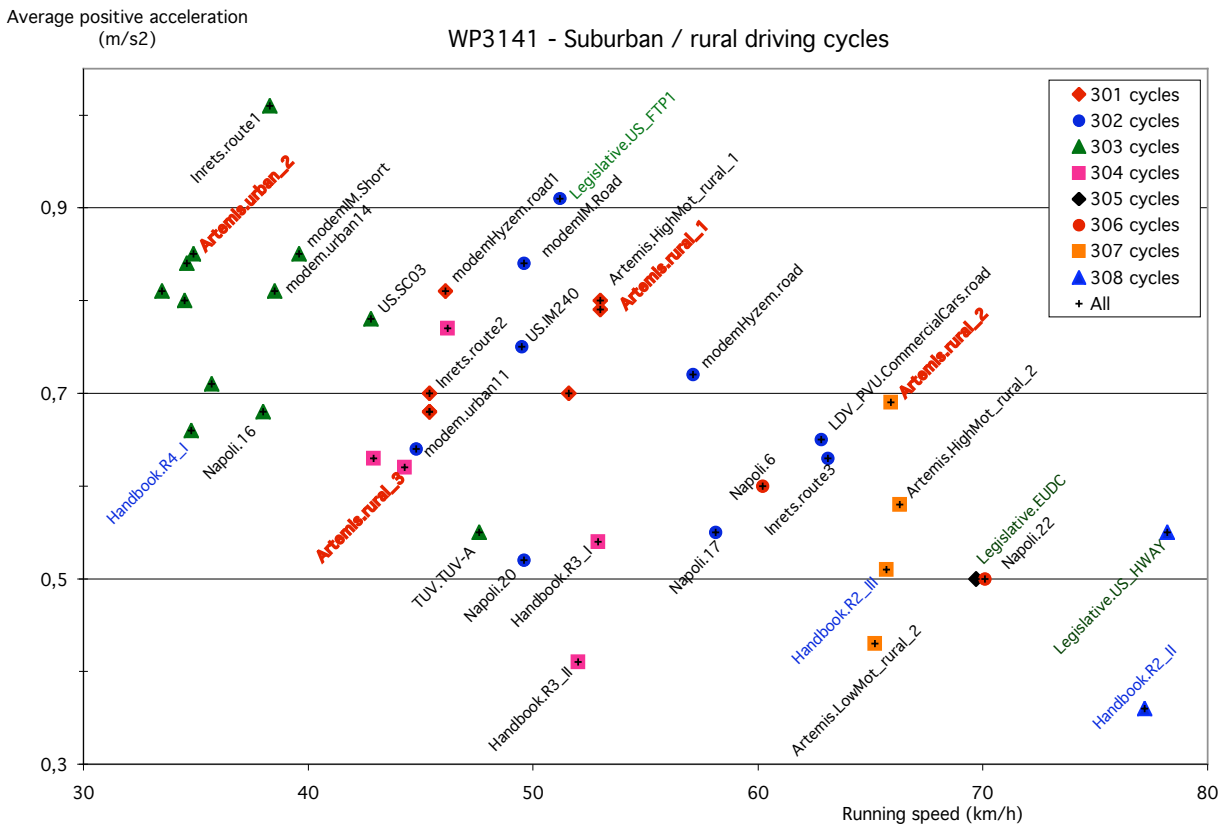


Figure 10: Classification of the rural-road / sub-urban driving cycles as regards the running speed (in x) and the average positive acceleration (in y).

1.7.2. Speed - acceleration Analysis for the rural driving cycles

The analysis of the speed x acceleration distribution and the classification define 8 classes as described in Table 6 and shown in Figure 10. The factorial axes can be defined as follows:

- axis 1 (33%) opposes high speeds (80-140 km/h) to low speeds with high stop number and duration,
- axis 2 (14%) opposes stable speeds (60-80 km/h) to high and variable speeds,
- axis 3 (12%) opposes cycles with quite high speeds to cycles with low and high speeds, stops and strong accelerations.

Class and characteristics of the cycles	Number of cycles or sub-cycles	Average speed (km/h)	Running speed (km/h)	Average positive acceleration (m/s ²)	Number of accelerations /km	Stop duration (%)	Number of stops /km
1. speeds 60-80 km/h, strong acceleration, high number of acceleration, strong accelerations, stops	7	44,0	47,8	0,74	3,9	8,0	0,65
2. long cycles, speeds 100 km/h, average accelerations	9	50,2	53,9	0,69	2,7	6,8	0,38
3. high stop number and duration, speeds 20-40 km/h, strong acceleration and high number of strong acceleration	12	32,7	37,9	0,78	3,6	13,7	1,45
4. stable speeds 60 km/h, few stops, low acceleration	5	48,2	49,1	0,59	2,5	2,0	0,21
5. speeds 120-140 km/h and stop, high speeds, low acceleration	1	62,6	69,7	0,50	0,6	10,3	0,29
6. high speeds (100-120 km/h), few stops, high speed, low acceleration	2	67,2	68,1	0,55	3,5	1,3	0,07
7. speeds 80 km/h, no stop, low acceleration, fluctuations	4	65,7	65,7	0,55	1,3	0,0	0,00
8. speeds 100-80 km/h, no stop, low acceleration	2	77,5	77,9	0,46	0,5	0,5	0,09
All together	42	49,7	53,4	0,68	2,7	6,9	0,46

Table 6: Average characteristics of the clusters of rural-road / sub-urban driving cycles, determined through analysis and automatic classification

Class	Ranked representative cycles
1. speeds 60-80 km/h, strong acceleration, high number of acceleration, strong accelerations, stops	<u>Artemis.LowMot_rural_1</u> ; Inrets.route2; modermHyzem.road1; Inrets.routecourt; Inrets.routecourt; Artemis.HighMot_rural_1; <u>Artemis.rural_1</u> ;
2. long cycles, speeds 100 km/h, average accelerations	<u>modermHyzem.road</u> ; moderm.urban11; US.IM240; <u>Napoli.17</u> ; Napoli.20; modermIM.Road; Legislative.US_FTP1; LDV_PVU.CommercialCars.road; Inrets.route3;
3. high stop number and duration, speeds 20-40 km/h, strong acceleration and high number of strong acceleration	<u>Artemis.urban_2</u> ; Artemis.HighMot_freeurban_2; moderm.urban14; Artemis.HighMot_urban_2; <u>Artemis.LowMot_urban_2</u> ; US.SC03; <u>Artemis.LowMot_freeurban_2</u> ; Inrets.route1; modermIM.Short; Napoli.16; <u>Handbook.R4_I</u> ;
4. stable speeds 60 km/h, few stops, low acceleration	<u>Artemis.rural_3</u> ; Artemis.HighMot_rural_3; <u>Artemis.LowMot_rural_3</u> ; <u>Handbook.R3_I</u> ; <u>Handbook.R3_II</u> ;
5. speeds 120-140 km/h and stop, high speeds, low acceleration	Legislative.EUDC;
6. high speeds (100-120 km/h), few stops, high speed, low acceleration	Napoli.22; <u>Napoli.6</u> ;
7. speeds 80 km/h, no stop, low acceleration, fluctuations	Artemis.HighMot_rural_2; <u>Artemis.rural_2</u> ; <u>Artemis.LowMot_rural_2</u> ; <u>Handbook.R2_III</u> ;
8. speeds 100-80 km/h, no stop, low acceleration	Legislative.US_HWAY; <u>Handbook.R2_II</u> ;

Table 7: Rural/suburban cycles classes. In yellow underlined, the candidate cycles/sub-cycles

The analysis of these clusters suggests that:

- Classes 1 to 4 are in the range of speeds 38-54 km/h. Classes 1 and 3 present higher level in accelerations (level and number), class 4 has the lowest acceleration rate (in average).
- Class 5 (one cycle) is very particular, with high speeds low acceleration and stop.

- Classes 6, 7, 8 have the highest speed levels (65 to 78 km/h) and differ by their stop and accelerations frequencies.

We can select representative cycles and sub-cycles in these classes, taken into account that:

- Artemis.rural and urban sub-cycles are present in classes 1, 3, 4, 7.
- For class 2, modemHyzem.road and LDV-PVU.CommercialCars_road are two well contrasted cycles.
- Artemis.rural_1 (and Artemis.LowMot_Rural_1) would provide a good coverage of class 1.
- Artemis.urban_2 and Handbook.R4_I are contrasted in class 3.
- Artemis.rural_3 and Handbook.R3_I or II offer a large contrast in the class 4.
- Legislative.EUDC (NEDC extra-urban part) determines the class 6. By the fact, it appears as an atypical cycle (compared to the actual transient cycles). As we did not consider the urban part of NEDC, we won't use also this extra-urban part.
- Two Neapolitan driving patterns (22 and 6) constitute the 6th class. As the 22 is too long, it could be more interesting to consider the driving pattern 6, within a composite cycle.
- Artemis.rural_2 and Artemis.LowMot_Rural_2 or Handbook.R2_III cover the class 7.
- Handbook.R2_II and US highway constitute the 8th class.

This leads to the selection of: Artemis.rural (sub-cycles 1, 2, 3) and Artemis.urban (sub-cycle 2) already considered, Handbook.R2 (sub-cycles II, III), R3 (sub-cycles I, II) and R4 (sub-cycle I) these cycles being already considered in the other selections, modemHyzem.road and a Neapolitan cycle based on driving patterns 6 and 17.

1.8. Recapitulation and conclusion

This chapter has enabled the review of a large range of cycles with the aim of studying their influence on the pollutant emissions. A characterization approach was developed, by considering the 2-dimensionnal distribution of the instantaneous speed and acceleration. The automatic classification identified first a clustering into 4 main categories of driving (motorway, main roads, rural and urban). A further classification within these categories enabled then the selection of contrasted cycles and sub-cycles.

According to the previous analyses, the following list of cycles / sub- cycles enables then a optimized coverage of the whole range of urban, rural-road, highway and motorway driving cycles (as shown in Figure 11) as follows:

1. Motorway and highway driving:

- Artemis.motorway_150 (alternatively Artemis.motorway_130, sub-cycles 1-4), Artemis.LowMot_Motorway (sub-cycles 1-4), Handbook.R1 (sub-cycles I,II,III),
- Artemis.rural (sub-cycles 4 and 5), LDV-PVU.CommercialCars_motorway_1, and Handbook.R2 (sub-cycle I).

2. Rural-road and sub-urban driving:

- Artemis.rural (sub-cycles 1-3) and Artemis.urban (sub-cycle 2),

- Handbook.R2 (sub-cycles II,III), R3 (I,II) and R4 (I),
- modemHyzem.road and Neapolitan driving patterns 6 and 17.

3. Urban driving:

- Artemis.urban (sub-cycles 1, 3, 4, 5),
- Neapolitan driving patterns 10, (possibly 11), 15, 21,
- Modem.urban sub-cycles numbers 5-7-13,
- possibly Handbook.R3_III,

and for the very low speeds :

- Handbook.R4_II and III,
- Neapolitan driving patterns 18, 19, 23.

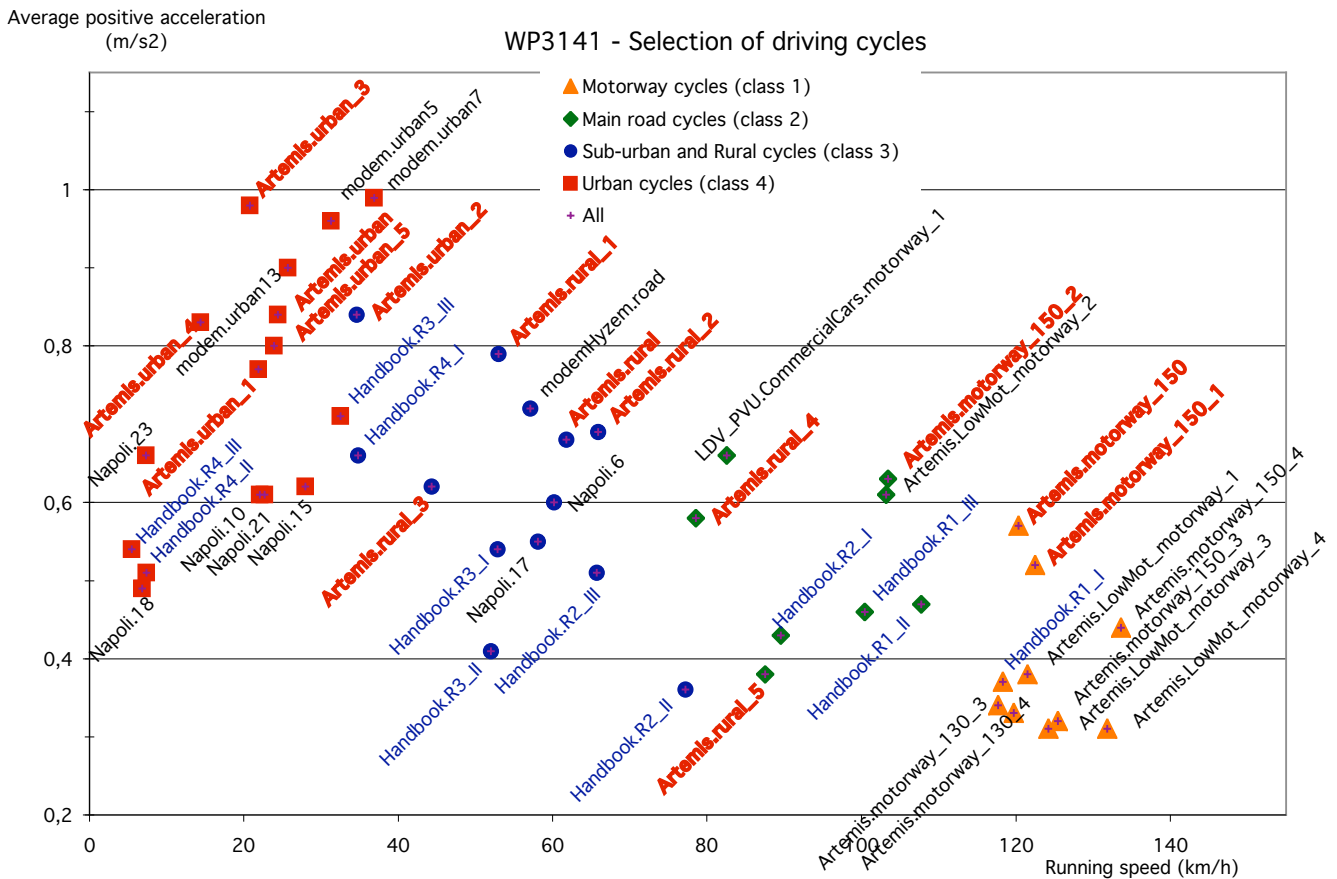


Figure 11: Final selection of the cycles and sub-cycles and their coverage as regards running speed and acceleration

2. Experimental protocol and emission datasets

An experimental approach including the selection of about 16 test cycles and emissions measurements performed by 5 laboratories on a total sample of 11 cars were envisaged to study the influence of the driving cycles on the emissions. We recapitulate hereafter the main methodological aspects of these measurements.

As complementary emissions datasets were finally used in the analyses, a brief overview of these datasets is added at the end of this chapter.

2.1. Adjustments and rules of usage

The previous selection of cycles (Chapter 1) implies the elaboration of the new composite cycles (based on *modem.urban* and *Napoli* sub-cycles) as well as the setting-up of the rules of usage of all the cycles.

2.1.1. Elaboration of 4 new composite driving cycles

A new *Modem* cycle (called *modem.urban5713* in the *Artemis* database) was built-up using the existing *modem.urban5*, 7 and 13 sub-cycles. In that aim, *modem.urban5* (1027 sec.) was shortened to 700 sec. (from second 160 to 860), while keeping nearly constant the main kinematic parameters. The overall duration of this new cycle is then 1426 sec.

Three Neapolitan cycles were elaborated and organised as follows :

- a. A Neapolitan cycle based on driving patterns 6 and 17. To get a sufficient transition between the 2 sub cycles and at the end of the cycles (allowing in particular to stabilize the emissions in the sampling system, and to sample the last period of driving), it is better to manage an idle period at the end of the sub-cycles and cycles. In this aim, 8 sec. of idle were taken from the beginning of driving patterns 6 and put at the end of this sub-cycle, 10 sec. were transferred from driving patterns 17 to the end of this sub-cycle and of the cycle.
- b. For the 2 other cycles, the initial order was changed to get a mix of urban conditions (rather than a very long accumulation of congested driving). On the other hand the driving patterns 19 (quite similar to 18) was cancelled, and the driving patterns 15 (89 sec.) was doubled to allow a sufficient duration of measurement. We have then a driving cycle based on 15, 18 and 21, and a cycle based on 10 and 23.
- c. As for the first Neapolitan cycle, some idle seconds were transferred from the sub-cycles to the transitions and end of cycles. Two or three isolated seconds with a speed of 1-2 km/h were cancelled to 0 km/h as these conditions are source

of difficulties on the chassis dynamometer.

Then 3 new Neapolitan cycles were built-up and named as: "Napoli.6_17", "Napoli.15_18_21", and "Napoli.10_23".

2.1.2. Rules of usage and experimental protocol

For all the cycles, the sampling of the emissions in the bags and the continuous emissions measurements are necessary to assess the emissions at the sub-cycle level. Rules of usage of the cycles including the gear shifting strategy have been defined and are recapitulated in Annex 4. An experimental protocol was also defined to ensure homogeneous practices between the different laboratories in charge of conducting the tests (Annex 4).

2.2. Vehicles tested

The experimental program foresaw a total of 12 vehicles tested over 16 cycles. In fact the previous analyses led to a selection of 14 cycles and unfortunately, tests on three cars have been cancelled or have not been made available in time for the analyses. The remaining 9 cars are listed in Annex 7. Their selection according to make, model, engine capacity and fuel was done according to the current rules defined in Artemis WP300 to constitute representative samples at the scale of the task as well as representative sample for the whole emission measurement program. These tests were distributed as shown in Table 8.

Laboratory	Vehicle number	Cycles number	Test number
<i>Tests realized</i>			
INRETS	6 vehicles	14 cycles	84 tests
IM	1 car	14 cycles	14 tests
KTI	1 car	14 cycles	14 tests
TNO	1 car	14 cycles	14 tests
<i>Tests cancelled</i>			
<i>Renault</i>	<i>2 recent cars (model year 2000)</i>	<i>8 cycles, 2 repetitions</i>	<i>28 tests</i>
<i>TUG</i>	<i>1 car</i>	<i>14 cycles</i>	<i>14 tests</i>

Table 8: Experimental program

2.3. Other emission data sets

Due to the limited size of the previous emission dataset, 2 complementary datasets have also been considered for the analyses that are developed in the following sections.

2.3.1. The PNR-Ademe emissions dataset

The first complementary data set (named PNR-Ademe) concerns the test of 30 French

cars, in the frame of a national research project (Joumard et al. 2004). These 30 cars include the 6 cars already tested by INRETS in the W3141 experimentation. They were selected to represent the French car fleet and their characteristics are provided in Annex 8. These cars were tested using 3 sets of driving cycles:

- the Artemis driving cycles (i.e. urban, rural and motorway cycles),
- the 2 sets of 5 cycles dedicated to high and low motorized cars (each car being tested according to its characteristics using the one or the other cycles set). The five cycles are respectively urban, rural, motorway cycles – totally compatible with the Artemis cycles in their structure and method of elaboration -, and a dense and a free-flow urban cycles.

Due to the similarity between the cycle sets (equivalence in the traffic situation but difference in the driving patterns), this emission dataset constitutes a good basis to analyse the influence of the driving patterns on the emissions. However, the sets of cycles being developed with the same data and same methods, the differences are very limited (compared to those observed in the previous section between the large range of cycles). This dataset should also enable to assess the influence of considering a single set of cycles common to all the cars, rather than developing specific cycles according to the vehicle characteristics.

2.3.2. The Artemis emissions dataset

The second complementary set of emission data is the whole Artemis emission database. In that case, the data is the compilation of most of the existing datasets in Europe. The vehicle list is very long and does not really follow representativity rules. These vehicles were tested using a very large range of different cycles.

The Artemis cars emission database accounts for 2800 cars, 27,000 vehicle x test cycles and more than 800 cycles or sub-cycles for which emissions are measured.

This high diversity of test cycles constitutes certainly a high richness to analyse the influence of the driving conditions on the emissions, but the very high heterogeneity of this dataset (different laboratories, various conditions of measurement, etc.) and the lack of overlapping between the different experimentations are a strong limitation to the analyses that would enable an understanding of the relations between emissions and driving conditions.

3. Influence of the driving cycles on the emissions

We present hereafter a synthesis of the analyses that have been conducted to highlight and understand the influence of the driving cycles on the pollutant emissions.

In a first step, we attempt to identify and rank the factors which influence the pollutant emissions. In that aim, we use 2 experimental datasets: the so-called “WP3141 emissions data” measured within the WP3141 task of the Artemis project, by using the selection of driving cycles described in the previous section, and the “PNR-Ademe emissions data” funded by a French national project, but also part of the Artemis project.

On this basis, we analyse then the influence of the driving cycles and of their kinematic parameters on the pollutant emissions.

3.1. Data sets and method

3.1.1. Data sets

The analyses have been conducted using two datasets:

- the WP3141 dataset which consists in 9 passenger cars Gasoline + Diesel, tested on 14 driving cycles described in the previous chapter, 40 sub-cycles, (in all 430 data for each of the regulated pollutants),
- the PNR-Ademe dataset (issued from INRETS measurements only) which includes 30 cars, of which: 5 gasoline cars with low motorisation (low power-to-mass rate), 8 with high rate and 17 diesel (considered as low motorised). These vehicles were tested using 8 driving cycles including the Artemis cycles as well as 8 specific driving cycles, built-up in two sets according to the power-to-mass ratio, each set being then dedicated respectively to high or low motorised cars. The whole set of data represents 32 sub-cycles and 1190 emission data for each of the regulated pollutants).

Taking into account of the driving classification into urban, rural/sub-urban and motorway/main roads established in the previous chapter, the driving cycles considered in these experimental datasets can be recapitulated as shown in Table 9.

Motorway / main roads	Rural / sub-urban	Urban
WP3141 dataset		
Artemis.motorway_150 (1 to 4) (alt. Artemis.motorway_130 (1 to 4) Artemis.rural (4, 5) -	Artemis.rural (1 to 3) Artemis.urban (2)	Artemis.urban (1, 3 to 5)
Handbook.R1_(I,II,III) Handbook.R2_I	Handbook.R2_(..., II,III) Handbook.R3_(I,II,...) Handbook.R4_(I,...)	Handbook.R3_(..., III) Handbook.R4_(..., II,III)
LDV_PVU.CommercialCars.motorway_1 Artemis.LowMot_motorway	modemHyzem.road Naapoli.6_17	modem.urban5713 Napoli.15_18_21 Napoli.10_23
PNR-Ademe dataset		All vehicles
Artemis.motorway_150 (1 to 4) (alt. Artemis.motorway_130 (1 to 4) Artemis.rural (4, 5)	Artemis.rural (1 to 3) Artemis.urban (2)	Artemis.urban (1, 3 to 5)
Artemis.LowMot_motorway (1 to 4) Artemis.LowMot_rural (4, 5)	Artemis.LowMot_rural (1 to 3) Artemis.LowMot_urban (2)	Vehicles with low motorisation Artemis.LowMot_urban (1, 3 to 5) Artemis.LowMot_urbdense (1 to 3) Artemis.LowMot_freeurban (1, 3)
Artemis.HighMot_motorway (1 to 4) Artemis.HighMot_rural (4, 5)	Artemis.HighMot_rural (1 to 3) Artemis.HighMot_urban (2)	Vehicles with high motorisation Artemis.HighMot_urban (1, 3 to 5) Artemis.HighMot_urbdense (1 to 3) Artemis.HighMot_freeurban (1, 3)
	Artemis.HighMot_freeurban (2)	

Table 9: Distribution of the driving cycles and sub-cycles according to the 3 types of driving : motorway / rural / urban. The numbers in brackets indicate the sub-cycle numbers

3.1.2. Coverage of the driving cycles

As shown in Figure 12, the 2 sets of cycles present a large coverage of the driving conditions (represented as a function of the running speed and acceleration rate). Although the Artemis cycles and sub-cycles offered already a quite large coverage (compared to ancient driving cycles and taking into account their necessary limited duration), the 2 sets of complementary cycles enlarge quite significantly the coverage. We observe also that the WP3141 cycles – selected to maximise the contrasts – are more dispersed than the 2 sets of cycles developed for high and low motorisation. Indeed these ones have been developed first with an objective of representativity, as were the Artemis cycles.

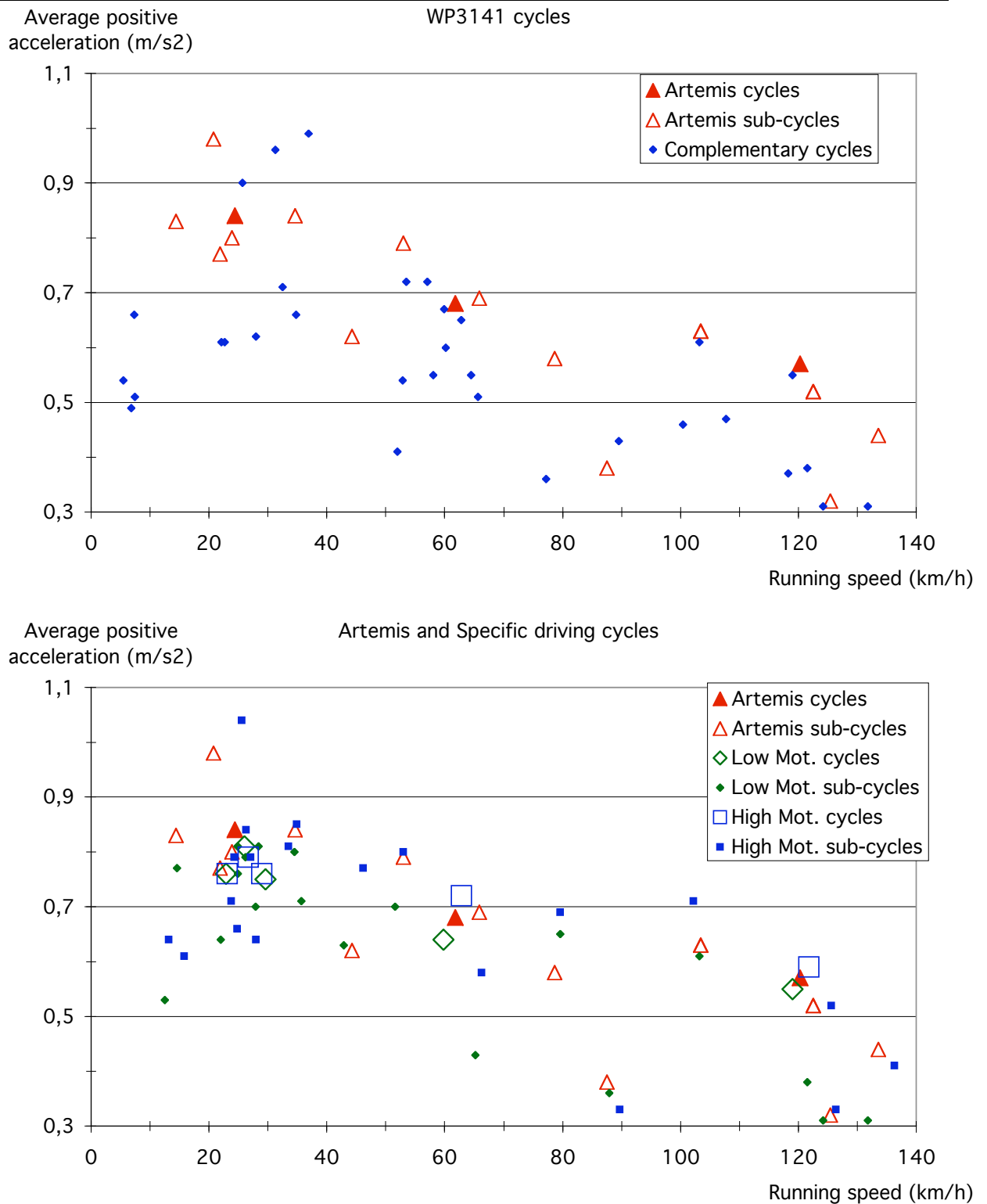


Figure 12: Coverage of the 2 sets of driving cycles and sub-cycles (top: WP3141, bottom: Specific cycles) and comparison with the Artemis driving cycles (in red triangles)

3.1.3. Emissions data and emissions per vehicle

The number of vehicles tested as regards the experimentation and their technical characteristics (fuel and emission regulation) is provided in Table 10. It can be seen that the samples per vehicle category (fuel x emission regulation) are quite limited. The most significant samples concern the EURO2 and diesel vehicles. Obviously these limited sample sizes

should limit the extent of the conclusions of the analyses, as far as statistical criteria are used.

One should also note that 6 out of the 9 cars tested in WP3141 have been also tested in PNR-Ademe. These cars have then been tested using the 2 cycles sets.

Emissions standard	PNR-Ademe		WP3141		Total
	Diesel	Petrol	Diesel	Petrol	
Pre-EURO	2				2
EURO1	3 (1)	3	2		8
EURO2	10 (2)	6	2 (1)	1 (1)	19
EURO3	2	4 (1)	1	3 (1)	10
Total	17	13	5	4	39

Table 10: Recapitulation of the vehicles tested in the 2 experimentations (in brackets, cases of high emitting vehicles, see next section)

In Table 11, the 2 sets of emissions have been computed for each of the vehicles. The results are sorted according to the fuel and to the emission regulation. The 6 cars mentioned previously appear then 2 times. The average emissions are exact figures, taking into account the actual distance of each cycle. They represent then an average emission factor, corresponding to a given set of driving cycles, i.e. an given driving condition resulting from the aggregation of the different cycles (without other weighing).

The average kinematic characteristics of these driving conditions are provided also in that table. We observe then than the PNR-Ademe emissions were measured at about 52 km/h, with 15% of stops, with 0.8 stops per km and 2.1 accelerations per km, while the WP3141 emissions were measured at 58 km/h, 11% of stops, 0.6 stops and 1.9 accelerations per km.

The driving conditions of the 2 datasets differ then quite significantly, due likely to a higher number of urban and low-speed cycles in the PNR-Ademe dataset (or to higher distances represented by these cycles). These differences are shown in Table 12 where we can measure the difference per driving type (urban, rural, motorway).

However, despite these differences in the driving conditions, we observe a good coherence of the emissions for the paired vehicles (the differences being generally below 10%, with some exceptions). This means that there is not “extraordinary aspects” to be found behind these 2 data sets (no cycle that would be totally of the range, providing then very high or low emissions not measured in the other case). We can probably conclude that – despite the observed differences – the cycles sets are relatively comparable and of a similar nature.

Table 11 shows also vehicles that look like as abnormal emitters (for one or the other pollutant, the figure exceeds 50% to 100% the average emission of the category fuel x emission standard). These vehicles were quite early identified through the different statistical analyses and it seems that they could perturb considerably later analyses (attempt to model the emissions as regards the kinematic parameters, etc.). For these reasons, we have identified these 5 cars (2 being involved in the 2 experimentations) as “High emitters” and analysed their behaviour through the analyses.

EXPER IM.	Fuel	Regl.	IDVehicle	Data		CO2 CO (g/km)	Fuel Cons. (g/km)	HC (g/km)	NOx (g/km)	Average speed (km/h)	Stop duration (%)	Stop frequency (1/km)	Acceleration frequency (1/km)	
				HighE mit.	number (maxi.)									
					1648	1,251	184	57,6	0,039	0,651	53,7	13,9	0,73	2,06
2	Diesel	preEURO	120011		31	0,505	163	49,2	0,050	0,879	50,5	15,0	0,82	2,21
2			120026		42	0,683	213	68,3	0,079	1,022	52,0	15,2	0,81	2,12
2		EURO1	120008	1	42	0,456	199	63,8	0,043	0,745	52,0	15,2	0,81	2,12
2			120029		42	0,324	159	50,8	0,019	0,745	52,0	15,2	0,81	2,12
1			120029		54	0,317	148	47,3	0,020	0,703	57,5	11,0	0,56	1,91
2			120034		37	0,204	208		0,034	0,832	51,6	16,0	0,84	2,11
1			120034		54	0,228	188		0,031	0,721	57,5	11,0	0,56	1,91
2		EURO2	120009	1	42	0,407	205	65,7	0,040	0,919	52,0	15,2	0,81	2,12
2			120010		42	0,028	174	55,6	0,009	1,080	52,0	15,2	0,81	2,12
2			120013		38	0,046	186	58,2	0,010	1,532	54,1	14,0	0,75	2,04
2			120014		42	0,189	216	68,8	0,033	1,333	52,0	15,2	0,81	2,12
2			120015		39	0,128	236	75,2	0,012	1,132	53,5	15,1	0,76	2,03
2			120017		42	0,185	202	64,4	0,018	0,922	52,0	15,2	0,81	2,12
2			120020		42	0,097	185	59,1	0,025	0,948	52,0	15,2	0,81	2,12
2			120031		42	0,067	180	57,3	0,012	1,054	52,0	15,2	0,81	2,12
2			120032		42	0,218	185	52,5	0,019	1,067	52,0	15,2	0,81	2,12
1			120032		54	0,282	161	47,1	0,014	1,026	57,5	11,0	0,56	1,91
2			120033	1	42	0,758	188		0,007	0,791	52,0	15,2	0,81	2,12
1			120033	1	54	0,804	176		0,008	0,707	57,5	11,0	0,56	1,91
2		EURO3	120021		42	0,035	187	59,7	0,010	1,193	52,0	15,2	0,81	2,12
2			120028		42	0,024	177	56,6	0,010	1,118	52,0	15,2	0,81	2,12
1			120028		54	0,014	167	53,3	0,007	1,078	57,5	11,0	0,56	1,91
2	Petrol	EURO1	120006		42	3,019	178	57,1	0,138	0,781	52,9	15,1	0,84	2,15
2			120022		42	1,446	157	50,1	0,141	0,241	52,0	15,2	0,81	2,12
2			120025		42	4,592	164	53,8	0,163	0,401	52,0	15,2	0,81	2,12
2		EURO2	120005		42	0,861	175	55,2	0,052	0,463	52,0	15,2	0,81	2,12
2			120007		35	2,855	231	70,3	0,111	0,461	51,3	14,5	0,88	2,28
2			120016		42	3,402	175	56,1	0,054	0,244	52,0	15,2	0,81	2,12
2			120018		42	0,851	227	71,7	0,027	0,088	52,9	15,1	0,84	2,15
2			120023		42	0,397	179	56,2	0,031	0,143	52,9	15,1	0,84	2,15
2			120024		42	0,529	200	62,9	0,042	0,078	52,9	15,1	0,84	2,15
1			140002	1	22	5,560	136	45,6	0,086	0,037	67,0	5,4	0,24	1,46
2		EURO3	120012		42	0,848	184	58,1	0,026	0,070	52,9	15,1	0,84	2,15
2			120019		42	0,737	205	70,5	0,035	0,144	52,9	15,1	0,84	2,15
2			120027		42	0,410	204	64,2	0,018	0,128	52,9	15,1	0,84	2,15
2			120030	1	42	3,534	191	61,0	0,083	0,377	52,0	15,2	0,81	2,12
1			120030	1	54	2,386	177	56,5	0,068	0,319	57,5	11,0	0,56	1,91
1			130002		30	0,875	140	44,7	0,029	0,033	52,2	11,7	0,63	2,20
1			170009		54	0,601	197	62,3	0,008	0,096	57,2	11,0	0,56	1,95

Table 11: Average emissions computed per vehicle (by weighting the emissions according to the cycle distances)
 - Experimentations: 1-WP3141, 2-PNR-Ademe

Driving type	Experimentation	Average Speed (km/h)	Stop duration (%)	Stop frequency (1/km)	Acceleration frequency (1/km)
Urban	1	15,5	27,3	4,87	7,80
	2	17,3	29,9	4,26	6,61
Rural / sub-urban	1	54,5	3,2	0,24	2,44
	2	51,6	4,7	0,53	2,62
Motorway / main roads	1	108,6	0,2	0,01	0,69
	2	114,4	0,0	0,00	0,66
All driving types	1	57,5	11,0	0,56	1,91
	2	52,1	15,2	0,80	2,11

Table 12: Average driving characteristics computed over the 2 respective driving cycles sets for each of the experimentations: 1-WP3141, 2-PNR-Ademe

3.2. Factors influencing the emission

The following analysis intends to analyse and establish the dependency between emissions and driving cycles or driving conditions. However, within our limited data samples, numerous other factors can influence significantly the emissions: the fuel, the emission standard, etc.

In a first step we rank the influence of these different factors, considering all the data. The significant parameters (out of the driving factors) should imply an analysis at a lower level (i.e. if the fuel is a significant parameter, it is necessary to analyse separately Diesel and Petrol data).

We attempt then to identify the necessary level of disaggregation of the sample that would enable analysing the influence of the driving conditions (i.e. the driving cycles or the underlying kinematic parameters).

In that aim, we perform a characterization analysis, in which continuous variable (pollutant emission) is analysed as a function of modalities or qualitative factors (fuel, driving cycles, etc.) and as a function of continuous variables (i.e. kinematic parameters). The statistics relies on a F Fisher test, for variance analysis.

3.2.1. Relative importance of the different factors influencing the emissions

Considering the whole dataset (2 experimentations, all fuels and vehicle categories), a rough analysis identifies the significant factors (i.e. implying a significant variation in the emission) and rank them according to the level of variation induced. These factors can differ for the different pollutants (Table 13).

Three parameters are unavoidable: fuel type (petrol, diesel), the emission standard and the driving condition (driving type, i.e. urban, rural, motorway/main roads and/or driving cycles). The variability between vehicles (factor: vehicle) is one of the main parameter except for CO₂, for which the vehicles parameters and characteristics appear to be less important than the driving type or the driving cycle (which are obviously correlated). This means that the variation of CO₂ between petrol and diesel cars and even between the different emission regulations is quite low

or insignificant.

The variations induced by the driving conditions can be more significant than the variation induced by the fuel type (HC, CO₂) or by the emission standard (NO_x, CO₂), or even between the vehicles. This highlights well the importance of the driving cycle and more generally of the driving conditions on the emission.

CO (g/km)	CO ₂ (g/km)	HC (g/km)	NO _x (g/km)
<i>The following factors are significant in decreasing order (i.e. their influence on emission is statistically demonstrated)</i>			
Vehicle	Driving Cycle	Vehicle	Vehicle
Fuel Type	Driving (Urb./Rur/Mway)	Emission_Standard	Fuel Type
Emission_Standard	Vehicle	Driving (Urb./Rur/Mway)	High/Low motorisation
Driving Cycle	High/Low motorisation	Driving Cycle	Driving Cycle
Driving (Urb./Rur./Mway)	Emission_Standard	Fuel Type	Emission_Standard
Emitter_Status (Normal/High)	Cycle/SubCycle	Data set	Driving (Urb./Rur/Mway)
Cycle/SubCycle		High/Low motorisation	
<i>The following factors are not significant (i.e. their influence on emission is not statistically demonstrated)</i>			
High/Low motorisation		Emitter_Status (Normal/High)	Cycle/SubCycle
Data set	Fuel Type	Cycle/SubCycle	Emitter_Status (Normal/High)
	Data set		Data set
	Emitter_Status (Normal/High)		

Table 13: Relative importance of different factors as regards the pollutant emissions

It should be also noted that the following factors are generally not significant:

- the Emitter status (except for CO) – This is due to 2 reasons: 1) this status is defined taking into account an over-emission for one given pollutant but is applied for the identified car. The status applies then also for the other pollutants even if these ones are normal. 2) the number of data concerned is low, then the significance is low.
- The emission data set (except for HC). This demonstrates a certain coherence in the data and then allows the combined analysis of the 2 sets.
- The Cycle/Sub-cycle criteria (which differentiate the emission measured using a whole cycle or using a sub-cycle).

3.2.2. Identification of the possible level of analysis

The previous analysis has demonstrated that further investigations should be conducted while separating the emissions data according to the fuel type, to the emissions standard, and also according to the driving type. However, such a disaggregation should lead to very small sub-samples that should preclude any statistical significance. From Table 10, we can see that the only categories that would enable satisfying analyses are the EURO2 Diesel cars and possibly the Diesel EURO1, the Petrol EURO1 to 3.

The previous analysis was conducted again while separating Petrol and Diesel data. The results are quite similar and identify more systematically the driving conditions as a preponderant emission parameters (Table 14). Roughly, from this table, it appears that Driving Type, Driving Cycle and Vehicle are the preponderant factors for Diesel cars (i.e. the factors of the most significant variation of the emission), while Vehicle and Emission Standard are preponderant for petrol cars.

The Emitter status appears now as almost always significant (except for CO₂ and Petrol HC). The emission standard is also a preponderant parameter except for CO₂ Diesel and should

then demonstrate the necessity to analyse the data by vehicle category.

However, when examining which variation is induced by the emission standard, we observe generally an opposition between preEURO, and EURO1 on one side, and EURO2-EURO3 on the other side (Table 15). Depending on the pollutant and fuel, we can observe a clear similarity between EURO2-EURO3 and at least no opposed influence of these categories on the pollutant. This demonstrates that it is possible to associate these 2 categories for further investigations.

CO (g/km)	CO2 (g/km)	HC (g/km)	NOx (g/km)
<i>The following factors are significant in decreasing order (i.e. their influence on emission is statistically demonstrated)</i>			
- DIESEL CARS			
Vehicle	Driving Cycle	Vehicle	Driving Cycle
Driving Cycle	Driving (Urb./Rur./Mway)	Driving (Urb./Rur./Mway)	Driving (Urb./Rur./Mway)
Driving (Urb./Rur./Mway)	Vehicle	Emission_Standard	Vehicle
Emission_Standard		Driving Cycle	Emission_Standard
Emitter_Status (Normal/High)		Data set	Emitter_Status (Normal/High)
Cycle/SubCycle		High/Low motorisation	Cycle/SubCycle
High/Low motorisation		Emitter_Status (Normal/High)	High/Low motorisation
Data set			Data set
- PETROL CARS			
Vehicle	Driving Cycle	Emission_Standard	Vehicle
Emission_Standard	Driving (Urb./Rur./Mway)	Vehicle	Emission_Standard
High/Low motorisation	Vehicle	High/Low motorisation	High/Low motorisation
Driving Cycle	Emission_Standard	Driving Cycle	Data set
Driving (Urb./Rur./Mway)	High/Low motorisation	Driving (Urb./Rur./Mway)	Driving (Urb./Rur./Mway)
Emitter_Status (Normal/High)		Data set	Driving Cycle
			Emitter_Status (Normal/High)

Table 14: Relative importance of different factors as regards the Diesel and Petrol pollutant emissions

	CO (g/km)	CO2 (g/km)	HC (g/km)	NOx (g/km)
Influence	DIESEL cars			
High emission	Urban preEURO High Emitter PNR-Ademe data	Urban	Urban preEURO PNR-Ademe data EURO1 High Emitter	Urban Normal Emitter EURO2
average emission				
	Rural/Sub. WP3141 data EURO3 Normal Emitter	Motorway/Main road	Normal Emitter WP3141 data Rural/Sub. EURO2 EURO3	High Emitter EURO1
Low emission	Motorway/Main road	Rural/Sub.	Motorway/Main road	Rural/Sub.
	PETROL cars			
High emission	EURO1 <i>Low motorization</i> Motorway/Main road High Emitter	Urban <i>High motorization</i> EURO3	EURO1 <i>Low motorization</i> Urban PNR-Ademe data	EURO1 PNR-Ademe data <i>Low motorization</i> Urban Normal Emitter
average emission				
	Normal Emitter Rural/Sub. <i>High motorization</i>	<i>Low motorization</i> EURO1 Motorway/Main road	<i>High motorization</i> WP3141 data EURO2 Rural/Sub.	High Emitter Rural/Sub. EURO3
Low emission	EURO3	Rural/Sub.	EURO3	WP3141 data

Table 15: Significant categories as regards the Diesel and Petrol pollutant emissions

A similar analysis was done as regards the driving type. Indeed, a similarity between 2 driving conditions (i.e. rural and motorway/main roads) should enable the analysis of more consequent data sample. However, this analysis (Table 15) demonstrates that we can conclude to a similarity between rural and motorway driving as regards CO₂, HC, but not in the case of CO Petrol and even NO_x Diesel, for which emission is low in rural driving but high in urban and in motorway driving (for certain motorway cycles for NO_x Diesel).

The above analyses lead us to analyse the emissions by fuel, by driving type. The EURO2 and EURO3 categories will be analysed together enabling to get sufficient data, while the other categories will not be analysed due to the too low number of vehicles.

3.2.3. Influence of the driving type

From (Table 15), we can also conclude that:

- for the Diesel cars, the urban driving leads systematically to higher emissions, while the rural and motorway driving leads to low emissions,
- for the Petrol cars, the urban implies higher CO₂, HC and NO_x emissions, while CO emission is rather associated with the motorway driving. For these vehicles, the rural driving leads systematically to lower emission.

3.2.4. Influence of the motorisation

In the above tables, we have also observed that the motorisation factor (“High / Low motorisation”) is systematically significant for the petrol cars.

In fact, this factor measures the difference in emissions between 2 car categories (high and low motorisation) but these categories were tested using two different sets of driving cycles. It is then not possible to conclude directly that the motorisation influences the emissions, as the factor implied here is the combination of the motorisation categories and of their respective driving conditions. A specific analysis of these aspects is proposed in Chapter 4.

3.3. Driving cycles and kinematic parameters influencing emission

The following analyses have been conducted by considering separately the 2 fuel types (Diesel and Petrol), the 3 types of driving (urban, rural, motorway). The EURO2 and EURO3 categories are considered and analysed together. The High Emitters have been omitted in the analyses, as the objective at this stage is to attempt to identify possible correlations between emissions and driving cycles and kinematic parameters.

A systematic analysis at this level demonstrates that the driving cycle is a preponderant factor (CO₂, NO_x Diesel), and significant in 18 cases out of 24 (2 fuels, 3 driving types, 4 pollutants). It is of lower importance for petrol cars (HC emission, NO_x on motorway).

3.3.1. Remarkable driving cycles

An attempt to identify the particular driving cycles responsible of this influence is highlighted in Table 16. Several cycles show a significant influence on certain pollutants. These cycles can differ according to the fuel and to the pollutant:

- the Artemis.urban_3 sub-cycle (congested with a lot of stops) and its equivalent Artemis.LowMot_Urban_3 produces higher CO₂ and NO_x Diesel and CO₂ Petrol emissions in urban conditions, while the free-urban driving records lower Diesel emissions (CO₂, NO_x),
- the Artemis.motorway_150_3 sub-cycle (very high speed) produces high CO₂ emissions, while the Artemis.motorway_150_4 sub-cycle (high unsteady speed) generates NO_x Diesel and CO Petrol emissions. On the other side, the Artemis.rural_5 sub-cycle (steady and high speeds on main roads) and its equivalents record low CO₂ and Diesel NO_x emissions.
- The rural driving opposes the Artemis.urban_2 sub-cycle (free-flow urban driving considered as suburban/rural driving through the classification in chapter 1) and its equivalent for the high and low motorisations as well as the Artemis.rural_1 sub-cycle (secondary roads, unsteady speed), to the Artemis.rural_2 sub-cycle and equivalent (steady speeds on secondary roads).

We observe then certain similarities between diesel and petrol cars, but these ones are never systematic for all the pollutants.

EURO2 + EURO3 ONLY		High Emitters excluded		
Influence	CO (g/km)	CO2 (g/km)	HC (g/km)	NOx (g/km)
DIESEL		URBAN		
High emission	NA	Artemis.urban_3 Artemis.LowMot_urban_3	Artemis.LowMot_urban_1	Artemis.urban_3 Artemis.LowMot_urban_3 Artemis.LowMot_urbdense_3 Artemis.urban_4
average emission				
Low emission		Artemis.LowMot_freeurban Artemis.LowMot_urban_5 Artemis.LowMot_freeurban_3		Artemis.LowMot_freeurban Artemis.LowMot_freeurban_3
PETROL		URBAN		
High emission	LDV_PVU.CommercialCars.motorway_1	Artemis.LowMot_motorway_3 Artemis.motorway_150_3		Artemis.LowMot_motorway_4 Artemis.motorway_150_4
average emission				
Low emission		Artemis.LowMot_rural_5 Artemis.rural_5		Artemis.LowMot_rural_5 Artemis.rural_5
PETROL		URBAN		
High emission	Artemis.urban_2	Artemis.urban_2 Artemis.LowMot_freeurban_2 Artemis.LowMot_urban_2 Artemis.LowMot_rural_1	Artemis.LowMot_urban_2	Artemis.urban_2 Artemis.LowMot_freeurban_2
average emission				
Low emission		Artemis.rural_2 Artemis.LowMot_rural_2		Artemis.LowMot_rural_3 Artemis.rural_2 Artemis.LowMot_rural_2
PETROL		URBAN		
High emission	NA	Artemis.urban_3	Artemis.HighMot_urbdense_1	NA
average emission				
MOTORWAY				
High emission	Artemis.motorway_150_4 Artemis.LowMot_motorway_4	Artemis.HighMot_motorway_3 Artemis.motorway_150_3 Artemis.HighMot_motorway_1	NA	NA
average emission				
Low emission		Artemis.rural_5 Artemis.HighMot_rural-5		
PETROL		RURAL		
High emission	Artemis.rural_1	Artemis.urban_2 Artemis.HighMot_freeurban_2 Artemis.HighMot_urban_2	Artemis.HighMot_rural_1	Artemis.rural_1 Artemis.urban_2
average emission				
Low emission		Artemis.rural_2		

Table 16: Significant cycles and their influence on the Diesel and Petrol pollutant emissions

3.3.2. Emissions and kinematic parameters

Using the same level of analysis and the same statistical tools and methods it is possible to highlight the correlations between the pollutants and the kinematic parameters describing the cycles. The significant parameters and their influence on the emissions are given in Table 17 and Table 18 for Diesel and Petrol cars respectively. These tables have been considerably simplified to make their reading easier (some hundreds of other parameters have been omitted).

	EURO2 + EURO3 ONLY		High Emitters excluded	
	CO (g/km)	CO2 (g/km)	HC (g/km)	NOx (g/km)
	DIESEL	URBAN		
High emission	V(80-100km/h)	Stop/km	Stop/km	Stop duration in %
	V(60-80km/h)	Stop duration in %	Stop duration in %	Stop/km
	V(60-80km/h)-A*(<-1.4ms/2)	Accelerations/km	Accelerations/km	Strong Accelerations/km
	Stop/km	V(<20km/h)	Aver Negativ Accel	Std Dev. Accel
	V(40-60km/h)-A*(>+1.0 ms/2)	Strong Accelerations/km	V(<20km/h)-A*(-0.2 +0.2ms/2)	Average Positive Accel
	V(40-60km/h)-A*(<-1.4ms/2)			V(<20km/h)
				Accelerations/km
Average emission				
	V(40-60km/h)	Positive Kinetic Energy	Positive Kinetic Energy	distance (m)
	A*(+0.2 +0.6ms/2)	distance (m)	A*(-1.4 -0.6ms/2)	A*(-0.2 +0.2ms/2)
	A*(+0.6 +1.0 ms/2)	V(40-60km/h)	A*(+0.6 +1.0 ms/2)	Running Speed (km/h)
	distance (m)	Running Speed (km/h)	Running Speed (km/h)	V(40-60km/h)
		V(20-40km/h) *	V(20-40km/h)	V(20-40km/h)
Low emission		Average speed (km/h)	Average speed (km/h)	Average speed (km/h)
	DIESEL	MOTORWAY		
High emission	V(20-40km/h)	Max Speed		Max Speed
	V(40-60km/h)	Average speed (km/h)		V(>140km/h)
	Stop duration in %	Running Speed (km/h)		Running Speed (km/h)
	V(<20km/h)	V(120-140km/h)		Average speed (km/h)
	Stop/km	V(>140km/h)		Positive Kinetic Energy
	V(60-80km/h)	Positive Kinetic Energy		V(120-140km/h)
	Accelerations/km	Std Dev. Speed		V(>140km/h)-A*(>+1.0 ms/2)
	A*(-1.4 -0.6ms/2)	V(100-120km/h)		V(120-140km/h)-A*(>+1.0 ms/2)
	A*(+0.6 +1.0 ms/2)	distance (m)		Std Dev. Speed
Average emission				
	Max Speed	A*(-0.2 +0.2ms/2)	V(100-120km/h)-A*(>+1.0 ms/2)	Aver Negativ Accel
	V(120-140km/h)	Aver Negativ Accel		Average Positive Accel
	Running Speed (km/h)	V(60-80km/h)		A*(-0.6 -0.2ms/2)
	Average speed (km/h)	Négativ Kinetic Energy		A*(-0.2 +0.2ms/2)
		A*(-0.6 -0.2ms/2)		V(60-80km/h)
Low emission		V(80-100km/h)		V(80-100km/h)
	DIESEL	RURAL		
High emission	A*(-1.4 -0.6ms/2)	Std Dev. Accel	Stop/km	Std Dev. Accel
	V(20-40km/h)	A*(>+1.0 ms/2)	V(20-40km/h)	A*(>+1.0 ms/2)
	Stop/km	Strong Accelerations/km	V(<20km/h)	Strong Accelerations/km
	Strong Accelerations/km	Stop duration in %	A*(-1.4 -0.6ms/2)	Stop duration in %
	A*(+0.6 +1.0 ms/2)	A*(<-1.4ms/2)	Stop duration in %	A*(<-1.4ms/2)
	V(<20km/h)	Average Positive Accel	Strong Accelerations/km	A*(+0.6 +1.0 ms/2)
	Stop duration in %	A*(+0.6 +1.0 ms/2)	Accelerations/km	Average Positive Accel
	A*(<-1.4ms/2)	Stop/km	A*(+0.6 +1.0 ms/2)	Stop/km
		V(20-40km/h)		Std Dev. Accel
		V(<20km/h)		V(20-40km/h)
		Accelerations/km	Average Positive Accel	V(<20km/h)
				Accelerations/km
Average emission				
	V(60-80km/h)	Max Speed	distance (m)	Running Speed (km/h)
	A*(-0.2 +0.2ms/2)	V(80-100km/h)	V(80-100km/h)	A*(-0.6 -0.2ms/2)
	V(100-120km/h)-A*(+0.6 +1.0 ms/2)	V(60-80km/h)	Positive Kinetic Energy	V(60-80km/h)
	V(80-100km/h)-A*(-0.6 -0.2 ms/2)	A*(-0.6 -0.2ms/2)	V(60-80km/h)	Average speed (km/h)
	Running Speed (km/h)	Running Speed (km/h)	Max Speed	A*(-0.2 +0.2ms/2)
	Average speed (km/h)	Average speed (km/h)	A*(-0.2 +0.2ms/2)	Aver Negativ Accel
		A*(-0.2 +0.2ms/2)	Running Speed (km/h)	
		Aver Negativ Accel	Average speed (km/h)	
Low emission				

Table 17: Significant kinematic parameters and their influence on the Diesel pollutant emissions, in urban, motorway and rural driving -

Legend: V(20-40 km/h) % of time spent at speed ranging from 20-40 km/h
 A*(-1,4 -0,6m/s²) % of time spent at acceleration ranging from -1,4 -0,6m/s²
 V(20-40 km/h)- A(-1,4 -0,6m/s²) % of time spent at speed from 20-40 km/h with acceleration from -1,4 -0,6m/s²

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

EURO2 + EURO3 ONLY		High Emitters excluded		
	CO (g/km)	CO2 (g/km)	HC (g/km)	NOx (g/km)
	PETROL	URBAN		
High emission	V(60-80km/h)	Stop/km	Std Dev. Accel	V(<20km/h)-A*(>+1.0 ms/2)
	V(80-100km/h)	Stop duration in %	Std Dev. Speed	Strong Accelerations/km
	V(40-60km/h)-A*(>+1.0 ms/2)	Négativ Kinetic Energy	A*(>+1.0 ms/2)	A*(-1.4 -0.6ms/2)
	V(40-60km/h)-A*(<-1.4ms/2)	Accelerations/km	V(80-100km/h)	V(<20km/h)-A*(-1.4 -0.6ms/2)
	Positive Kinetic Energy	Strong Accelerations/km	V(60-80km/h)	
	V(20-40km/h)-A*(>+1.0 ms/2)	V(<20km/h)	Average Positive Accel	
	A*(>+1.0 ms/2)		Stop duration in %	
	A*(<-1.4 ms/2)			
Average emission				
		Std Dev. Speed		
		distance (m)	A*(+0.2 +0.6ms/2)	A*(-0.2 +0.2ms/2)
		V(40-60km/h)	A*(-0.2 +0.2ms/2)	
		V(20-40km/h)		
		Average speed (km/h)		
Low emission		Running Speed (km/h)		
	PETROL	MOTORWAY		
High emission	V(>140km/h)-A*(+0.6 +1.0 ms/2)	Max Speed	V(>140km/h)-A*(>+1.0 ms/2)	V(40-60km/h)-A*(-0.6 -0.2ms/2)
	V(>140km/h)	V(>140km/h)-A*(-0.2 +0.2ms/2)	V(>140km/h)-A*(+0.6 +1.0 ms/2)	V(60-80km/h)-A*(<-1.4ms/2)
	V(>140km/h)-A*(>+1.0 ms/2)	V(>140km/h)		
	V(120-140km/h)-A*(-1.4 -0.6ms/2)	Running Speed (km/h)		
	V(>140km/h)-A*(+0.2 +0.6ms/2)	Average speed (km/h)		
	V(>140km/h)-A*(-1.4 -0.6ms/2)	Positive Kinetic Energy		
	V(120-140km/h)-A*(<-1.4ms/2)	V(120-140km/h)		
	Max Speed	Std Dev. Speed		
	Running Speed (km/h)	distance (m)		
	Average speed (km/h)			
	Std Dev. Speed			
Average emission				
	V(80-100km/h)	Négativ Kinetic Energy		
	V(80-100km/h)-A*(-0.2 +0.2ms/2)	V(60-80km/h)		
	Négativ Kinetic Energy	A*(-0.2 +0.2ms/2)		
	A*(-0.2 +0.2ms/2)	A*(-0.6 -0.2ms/2)		
		V(80-100km/h)		
Low emission				
	PETROL	RURAL		
High emission	V(40-60km/h)-A*(>+1.0 ms/2)	Std Dev. Accel	A*(>+1.0 ms/2)	Strong Accelerations/km
	V(60-80km/h)-A*(-1.4 -0.6ms/2)	Strong Accelerations/km	V(40-60km/h)-A*(>+1.0 ms/2)	Std Dev. Accel
	A*(+0.2 +0.6ms/2)	A*(>+1.0 ms/2)	Std Dev. Accel	A*(>+1.0 ms/2)
	V(60-80km/h)-A*(>+1.0 ms/2)	Stop/km	Average Positive Accel	V(20-40km/h)-A*(+0.2 +0.6ms/2)
	Std Dev. Speed	Average Positive Accel	Strong Accelerations/km	Average Positive Accel
	Accelerations/km	Stop duration in %	Accelerations/km	Stop duration in %
	A*(>+1.0 ms/2)	A*(+0.6 +1.0 ms/2)	V(20-40km/h)-A*(+0.2 +0.6ms/2)	Stop/km
	Positive Kinetic Energy	V(<20km/h)	Stop duration in %	Accelerations/km
	Std Dev. Accel	V(20-40km/h)		A*(+0.6 +1.0 ms/2)
		Accelerations/km		V(20-40km/h)
		Std Dev. Speed		V(<20km/h)
Average emission				
	Négativ Kinetic Energy	Positive Kinetic Energy	Aver Negativ Accel	Max Speed
	A*(-0.2 +0.2ms/2)	A*(-0.6 -0.2ms/2)	A*(-0.2 +0.2ms/2)	V(80-100km/h)
		Max Speed		Running Speed (km/h)
		V(80-100km/h)		Average speed (km/h)
		V(60-80km/h)		Aver Negativ Accel
		Running Speed (km/h)		A*(-0.2 +0.2ms/2)
		Aver Negativ Accel		
		Average speed (km/h)		
Low emission		A*(-0.2 +0.2ms/2)		

Table 18: Significant kinematic parameters and their influence on the Petrol pollutant emissions, in urban, motorway and rural driving

Legend: V(20-40 km/h) % of time spent at speed ranging from 20-40 km/h
A*(-1,4 -0,6m/s²) % of time spent at acceleration ranging from -1,4 -0,6m/s²
V(20-40 km/h)- A(-1,4 -0,6m/s²) % of time spent at speed from 20-40 km/h with acceleration from -1,4 -0,6m/s²

As regards Diesel cars (Euro2 and Euro3, normal emitters, Table 17), we can observe that:

- Within urban driving,
- all the pollutants increase with the stop frequency and duration,
 - all except CO decrease when the speed increases, while the CO emission is sensitive to high speeds (60-100 km/h),
 - NOx and CO2 are sensitive to the frequency of accelerations and of strong accelerations

-
- On motorway and main roads,
- NOx and CO2 are sensitive to the high speeds (120-140 km/h) and also to the variability of these speeds (standard deviation of the speed); they decrease at intermediate speeds (60-100 km/h)
 - CO increases with the occurrence of intermediate or low speeds, of stops and of accelerations, and is low at high speed.
- On rural roads,
- all the pollutants increase with the stop frequency and duration,
 - all the pollutants decrease when the speed increases, and are sensitive to low speeds (20-40 km/h or less) and to the accelerations (average positive acceleration, standard dev. accelerations frequency). The CO emission seems however rather sensitive to the strongest acceleration / deceleration.

Concerning the petrol cars (Euro2 and Euro3, normal emitters, Table 18), we observe that:

- Within urban driving
- all the pollutants are sensitive to acceleration parameters (frequency of accelerations and strong accelerations, average acceleration, time spent at high acceleration),
 - CO and HC emission is sensitive to high speeds (60-100 km/h) and strong acceleration
 - CO2 and HC increase with the stops, CO2 decreases when the speed increases.
- On motorway and main roads,
- all the pollutants are sensitive to accelerations occurring at high speeds. CO2 and CO are furthermore high at high speeds (120-140 km/h and above) and low at intermediate speeds (60-100 km/h)
- On rural roads,
- as for urban driving, all the pollutants are strongly sensitive to acceleration parameters (frequency of accelerations and strong accelerations, average acceleration, time spent at high acceleration),
 - CO2, HC and NOx increase with the stops (duration or frequency),
 - CO2 and NOx decrease when the speed increases.

We observe then quite contrasted behaviour between Diesel (rather sensitive to speed and stop parameters) and Petrol cars (rather sensitive to accelerations). There is also a certain similarity between urban and rural driving for both the categories of vehicles.

3.3.3. Characteristic kinematic parameters regarding the emissions

From the previous analysis, we can draw some rough conclusions as regards which parameters could be used in a attempt of modelling the emissions. Indeed, :

- For the motorway driving, the most observed parameters are the occurrence of high speed ($V > 140$ km/h, $V_{120-140}$), and of high accelerations at high speeds, the level of speed (max speed, running speed, average speed) and its variability (standard deviation of the speed),
- For the rural driving, they are the occurrence of high or low speeds ($V_{100-120}$ km/h, $V_{<20}$ km/h, V_{20-40} km/h), the frequencies of stops, accelerations and strong accelerations, the occurrence of high acceleration / deceleration, the stop duration, most of the times the standard deviation of the acceleration, and sometimes the average positive acceleration.
- For the urban driving, the most observed parameters are the occurrence of low speeds ($V_{<20}$ km/h, V_{20-40} km/h), the frequencies of stops, accelerations and strong

accelerations, the occurrence of high acceleration / deceleration, the stop duration (%), sometimes the standard deviation and the average positive acceleration.

3.4. Detailed analysis per cycle

The synthesis of the emissions data, for all vehicles and per driving type and cycles, is provided in Annex 9. The influence of each cycle on the different pollutants is recapitulated in Table 19 to Table 21, per driving type and fuel.

In urban, we observe a quasi-systematic decrease of all pollutant for the free-urban driving. The "dense" conditions, the Neapolitan driving patterns 18 and 23 as well as the stop-and-go (Handbook R4_III, Artemis.urban_3) lead to high emissions (except NOx for Petrol cars).

As regards the rural driving, we observe low emissions for almost all the Handbook cycles, for the Artemis.rural 2 and 3 sub-cycles (as well as for their equivalent for High- and low-motorized cars). On the other hand, the urban/suburban cycles (affected to this driving type, i.e. Artemis.urban_2 and its equivalent) lead systematically to quite high emissions.

Finally, as regards motorway driving, we observe again a quasi-systematic increase of the CO2 and NOx emissions for the Artemis.motorway cycles (and their equivalent). The emissions seem particularly sensitive to the sub-cycles 3 and 4 (at very high speeds). On the other hand, the Handbook cycles and the high speed rural driving lead to lower emissions (except several cases).

3.5. Conclusion

The previous analyses have demonstrated the significant and even preponderant influence of the driving cycles on the emissions. The analysis of the emissions should be conducted by driving type (urban, rural, motorway), by fuel and by vehicle emission categories. The high emitters should be analysed separately as they induce a large perturbation of the analyses.

We observe then quite contrasted emission behaviours for Diesel (rather sensitive to speed and stop parameters) and Petrol cars (rather sensitive to accelerations). There is also a certain similarity between urban and rural driving for both the categories of vehicles.

The most observed kinematic parameters (as regards their significant impact on emissions) are the occurrence of high speeds, of high accelerations at high speeds, the level of speed and its variability within motorway driving. For the rural and urban driving, they are the occurrence of high or low speeds, the frequencies of stops, of accelerations and of strong accelerations, the occurrence of high acceleration / deceleration, the stop duration, and finally the acceleration level.

	Driving type (U/R/M)	Urban				Petrol			
		Diesel				CO	CO2	HC	NOx
	Cycle Name	CO	CO2	HC	NOx	CO	CO2	HC	NOx
1	Artemis.HighMot_freeurban_1							(-)	+
2	Artemis.HighMot_freeurban_3					-	-	(-)	-
3	Artemis.HighMot_freeurban_total					-	-	-	-
4	Artemis.HighMot_urban					-		-	
5	Artemis.HighMot_urban_1							+	
6	Artemis.HighMot_urban_3						+		
7	Artemis.HighMot_urban_4						+		
8	Artemis.HighMot_urban_5						(-)	-	
9	Artemis.HighMot_urbdense_1					+		+	+
10	Artemis.HighMot_urbdense_2						+		
11	Artemis.HighMot_urbdense_3						+	-	
12	Artemis.HighMot_urbdense_total					(+)		+	+
13	Artemis.LowMot_freeurban_1	+							+
14	Artemis.LowMot_freeurban_3	(-)	-	-	-	-	-	-	(-)
15	Artemis.LowMot_freeurban_total	-	-	-	-	-	-	(-)	
16	Artemis.LowMot_urban								
17	Artemis.LowMot_urban_1			+					
18	Artemis.LowMot_urban_3		+	+	+		+		
19	Artemis.LowMot_urban_4		+				+		
20	Artemis.LowMot_urban_5		-	-			-	-	
21	Artemis.LowMot_urbdense_1							+	
22	Artemis.LowMot_urbdense_2		+		+		+		-
23	Artemis.LowMot_urbdense_3		+		+	+	+		
24	Artemis.LowMot_urbdense_total								
25	Artemis.urban					+(euro3)			
26	Artemis.urban_1							+	
27	Artemis.urban_3	+	+	+	+	+	+	+	
28	Artemis.urban_4		+			(+)	+		
29	Artemis.urban_5		(-)	-				-	
30	Handbook.R3_III		-	-	-			-	-
31	Handbook.R4		-		-				-
32	Handbook.R4_II								
33	Handbook.R4_III		+	+	+		+		
25	modem.urban13b	(+)	-	(-)	(+)				
34	modem.urban2x7	+		-		+			
35	modem.urban5713	(+)		-		+			
36	modem.urban5b	+				+			
37	Napoli.10		-						
38	Napoli.10_23							-	
39	Napoli.15		-	-	-			-	+
40	Napoli.15_18_21							-	
41	Napoli.18		+	+	+		+	(+)	-
42	Napoli.21								
43	Napoli.23	+	+	+	+		+	+	-

Table 19: Influence of the urban driving cycles on the pollutant emissions ;
 (+) / (-): systematic increase / decrease for all the vehicle categories, (+) / (-) quasi systematic variation

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

	Driving type (U/R/M)	Rural/Suburb.							
		Diesel				Petrol			
	Cycle Name	CO	CO2	HC	NOx	CO	CO2	HC	NOx
1	Artemis.HighMot_freurban_2					-	+		
2	Artemis.HighMot_rural					+			
3	Artemis.HighMot_rural_1					+		+	
4	Artemis.HighMot_rural_2								-
5	Artemis.HighMot_rural_3					-		-	
6	Artemis.HighMot_urban_2						+		+
7	Artemis.LowMot_freurban_2	+	+		+	+	+		+
8	Artemis.LowMot_rural	-				+			
9	Artemis.LowMot_rural_1							+	
10	Artemis.LowMot_rural_2		-				-	-	
11	Artemis.LowMot_rural_3					-			-
12	Artemis.LowMot_urban_2		+	+			+		
13	Artemis.rural	-							
14	Artemis.rural_1	+				+			+
15	Artemis.rural_2	-	-	-	-	-	-	-	-
16	Artemis.rural_3	-				-		-	
17	Artemis.urban_2	+	+	+	+		+		(+)
18	Handbook.R2	-		-	-	-			-
19	Handbook.R2_II	-	-	-	-	-	-		-
20	Handbook.R2_III		-	-	-	-	-		-
21	Handbook.R3				-	-			-
22	Handbook.R3_I						+		
23	Handbook.R3_II		-		-	-	-		-
24	Handbook.R4_I			+					
26	modemHyzem.road					+			
27	Napoli.17			-				-	
28	Napoli.6			+	(+)			+	+
29	Napoli.6_17					-			+

Table 20: Significant influence of the rural driving cycles on the pollutant emissions - (+): systematic increase for all the vehicle categories, (+) : quasi systematic variation

	Driving type (U/R/M)	Motorway/Main road							
		Diesel				Petrol			
	Cycle Name	CO	CO2	HC	NOx	CO	CO2	HC	NOx
1	Artemis.HighMot_motorway					+			
2	Artemis.HighMot_motorway_1					-	+		
3	Artemis.HighMot_motorway_2					-			-
4	Artemis.HighMot_motorway_3					(+)	+		
5	Artemis.HighMot_motorway_4					(+)			
6	Artemis.HighMot_rural_4							+	+
7	Artemis.HighMot_rural_5					-	-		
8	Artemis.LowMot_motorway		+				+		
9	Artemis.LowMot_motorway_1		+			(-)	+		
10	Artemis.LowMot_motorway_2								
11	Artemis.LowMot_motorway_3		+		+		+		(+)
12	Artemis.LowMot_motorway_4		+		+	+	+		(+)
13	Artemis.LowMot_rural_4			+		+		+	
14	Artemis.LowMot_rural_5		-		-	-	-		-
15	Artemis.motorway_130								
16	Artemis.motorway_130_3								
17	Artemis.motorway_130_4								
18	Artemis.motorway_150					+			
19	Artemis.motorway_150_1		+			-	+		
20	Artemis.motorway_150_2					(-)			
21	Artemis.motorway_150_3		+		+	(+)	+		(+)
22	Artemis.motorway_150_4		+		+	+	+		(+)
23	Artemis.rural_4	+			(-)	-			+
24	Artemis.rural_5		-		-	-	-	-	-
25	Handbook.R1	-	-			-			
26	Handbook.R1_I					-		-	
27	Handbook.R1_II		-			-	-		-
28	Handbook.R1_III	(-)	-			-	-	-	-
29	Handbook.R2_I		-	-	-	-	-		-
30	LDV_PVU.CommercialCars.motorway_1	+	-			+	+	+	

Table 21: Significant influence of the motorway / main road cycles on the pollutant emissions - (+): systematic increase for all the vehicle categories, (+) : quasi systematic variation

4. Sensitivity of the emissions to the test protocol: common versus specific cycles

In this chapter, this PNR-Ademe dataset is analysed to assess the incidence of using a single set of common driving cycles (which is the usual test procedure) instead of using dedicated cycles according to the motorisation of the vehicles.

The sample of 30 cars (17 with a diesel engine and 13 with a petrol engine) representative of the French car fleet was tested using the Artemis cycles on one side, and specific driving cycles, built-up specifically for high- and low-motorized vehicles on the other side. These last cycles were indeed derived using the same database and principles than those used for the Artemis cycles, but considering 2 different sub-samples of vehicles according to their power-to-mass rate. A brief comparison of the results is provided here, considering the aggregated emissions values (i.e. emissions factors measured on the urban, rural and motorway driving cycles, weighed in distance by the corresponding coefficients). Detailed results can be found in (André et al., 2005a).

4.1. Detailed and aggregated comparisons

To simplify, we compared only the aggregated emissions measured on the 3 ARTEMIS cycles on one side and the emissions measured on the 3 low or high-powered cycles (depending on the vehicles). We also set a 100 level for the ARTEMIS cycles (Table 24).

We observed a good coherence between the 2 sets of cycles for CO₂ emissions (less than 4% of variation). For the other pollutants, large discrepancies can be observed for the most recent vehicles (less pollutant). These gaps can easily reach 20 or 50% in both ways, i.e. the usual test procedure with a single set of cycles can lead to an overestimation (Petrol vehicles Euro2, CO diesel) or to an underestimation (HC of the Euro3 Petrol, of the Euro2 and 3 diesel cars, and diesel particulates).

As several comparisons are difficult due to the low number of vehicles tested, it is interesting to aggregate the results and to consider in particular most recent vehicles. From Table 23, we can conclude that the use of one unique set of driving cycles lead to a significant underestimation (by 15 to 20%) of the CO (petrol) and of the HC and particulates (diesel) of the recent cars (Euro 2 and Euro 3), and to an overestimation of the Diesel CO. The differences observed when considering the whole sample of vehicles are very limited, due to the strong influence of older cars through their high level of emissions.

Driving cycles	Pollutant	Petrol vehicles			Diesel vehicles			
		Euro 1	Euro 2	Euro 3	ECE 1504	Euro 1	Euro 2	Euro 3
Number of vehicles		3	6	4	2	3	10	2
Artemis cycles (reference)		100	100	100	100	100	100	100
Specific cycles for High- and Low-powered cars	CO	103	92	175	95	113	85	42
	HC	100	80	141	92	108	120	155
	Nox	112	94	87	108	114	99	92
	CO2	97	96	97	100	102	100	98
	Particulates				72	40	139	

Table 22: Comparison of pollutant emissions measured through a unique set of cycles (ARTEMIS) or using vehicle-specific cycles

Relative emissions		Petrol Euro2 +3	Diesel Euro2 +3	All vehicles
Two sets of specific driving cycles	CO	115	<i>84</i>	105
	HC	<i>92</i>	123	102
	NOx	<i>92</i>	97	100
	CO2	<i>96</i>	100	99
	Particulates		150	96
One set of cycles		100	100	100

Table 23: Influence of test procedure on aggregated pollutant emissions: usual procedure with a unique set of cycles led to an underestimation (in bold) or to an overestimation (in italic)

Relative emissions		Urban	Rural	Motorway
Two sets of specific driving cycles	CO	<i>82</i>	<i>94</i>	103
	HC	<i>84</i>	108	106
	NOx	<i>94</i>	105	107
	CO2	<i>91</i>	104	103
	Particulates	<i>87</i>	148	<i>63</i>
One set of cycles		100	100	100

Table 24: Influence of test procedure as regards driving type: usual procedure with a unique set of cycles led to an underestimation (in bold) or to an overestimation (in italic)

4.2. Differences according to driving type

Considering the whole sample of vehicles as regards the 3 types of driving cycles highlights how errors due to the test procedure can affect “local” pollutant estimations (Table 24). Indeed, the usual testing procedure (i.e. a unique set of cycles) led to a significant overestimation of urban emissions (by 10 to 20%) whilst rural and motorway emissions were slightly underestimated. These trends should be reinforced when considering only recent cars, and also consequently in the future when these vehicles will become predominant.

Relative emissions		Petrol cars		Diesel cars
		High-powered	Low-motorized	Low-motorized
Two sets of specific driving cycles	CO	103	113	93
	HC	<i>89</i>	104	110
	NOx	<i>92</i>	106	101
	CO2	100	<i>90</i>	100
	Particulates			96
One set of cycles		100	100	100

Table 25: Influence of test procedure according to vehicle categories: a unique set of cycles led to an underestimation (in bold) or to an overestimation (in italic)

4.3. Differences regarding vehicle categories

Finally, we observe that low-powered cars are penalized by a common procedure as their CO₂ emission and fuel consumption are higher when measured using a common set of cycles, than when measured using appropriate cycles (Table 25). The usual procedure led also to an underestimation of CO and HC emissions from the small cars and to a slight overestimation of HC and NO_x from the most powerful.

4.4. Conclusions

These analyses demonstrate that the usual test procedure with one common set cycles for all the cars could led to strongly different emissions estimations, particularly for the most recent vehicle categories.

Although the increase of complexity induced by such a refinement of the test procedure, the taking into account of the vehicles performances and of their specific uses should become important in a short term, to improve the accuracy and quality of the emissions estimations, and also as the recent cars - more sensitive to the testing conditions -, will become predominant.

5. Emissions modelling as regards kinematic parameters

Various works have been conducted to attempt to model the car pollutant emissions as regards detailed kinematic parameters. The final objective is generally to have a better taking into account of the traffic dynamic than when using only an approach based on the average speed.

Amongst interesting works we can mention (Ericsson 2000 and 2001) who analysed first the variability of the urban driving patterns and then considered the incidence of a large range of kinematic parameters on the car emissions and fuel consumption (derived from an emission model). On the other hand (Joumard et al. 1999) and (De Haan et al, 2000) raised up the limitation and problems of the instantaneous emission modelling. We can also mention the works undertaken within the OSCAR research project (Boulter et al.), which envisages the emissions as regards a power-based index. However these works are in general limited by the emission dataset or by their context.

In this chapter we recapitulate first the main results from the numerous attempts that have been conducted with the Artemis data, using a large range of kinematic parameters and various methods.

We describe then an approach based on a hierarchical model, which was built-up to explain the logarithm of the total emission per cycle as a function of the cycle characteristics and applied to the Artemis database. This high-level model combines two individual Partial Least Square regression models, the first one being based on dynamic related parameters (i.e. average speed, square and cubic speed, idling etc.), second model considering the 2-dimensionnal distribution of the instantaneous speed and acceleration. Both models are based on principal components regression.

5.1. Possible parameters for an emission modelling

Within this framework, various attempt have been conducted to identify the possible parameters and to estimate the quality of the resulting models. These works have been based successively on the WP3141, PNR-Ademe and the whole Artemis database. Various statistical methods such as Multiple regression, Stepwise regression and variance analysis have been implemented considering the specific emissions (in g/km travelled) but also the hourly emission (g/h) and finally the total and log of the total emissions (in g). It is not possible to recapitulate all these works in that report because they remain to be completed. However we can recapitulate the main conclusions:

- It is necessary to work by vehicle category (emission standard) and fuel type (petrol, diesel).
- Better results are obtained when we consider separately the normal and the high emitters. Unfortunately, it seems that the share of high emitting cars can be quite high (2 to 4 cars out of 10).
- Better results are obtained when we analyse separately emissions measured within urban driving and those measured within rural / motorway driving.
- Generally better results are obtained with the total emissions and with the logarithm of the total emission. This is certainly due to the non-linearity introduced when we consider specific emission in g/km and parameters such as the speed in km/h. However a size effect could be another reason of the improvement (the longer is the cycle, the larger is the emission).
- A “vehicle by vehicle” analysis enables very good correlation for the normal emitters: the minimum expected regression coefficients are in that case in the order of 0.7 to 0.8 when considering the specific emission in g/km, while considering 4 to 5 kinematic parameters.
- When considering samples of vehicles, while considering only the normal emitters and separating urban from rural / motorway driving, we obtain the following results:
 - For petrol cars, EURO2 and EURO3, good results for CO₂, bad results for CO, HC urban, NO_x rural.
 - For Diesel cars, EURO2 and EURO3, good results for CO₂ and NO_x, bad results for CO and HC particularly in urban driving
 - However the minimum expected regression coefficients are in the range 0.5 (for CO and HC) providing that we consider 4 to 5 parameters which can differ according to the pollutant and the cases.
- In the previous analyses, the most frequent parameters considered by a stepwise regression are as follows:
 - Number of stops, of accelerations, of strong accelerations,
 - Stop duration, duration at steady speed,
 - Relative duration at speed above 80 km/h, and at speed above 140 km/h,
 - Considering the speed x acceleration distribution improves particularly the CO results.

5.2. Hierarchical approach combining 2 Partial Least Square regression models

The objective of this analysis is to assess the influence of driving cycles on emission factors of gasoline and diesel passenger cars, and at same time identifying kinematic parameters more important to characterize driving cycles and more effective as emission predictors in the regression models.

To this end a hierarchical statistical modelling approach based on Partial Least Squares method (PLS), has been developed. Emission models are intended to analyse emissions data

relative to different combinations of vehicles and driving cycle existing in a large data base (like the ARTEMIS database), determine average emission factors relative to a number of reference driving cycles and predict the average hot emission factors of urban, rural and highway trips.

This section presents some results of a validation effort performed on data sets taken from the December 2004 version of ARTEMIS database, relative to emission data of passenger cars obtained in ARTEMIS tasks, considering testing conditions which can be assumed as “reference hot conditions”. Analyses were performed separately for diesel and gasoline passenger cars data sets. Firstly, an analysis of variance was carried out on each set of data to examine the effects of driving cycle, EURO homologation and displacement class (assumed as qualitative factors) and to estimate the amount of emission variability contributed by each factor. Then, ten case studies relative to samples of passenger cars with specific EURO and displacements class were determined. For each case study, the effect of driving cycles on emission factors is estimated as a function of kinematic parameters, calculating PLS regression models. Results of PLS models are compared with the fit of a polynomial of second order considering as independent variable the overall mean speed.

5.2.1. Case studies

Vehicles were divided into classes making reference to their emission standard (EURO 1,2,3 and 4) and engine size. Three classes of engine capacity or displacement were assumed (1200-1400 cc, 1400-2000, over 2000) when data were available, otherwise data were grouped to obtain a consistent sample.

Seven samples were individuated for gasoline passenger cars, three samples for diesel PC. They are defined in Table 26 and Table 27, respectively. In the tables, the code in the cell individuates a class for which consistent data exist. For each case study the emission standard class is reported (E1, E2, E3, E4), as well as engine size class generally individuated by the first two digits (1020 stands for 1000-2000 cm³, 2000 for over 2000 cm³).

Emission standard Engine size	Euro 1	Euro 2	Euro 3	Euro 4
1200-1400	E1 GAS 1020	E2 GAS 12-14	E3 GAS 12-14	E4 GAS 10-20
1400-2000		E2 GAS 14-20	E3 GAS 14-20	
> 2000	n.a.	n.a.	E3 GAS 2000	n.a.

Table 26: GASOLINE case studies

Emission standard Engine size	Euro 1	Euro 2	Euro 3
1200-1400	E1 DIESEL 1700- 2000	E2 DIESEL 1600- 2000	E3 DIESEL 1400-2000
1400-2000			

Table 27: DIESEL case studies

5.2.2. Driving cycles

Emission data are relative to measurements performed with driving cycles, dividing each driving cycle into sub-cycles and computing sub-cycle emission quantity by the integral of instantaneous emission record. In the remainder a sub-cycle will be named as a driving cycle (DC). Then, emission data refer to the following sub-cycles: Artemis – Motorway (4 sub-cycles Motor 1-4), Artemis - Rural (5 sub-cycles Rural 1-5), Artemis – Urban (5 sub- cycles Urban 1-5). Each emission observation is the quantity related to each sub-cycle in the database. Motorway sub-cycles are very peculiar, when considered as a stand alone DC, resulting almost solely one mode: a constant speed or a strong acceleration/deceleration at high speed. This pattern is really different from other DC’s, which generally have as a minimum a starting and/or final transient phase. In Figure 13, the diagram of driving cycles ordered by mean overall speed is shown.

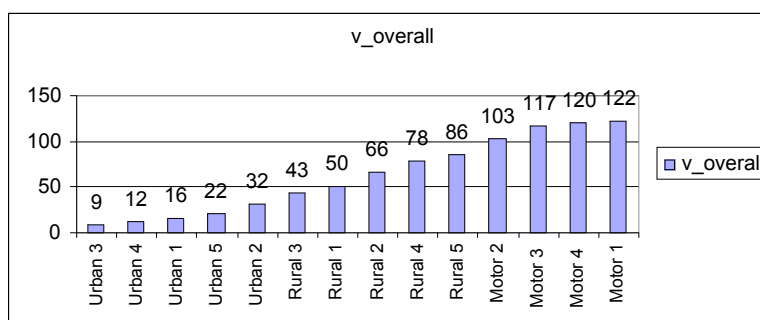


Figure 13: Diagram of driving cycles ordered by mean overall speed

5.2.3. Regression models

The considered response Y is the unit emission mass of CO, HC, NOX and CO2 measured in a driving cycle, expressed in (g/km). A log-transform of Y was applied in the regression because driving cycle’s (DC) emission quantities are close to zero with large coefficient of variation and because analysed emission data result generally distributed according to a lognormal distribution. Explicative variables characterize the kinematics of driving cycles, they were determined considering two complementary ways of explaining emission variation: the total energy spent by vehicle, the frequency of acceleration events at different speeds. Hence, variables were divided into two conceptually meaningful blocks. The first block refers to variables defined from the dynamic vehicle equation, plus idling time to consider emission production during vehicle stand still and the reciprocal of driven distance to take into account that response variables are unit emissions. The second block of variables determines the joint DC’s speed/acceleration distribution. This distribution was proposed and utilized in

ARTEMIS to analyse and determine driving cycles used in the different tasks on the basis of a wide collection of real driving cycles sampled in on road tests (André 2004a &b). The regression equations and applied statistical methods are reported into details in (Rapone et al. 2005a & b).

The list of explicative variables is shown in Table 28 and Table 29.

Variable	Description	Variable	Description
mv	Mean of running speed($v>0$)	Tidle	idling time $v=0$
mv2	Mean of square speed ($v>0$)	Trunning	total running time ($v>0$)
mv3	Mean of cube speed ($v>0$)	M_va_pos	Mean of instantaneous values of product ($a(t)\cdot v(t)$) when $v(t)>0$ and $a(t)>0$
		Invdist	the reciprocal of driving cycle length

Table 28: **BLOCK 1** Explicative Variables

a/v	$0 < v < 20$ km/h	$20 < v < 40$ km/h	$40 < v < 60$ km/h	$60 < v < 80$ km/h	$80 < v < 100$ km/h	$v > 100$ km/h
$a < -1.4$ m/s ²	FS_V20a1	FS_V40a1	FS_V60a1	FS_V80a1	FS_V100a1	FS_V101a1
$-1.4 < a < -0.6$	FS_V20a2	FS_V40a2	FS_V60a2	FS_V80a2	FS_V100a2	FS_V101a2
$-0.6 < a < -0.2$	FS_V20a3	FS_V40a3	FS_V60a3	FS_V80a3	FS_V100a3	FS_V101a3
$-0.2 < a < 0.2$	FS_V20a4	FS_V40a4	FS_V60a4	FS_V80a4	FS_V100a4	FS_V101a4
$0.2 < a < 0.6$	FS_V20a5	FS_V40a5	FS_V60a5	FS_V80a5	FS_V100a5	FS_V101a5
$0.6 < a < 1.0$	FS_V20a6	FS_V40a6	FS_V60a6	FS_V80a6	FS_V100a6	FS_V101a6
$a > 1.0$ m/s ²	FS_V20a7	FS_V40a7	FS_V60a7	FS_V80a7	FS_V100a7	FS_V101a7

Table 29: **BLOCK 2** Explicative Variables - FS_V*a* = centred LOG-transform of cycle time frequency in the cell

Considering the high number of X-variables, and that the most of variables are correlated, it is convenient to utilize a regression method based on principal components, which are latent variables function of original variables and orthogonal each other. In particular, the sparse matrix of data and the presence of missing values suggested to apply the Partial Least Square method and the NIPALS algorithm to estimate the regression model. Moreover, because response variables Y's may be correlated, a multivariate response Y (whose components are CO, CO₂, HC, NOX) was considered and a multivariate PLS method applied. To consider both the contributes of the two blocks of X-variables in one model, a Hierarchical Multi-block PLS method is adopted. Following this approach, a set (t_1, t_2, \dots, t_k) of principal components (X-scores) is estimated fitting a PLS base model to each block. Then, the super-block regression model (named top-model) is built, by applying the PLS regression of Y-variables on super-scores made by the union of scores of the two base models.

Following this approach, MG model base is calculated for block1, model base MVA for block2. The super level model, top model MT, is obtained by the PLS regression of response variables to the pooled scores of MG and MVA. Emission factors can be obtained by quantities predicted by each PLS model (MG, MVA or MT), according to the best fit. The vehicle effect is estimated by model MGD, which is an extension of model MG, including a dummy variable for each vehicle in the data set to consider the vehicle effect.

5.2.4. Main results

The PLS models (high-level model, model MG based on the dynamic related parameters, and model MVA considering the 2-dimensionnal distribution of the instantaneous speed and acceleration) are compared with the observed data as well as with a traditional polynomial regression model as regards the average speed (GLM model).

Detailed results given in the next sections demonstrate again that the driving cycle is a predominant factor as regards most emissions. The engine size is significant for CO₂ (petrol cars).

Most often, the best fit between the observed and predicted emissions is obtained using the model based on the distribution of the instantaneous speed and acceleration. The dynamic related model is satisfying for CO₂ Euro1 Diesel while a speed x acceleration model better explains the emissions in general. The high level model (combining the 2 previous ones) enhances slightly the prediction (Figure 14 and Figure 15). The average speed model (through a parabolic trend) is unable to predict the "tooth-shaped trend" emissions determined by the effect of critical driving cycles (acceleration factor at different speeds, see the observed data) and leads in some cases to a significant emission increase at high speed whereas there isn't.

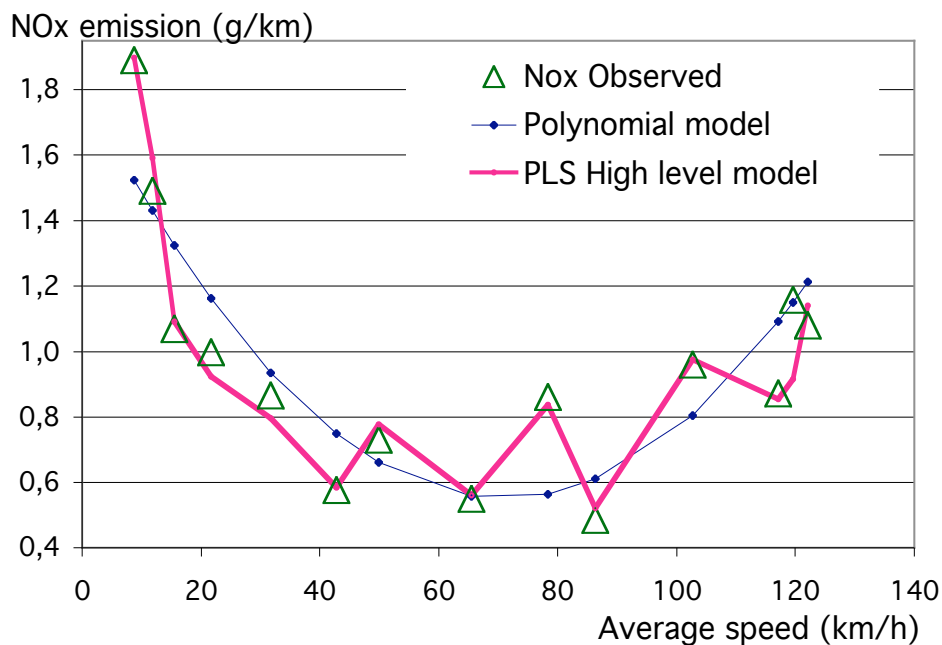


Figure 14: Diesel cars, EURO2, NO_x emission observed and predicted by a PLS high level model and by a polynomial model

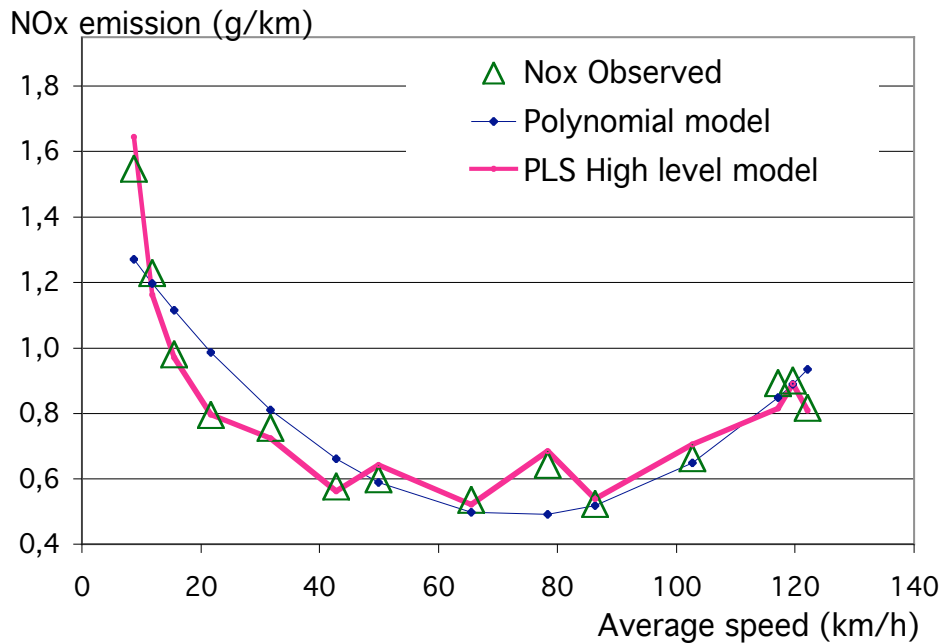


Figure 15: Diesel cars, EURO3, NOx emission observed and predicted by a PLS high level model and by a polynomial model

However, the model fit is generally good for CO₂ but less or not satisfying for the other pollutants due to a large variability between the vehicles, and in particular to a low number of "high emitting" cars in the gasoline cases. Further investigations should be conducted in that direction.

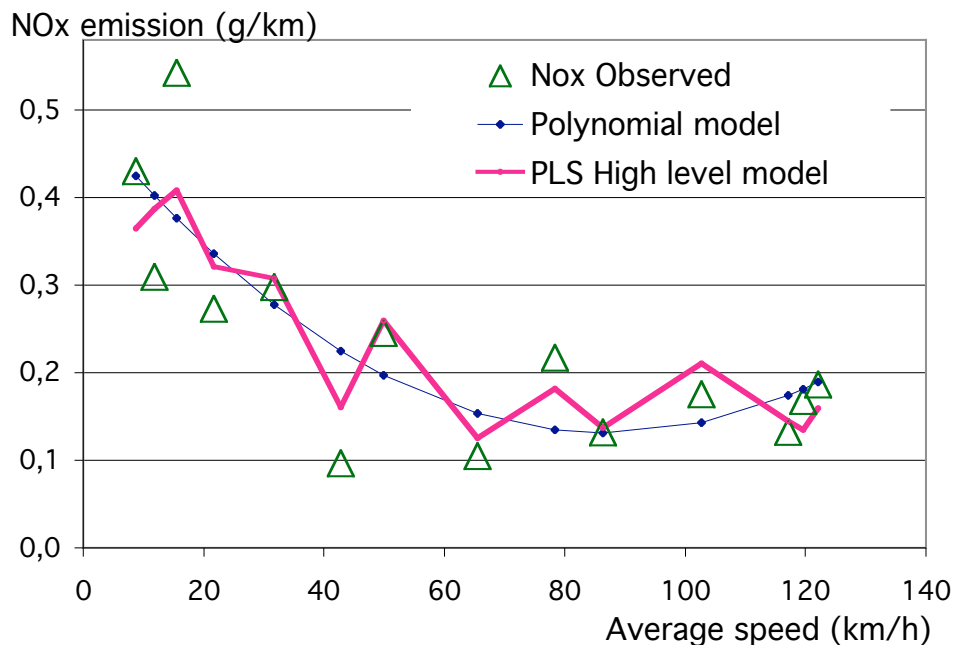


Figure 16: Petrol cars, EURO2, engine capacity:1200-1400 cm³ - NOx emission observed and predicted by a PLS high level model and by a polynomial model

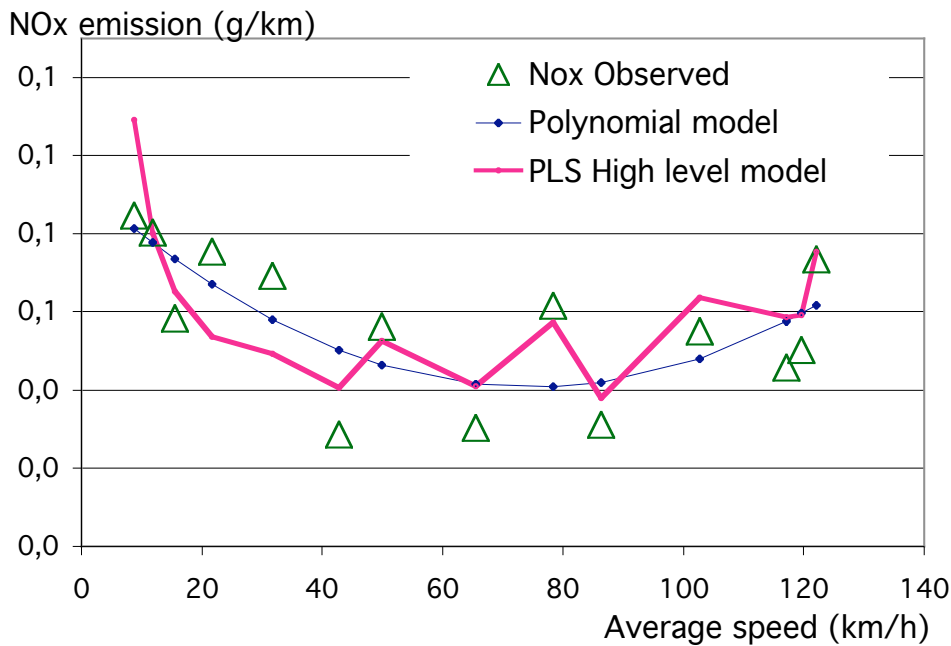


Figure 17: Petrol cars, EURO3, engine capacity:1200-1400 cm³ - NOx emission observed and predicted by a PLS high level model and by a polynomial model

R ²	CO	CO ₂	HC	NO _x
Gasoline cars				
MVA model (speed - acceleration distribution)	0.2 - 0.4	0.7 - 0.9	0.2 - 0.5	0.1 - 0.3
GLM model (average speed)	0.0 - 0.2	0.7 - 0.9	0.1 - 0.3	0.0 - 0.3
Diesel cars				
MVA model (speed - acceleration distribution)	0.5 - 0.7	0.8 - 0.9	0.5 - 0.7	0.6 - 0.9 (high level model)
GLM model (average speed)	0.1 - 0.8	0.7 - 0.8	0.4 - 0.6	0.6 - 0.8

Table 30: Synthesis of the model fits

5.2.5. Detailed results – Gasoline case studies

CO Driving cycles have a significant effect on CO, with a significant interaction with EURO class: EURO 1 and 2 show an overall decreasing trend passing from urban to motorway DC's, while EURO 3 and 4 show an opposite increasing trend. The amount of variability contributed by each of the factors is ~0 % for the emission standard and engine size, 18 % for the driving cycle, 82 % for Error.

For each EURO class, a relevant effect of driving cycles on CO trend is detected, a saw-tooth-shaped pattern of CO versus mean speed results for rural and motorway DC's, due to the effect of additional kinematic parameters influencing CO besides mean speed. In particular, Rural1,

Rural4, Motorway2 and Motorway1 are critical DC's, due to the relevant presence of accelerations at different speeds. More important variables for CO are Tidle, INVDIST, Trunning, differentiating urban from rural and motorway cycles, and M_va_pos explaining the contribution of acceleration for rural and motorway cycles (model MG), as well as frequency variables (model MVA) relative to positive acceleration at highest speed. Acceleration and speed distribution better explains the variation of CO emission which are related more to engine/catalyst instantaneous bad performance than to DC's energy. Data variance explained by PLS models is low respect to total CO variance, but comparable with variability contributed by driving cycles and quantified by ANOVA. The model with the best fit is model MVA (Speed*acceleration distribution), which has a determination coefficient R^2 in the range $0.16 \div 0.35$. As a reference, the coefficient of determination of GLM is in the range $0.02 \div 0.19$. Unexplained data variability is mostly caused by individual vehicle effect, which is bigger for CO respect to other emissions for the strong effect of few higher emitters. Including vehicle effect in PLS models enlarges the fraction of explained variance up to $0.53 \div 0.69$. Values of CO predicted by top model for motorway cycles result overestimated in some cases, due to their peculiarities and over weight of some variables in the scores calculated by MAV model.

CO₂ The analysis of CO₂ has to take into account the effect of vehicle displacement class. A significant (positive) effect of displacement results in the EURO2-EURO3 comparison of CO₂. These classes are significantly affected by driving cycles and not by EURO class. The contribution of three factors to variance resulted to be $\sim 0\%$ for the emission standard, 1.6 for the engine size, 87 % for the driving cycle and 11 % for error.

Data variation due to driving cycles is more relevant respect to data spread out, as a consequence model fit of all PLS models is good. Driving cycles effect is differentiated by energy related parameters as a whole in model MG. Model MVA gives the best fit, the coefficient of determination is in the range 0.75-0.91 (EURO I 1000-2000 – EURO III 1200-1400), the top model gives the best prediction in general. No difference of the overall model fit results respect to GLM model, which has a R^2 in the range $0.7 \div 0.9$, however PLS models explain better punctual effect of driving cycles respect to the parabolic trend of GLM.

HC The effect of Euro class on HC emission is significant. EURO 1 and EURO 2 have significantly higher emissions than EURO 3 and EURO 4, a strong interaction effect for these classes and urban cycles adds up to the main effect, explaining considerably higher values of HC with urban cycles. No significant difference results between EURO3 and EURO4 (except for EURO3 1200-1400). The amount of variability contributed by each of the factors is 22 % for the emission standard, $\sim 0\%$ for the engine size, 22 % for the driving cycle, 55 % for Error.

The trends of EURO1-2 and EURO3-4 result different for HC, as happened for CO (these pollutants are strongly correlated in the most cases), EURO 1-2 show significantly higher values for urban cycles and a decreasing trend, HC differences between EURO classes are not so significant as CO for rural and motorway cycles. When analysing HC separately, EURO3-4 show an overall not symmetric parabolic trend, with an increasing effect of urban and motorway cycles. PLS models point out peaks of critical cycles, more significant parameters are different from mean speed, they characterize urban cycles (idle time and reciprocal of distance) or are related to acceleration (mean product speed*accel.). About same considerations made for CO

apply also to HC as regards critical cycles and more important variables. DC acceleration and speed distribution better explains HC emission which (as CO) is related more to engine/catalyst instantaneous bad-performance than to DC's energy. In fact, the model with best fit is model MVA, which has a goodness of fit of $0.20 \div 0.54$, (EURO III 1400-2000 – EURO II 1200-1400), sufficient only in a few cases. Data variance explained by PLS models is low respect to total HC variance, but they are capable to explain more than the whole amount of variability contributed by driving cycles and quantified by ANOVA. GLM has a R^2 in the range 0.07-0.34. Unexplained data variability is mostly caused by vehicle effect. Including vehicle effect in PLS models enlarges the fraction of explained variance up to $0.53 \div 0.76$.

NOX: A significant (positive) effect of displacement results in the EURO2-EURO3 comparison of NOX (as in the case of CO₂). Taking into account this effect and comparing all seven cases, EURO1 show significantly higher emissions than EURO2, which in turn show higher values than EURO3 – 4. NOX level for EURO 3 and EURO 4 is really low, especially for rural and motorway DC's, and no significant differences result, except for EURO3 14-20, which presents higher mean values, due to the increasing effect of urban cycles. The amount of variability contributed by each of the factors is 36 % for the emission standard, 1,5 % for the engine size, 19 % for the driving cycle, 43 % for Error.

More significant parameters for NOX are running time, mean product speed*accel. Acceleration and speed distribution better explains NOX emission, which is influenced by instantaneous power and air fuel mixture richness, affecting also catalyst performance. Very likely for this reason, the model with best fit is model MVA (Speed*acceleration distribution), which has a R^2 in the range $.10 \div .30$ (EURO III over 2000 – EURO II 1200-1400), very varying but never sufficient. Data variance explained by PLS models is low respect to global NOX variance, but they are capable to explain more than the whole amount of NOX variation contributed by driving cycles and quantified by ANOVA. GLM has a R^2 in the range $0.03 \div 0.25$. Not explained data variability is mostly caused by vehicle effect. Including vehicle effect in PLS models enlarges the fraction of explained variance up to $0.39 \div 0.84$.

5.2.6. Detailed results – Diesel case studies

Analysing results relative to diesel passenger cars, it is to be underlined that the three case studies are very different each other. EURO1 cars number is very little: just three cars cannot be considered as a representative sample of EURO1 population. Another important note is that different aspects can differentiate diesel passenger cars: type of fuel injection (pre-chamber or direct injection), introduction of EGR and electronic injection control devices (with or without common rail), the presence of catalyst. Generally EURO1 cars have pre-chamber engines, without catalyst, EURO2 cars may have pre-chamber or direct injection engines with electronic injection control, with/without common rail, EURO3 have generally direct injection system with common rail, EGR and catalyst. Different homologation limits were set for different technology within EURO2 class. Thus the comparison among EURO classes may be biased by the effect of factors not considered in the analysis, especially for HC and NOX emissions and EURO2 class.

CO₂ A light but statistically significant effect of EURO class results for CO₂ with rural and motorway driving cycles, data show decreasing values from EURO1 to EURO2 and

EURO3. Urban driving cycles show CO₂ values significantly higher than rural and motorway cycles. The amount of variability contributed by each of the factors is ~0 % for the emission standard (as a whole), 87 % for the driving cycle, 19 % for error.

Models well fit CO₂ trend, goodness of fit is statistically good, because the contribution of driving cycles to the variance of CO₂ is significantly higher than data random variability. Driving cycles are well characterized by energy related parameters as a whole, more important variables are Tidle and INVDIST, Trunning, differentiating urban from rural and motorway cycles, and M_va_pos explaining the contribution of acceleration for rural and motorway cycles (model MG), as well as frequencies of positive acceleration at the higher speeds of driving cycle, in the speed/acceleration distribution (model MVA). Model with best fit is MVA, which has a R² in the range 0.84±0.91. R² of GLM is in the range 0.67 ±0.76.

NOX EURO2 result statistically different from and higher than EURO1 and 3. NOX of Urban 3 and 4 are significantly higher than other cycles. Rural (1 and 4), Motorway (1 and 2) result relatively critical. The amount of variability contributed by each of the factors is ~0 % for the emission standard (as a whole), 71 % for the driving cycle, 29 % for error.

In the single case study analysis, NOX and CO₂ are highly correlated. Same results obtained by model fit of CO₂ apply also to NOX, as regards trend, goodness of fit and kinematic variables. For NOX, the model with the overall best fit is top model MT, which has a R² in the range 0.60±0.94. R² of GLM is in the range 0.60 ±0.80.

CO A significant effect of EURO class and driving cycles results for CO, EURO1 are significantly higher than EURO3, EURO2 class shows a different behaviour. Urban driving cycles are significantly higher than rural and motorway cycles. The amount of variability contributed by each of the factors is 19 % for the emission standard, 32 % for the driving cycle, 49 % for error.

More significant kinematic parameters for CO are Tidle, Inv dist, Trunning, mv, mv2, mv3, as well as speed/acceleration distribution frequencies, differentiating urban from rural and motorway cycles. Model with best fit is MVA, which has a R² in the range 0.48±0.71. R² of GLM is in the range 0.10±0.81. Vehicle effect is relevant for EURO 1 and EURO2, including vehicle effect in PLS models increases R² up to 0.87.

HC A significant difference of EURO3 respect to EURO1, EURO2 result. Urban driving cycles are significantly higher than rural and motorway cycles. The amount of variability contributed by each of the factors is 14 % for the emission standard, 38 % for the driving cycle, 49 % for error.

Analysing trends for individual cases, CO and HC result correlated and similar results in model fit are obtained. More significant kinematic parameters for HC are Tidle, Inv dist, Trunning, mv, mv2, mv3, as well as speed/acceleration distribution frequencies, differentiating urban from rural and motorway cycles. Model with best fit is MVA, which has a R² in the range 0.46±0.69. R² of GLM is in the range 0.40±0.64. Vehicle effect is relevant for EURO 1 and EURO2, including vehicle effect in PLS models increases R² range to up to 0.69±0.89.

5.3. Conclusion

The analysis of the Artemis emissions data through a hierarchical approach combining both dynamic related parameters and the 2-dimensionnal distribution of the instantaneous speed and acceleration has also demonstrated the predominant influence of the driving cycle as regards for most emissions. Most often, the best fit between observed predicted emissions can be obtained using the distribution of the instantaneous speed and acceleration, while the high level model (combining the 2 previous ones) enhances slightly the prediction. A model based on the only average speed is unable to predict the emission behaviour induced by the dynamic of the cycles. However, the model fit is generally good for CO₂ but less or not satisfying for the other pollutants due to a large variability between the vehicles, and in particular to a low number of "high emitting" petrol cars.

Further investigations should be conducted considering separately the different types of driving (urban, motorway) as well as the normal and high emitters.

6. Emission data harmonization

The previous chapters have revealed the large range and heterogeneity of the driving cycles and their influence on the pollutant emissions.

Within the Artemis project, a high number of emission data has been measured or collected from ancient or actual campaigns of measurements. The objective of this data collection was obviously to enlarge the emission dataset and so to be able to build-up the better emissions factors and functions. These data were however measured using a high number of different cycles, constituting a larger sample than the one analysed in the previous chapters.

This raises up at least two correlated questions:

- How to harmonize these emission data (as regards the test cycle), i.e. how to correct the emission data by an eventual factor related to the cycle and/or to the driving conditions,
- How to derive European emissions factors from this heterogeneous data.

In this chapter, we examine first the context and objectives, we propose then the principles of an approach to deal with these issues and to be able to provide a set of emission factors.

6.1. Emission data in Artemis

Two main types of emission data have been collected or measured within the Artemis project:

- the data measured using the Artemis cycles and sub-cycles, and which – by consequence – satisfy the initial objectives (common set of cycles used by different laboratories in different contexts and then easier comparison and integration of the data, detailed analyses made possible through the sub-cycles analyses, European representativity as regards the driving conditions),
- the other emissions data, measured using other tests cycles.

6.1.1. Artemis data

The Artemis driving cycles have been designed to describe the “space” of the actual driving conditions in their diversity, i.e. through twelve typical driving patterns and 14 representative sub-cycles. These cycles enabled then the measurement and a detailed analysis of the emissions as regards kinematic parameters. A quite large number of emission tests was carried out using these cycles in the frame of the Artemis project but also in the frame national projects.

6.1.2. Non-Artemis data

Apart from these measurements, the Artemis project has also enabled the collection of a large number of emission data. Part of them was measured in the frame of Artemis, using the

Artemis driving cycles. But a large number of data was issued from complementary programmes (today's or ancient experimentations, Artemis and non-Artemis, European and national programmes). This large dataset relies on a high number of different driving cycles. This constitutes then a quite heterogeneous dataset, both subsets (Artemis/non-Artemis) covering different vehicles categories, but rarely the whole range of vehicles categories and fuels. It was then out of question to use only the Artemis data, because this wouldn't have enabled a sufficient coverage of the vehicles categories.

The problem was then to manage this heterogeneous emission dataset, by keeping and using the largest range of emission data while preserving also the interesting properties of the Artemis Driving cycles (detailed emissions analysis and European representativity), in order to build-up the European modelling approaches and emissions factors / functions.

One should remark that this difficulty (heterogeneity of the emission dataset) concerns all the scales and approaches of the emission modelling (speed or speed / acceleration dependency through a regression approach, instantaneous emission modelling, mezzo-scale emissions according to traffic situations, emissions aggregated at the urban/rural/motorway level, etc.).

6.2. Principles of the approach

Various approaches were envisaged to achieve these goals:

- The understanding of the link between emissions and kinematic parameters (speed, accelerations, stops, etc.) should have enable a correction of the emissions measured on a given test cycle according to its specific kinematic parameters. However, the previous sections have demonstrated the difficulties to establish clear dependencies and these ones are highly dependent on the vehicle category and on the pollutant.
- The understanding of the direct link between emissions and different cycles (without considering their kinematic parameters, but comparing the average level of emissions) should have also enable a correction according to the test cycle. However, such comparisons require at least several paired emissions data sets (i.e. sample of vehicles that would have been tested using 2 or more cycles that can be then compared). Unfortunately such paired dataset are exceptional in the whole dataset. Such an approach should be then reserved to some rare cases.
- The third approach attempts to consider similarities between cycles. If we succeed in grouping cycles that are "close" together (i.e. homogeneous from a kinematic point of view), we could consider that they constitute various measurements of the same reality (i.e. one typical driving conditions). In that case, aggregating the data without any correction would have a sense (in a similar way, we consider a sample of different vehicles to measure the emissions of a vehicle category). On the other hand, considering a group of "similar" test cycles would make easier the analysis of the emission gaps between these cycles and eventual corrections, and the identification of incoherencies.

The principles proposed in this approach are then as follows:

- **Classify the cycles as regards their kinematic contents**, and establish then a typology in

classes or patterns including cycles with homogeneous test / driving conditions.

- **Identify pertinent cycles to represent each of these typical test classes.**
- **Select good bases of cycles to compute the emissions of each test pattern**, and possibly envisage and the eventual emission corrections for certain cycles.
- From these cycles selections, **derive the “reference emissions”**, which should enable later the computation of the emissions factors and building-up of modelling approaches.

6.3. “Cartography” of the driving cycles

More than 800 cycles are recorded in the Artemis emission dataset, of which 824 – for which the speed curve was available - have been analysed. Most of them are described in Annex 1.

From of these numerous cycles, 116 are “macroscopic cycles” (including several phases, sub-cycles, pre, post or transition phases), 116 are pre, post or transition phases, and 217 are cycles used for parametric studies within Artemis (WP... families to study load, gradient, gear shifting, etc.). These 449 “cycles” are of low interest.

Roughly, the interesting cycles are then 217 full cycles and 158 sub—cycles (belonging generally to the full-cycles, they can indeed be considered for emissions estimation).

Out of these 375 cycles / sub-cycles, 75 are Artemis cycles (the basic Artemis cycles/sub-cycles as well as the cycles/sub-cycles dedicated to low/high powered cars), 79 are EMPA cycles (some of them duplicating other ones or being parametric cycles), 39 cycles concerns light-duty vehicles, and 16 are US and European legislative or assimilated cycles.

Cycle_Family	Meta-cycles	Cycles	Sub-cycles	Start phases	Pre, post, transition phases	Total	Total cycles & sub-cycles
Artemis	15	17	58	7	12	109	75
EMPA	22	70	9			101	79
Handbook	12	24			12	48	24
Inrets	9	25	46			80	71
LDV_PVU	13	31	8		20	72	39
Legislative	3	8	8			19	16
modem		7	17			24	24
modemHyzem	5	9	1		8	23	10
modemIM		5				5	5
MTC		2				2	2
Napoli		3	7			10	10
OSCAR		10				10	10
TRL		4	4			8	8
TUG		1				1	1
WP3142 *	29	29	130	10	32	230	
WP321 *	5	13	25		10	53	
WP324 *	3	4	16	1	4	28	
TUV		1				1	1
Total	116	263	329	18	98	824	375

Table 31: Cycles and sub-cycles recorded in the Artemis emission database (* cycles used in parametric studies)

To build-up a pertinent typology of these cycles for emission estimation, it is essential to select them carefully. Indeed, considering all of them should reveal from instance the parametric cycles (constant acceleration, etc.) or the legislative ones due to their particular kinematic. Then we have selected as “active cycles” (i.e those considered to build-up the typology) the main

families of transient and realistic cycles (Artemis, Handbook, Inrets, modem, modemHyzem, modemIM, MTC, Napoli, OSCAR, TRL) plus some individual cycles for which emissions data are numerous (EMPA.BAB, Legislative US cycles). These most significant driving cycles, i.e. those representing realistic driving conditions and for which there are a significant number of emission data are then a set of 98 cycles / sub-cycles.

The other cycles were considered as “illustrative cycles” (i.e. they do not contribute to the construction of the typology but are also classified according to this typology). These illustrative cycles are mainly the Artemis for high and low motorization (due to the similarity with the Artemis cycles), the parametric and “artificial” cycles (constant speed, constant acceleration, Legislative European), the light-duty vehicle cycles, all the different pre, post or transition, start, etc. phases mentioned above, and finally cycles that duplicate other ones.

As for the previous analyses, we consider the 2-dimensional distribution of the instant speed and acceleration to describe the cycles. We apply then a Binary Correspondence Analysis (factorial or multidimensional analysis) and an automatic clustering. We establish then a typology into 15 classes, which maximize the cycles homogeneity (as regards the driving test conditions) within the classes and the cycles heterogeneity between classes. We identify then **typical Reference Test Patterns (RTP) or classes**, including a sub-set of driving cycles (active and illustrative) that are similar from a kinematic point of view, and that should be combined together at a later stage to compute emissions.

6.4. Reference cycles

The previous classes should be used to compute emissions. An usual way should be to consider the class gravity centres as references for these calculation. However this would imply correcting all the emission data as regards these virtual points (which does not really exist except from a mathematical point of view). Instead, one or several **Reference Test Cycle(s) (RTC)** can be selected amongst the most significant cycles (according to their quality and representativity within the RTP, and also considering the number of associated emission data) for each of the classes. This leads to a slight distortion of the typology, but the retained points are then directly associated with emissions data. The statistical and pertinence criteria enable the selection of these Reference Test Cycles.

As expected, the driving patterns from the Artemis cycles and sub-cycles appeared naturally through this process and enable the identification of 13 test patterns. Two complementary patterns were also identified that correspond to driving conditions not considered as major from the analysis of the modem-Hyzem database (Table 32). These complementary points are:

- the very congested traffic or stop and go: the Artemis sub-cycles 3 and 4 (9 and 11 km/h) were indeed less severe than other stop-and-go cycles, such as OSCAR.H and TRL.WSL_CongestedTraffic (7-8 km/h), Handbook.R4_II and III (7 and 4 km/h), Inrets.urbainlent1 and 2 (4 and 7 km/h), or modem (5-7 km/h) and Naples driving test conditions (3 km/h). In fact this pattern identified distinctly the Handbook.R4_II and III cycles as a separate group due to their lower dynamic and stop duration.
- a motorway stabilized driving at about 100 km/h (of which

modemHyzem.motorway, EMPA.BAB, Handbook.R1_III and II, modemIM.motorway, etc.).

The detailed affectation of most of the analysed cycles is provided in Annex 1 (last columns). The clustering process measures also the “kinematic” distance from each cycle to the centre of its respective class (or to the reference cycles chose for this class), providing then a quality indicator of the similarity.

When an Artemis cycle (i.e. urban) and a sub-cycle (urban_1) are associated within a class, both are considered to constitute the “reference test cycle” (as far as they are close in emissions). This enables a significant improvement of the emission data quality and coverage, and will enable an easier estimation of the emission at the aggregated level: urban / rural / motorway.

Remark: Considering several cycles as “RTC” does not affect the process: a new RTP centre is defined (combination of the individual cycles), and the emissions of this RTP corresponds to slightly different kinematic conditions.

Average acceleration (m/s²)

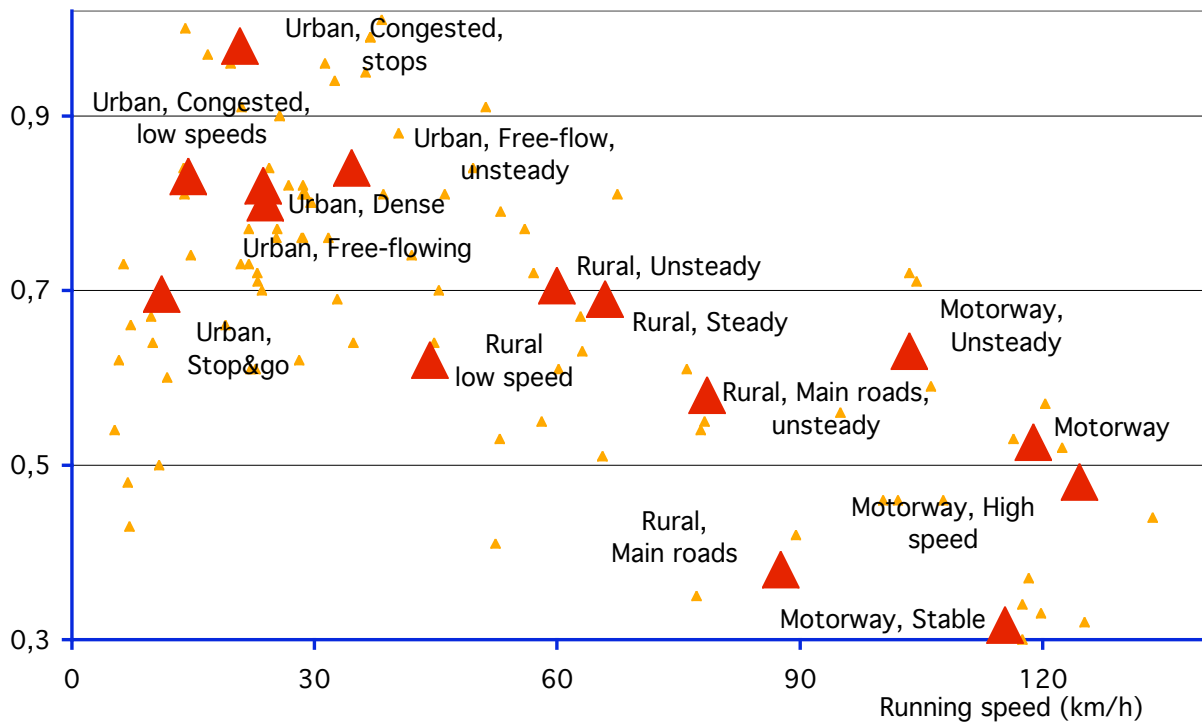


Figure 18: Test cycle variability and reference test patterns determined by automatic clustering, as regards speed and acceleration

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

Test pattern number and Characteristics			Reference test cycle	Average speed (km/h)	Average Positive acceleration (m/s ²)	Stop duration (%)	Stop/km
7	Urban	Stop&go	OSCAR.H1, OSCAR.H2, OSCAR.H3, TRL.WSL_CongestedTraffic	7	0,70	35	16,3
3	Urban	Congested, stops	Artemis.urban_3	9	0,98	58	10,2
2	Urban	Congested, low speeds	Artemis.urban_4	12	0,83	19	16,7
1	Urban	Dense	Artemis.urban, Artemis.urban_1	17	0,82	29	5,2
4	Urban	Free-flowing	Artemis.urban_5	22	0,80	10	4,3
5	Urban	Free-flow, unsteady	Artemis.urban_2	32	0,84	9	2,3
6	Rural	Low speed	Artemis.rural_3	43	0,62	3	0,5
11	Rural	Unsteady	Artemis.rural, Artemis.rural_1	58	0,71	3	0,3
9	Rural	Steady	Artemis.rural_2	66	0,69	0	0,0
10	Rural	Main roads, unsteady	Artemis.rural_4	79	0,58	0	0,0
8	Rural	Main roads	Artemis.rural_5	88	0,38	0	0,0
14	Motorway	Unsteady	Artemis.motorway_150_2	104	0,63	0	0,0
15	Motorway	Stable	EMPA.BAB, modermHyzem.motorway, TRL.MotorwayM113	115	0,32	0	0,0
13	Motorway		Artemis.motorway_130, Artemis.motorway_150_1	119	0,53	0	0,0
12	Motorway	High speed	Artemis.motorway_150, Artemis.motorway_150_3, Artemis.motorway_150_4	125	0,48	0	0,0

Table 32: Cartography of the cycles: definition and average characteristics of the test patterns and reference test cycles

Test pattern number and Characteristics			Speed (km/h)		Stops		Accelerations			
			Average	Running speed	Max. Speed	duration (%)	Frequency / km	Average Positive acc.	Acc. /km	Strong acc./km
7	Urban	Stop&go	7,1	11,1	41	35,4	16,3	0,70	10,6	1,7
3	Urban	Congested, stops	8,7	20,8	46	58,2	10,2	0,98	6,8	5,1
2	Urban	Congested, low speeds	11,7	14,4	40	18,6	16,7	0,83	16,7	4,8
1	Urban	Dense	16,9	23,7	55	28,7	5,2	0,82	8,0	2,2
4	Urban	Free-flowing	21,5	23,9	44	10,3	4,3	0,80	11,5	4,3
5	Urban	Free-flow, unsteady	31,6	34,6	58	8,5	2,3	0,84	5,2	1,7
6	Rural	Low speed	43,1	44,3	69	2,7	0,5	0,62	3,6	0,5
11	Rural	Unsteady	58,0	60,0	101	3,4	0,3	0,71	3,1	0,5
9	Rural	Steady	65,9	65,9	84	0,0	0,0	0,69	0,6	0,0
10	Rural	Main roads, unsteady	78,5	78,5	112	0,0	0,0	0,58	1,3	0,0
8	Rural	Main roads	87,6	87,6	104	0,0	0,0	0,38	0,5	0,0
14	Motorway	Unsteady	103,5	103,5	128	0,0	0,0	0,63	1,8	0,2
15	Motorway	Stable	115,3	115,3	146	0,1	0,02	0,13	0,06	0,0
13	Motorway		118,8	118,8	132	0,0	0,0	0,53	0,4	0,02
12	Motorway	High speed	124,6	124,6	150	0,0	0,0	0,48	0,5	0,02

Table 33: Detailed characteristics of the references test cycles (combination of one or several cycles)

6.5. Cycles selection for the emission estimation

At this stage, we have defined a 15 classes typology and the final objective is to compute / establish reference emissions for these 15 test patterns. For that we should use the corresponding driving cycles and particularly the reference test cycle(s) that have a better quality than the

other ones. This implies however 1- to analyse the coherency of the emissions within each class, 2-possibly to “correct” or cancel the emissions from certain cycles, and 3- to establish in fine the selection of cycles on which the reference emissions should be established.

6.5.1. Approaches

In this aim, at least 4 approaches have been considered:

- For each test pattern, compare the emissions computed for the whole group of cycles, for the reference cycles, and for the individual cycles. The computation of the average emissions, standard deviation and data number per test pattern, per fuel and vehicle category and for each driving cycle, should enable identifying eventual outliers, and selecting an appropriate basis for the final computation of the emissions.
- Analyse the particular and rare cases of the totally paired samples of vehicles (with at least 3 vehicles tested using both the reference cycles and an other driving cycle). This analysis should enable to propose eventually correction factors for such driving cycles.
- Analyse the variability of the driving cycles and emissions within each test pattern. The cycle affectation is an optimal process (each cycle is affected to the closest class), but this does not guarantee an absolute similarity of the driving conditions. We obtain then a certain variability within a RTP, in kinematic and then in emissions. The emission variability is furthermore made more complex due to the fact that different vehicles were measured with the different cycles, at different periods and by different laboratories. The engine capacity being not taking into account, we assume furthermore that this is not an important parameters of the emissions. The issue is then to assess if the observed variability is “acceptable” (in the range of the measurement variability, including both the inter-vehicle variability and the measurement accuracy) or if it is due to driving cycles that are too far to be considered as similar. Both the average emission value per cycle within a RTP and the statistical distance of the cycle to the centre of the class or to the Reference Test Cycle can be analysed to conclude on this point and to identify cycles that are in the range of the RTP and those that are not.
- Analyse the coherency of the emissions throughout the different vehicle categories for a given driving cycle and compare this evolution with those observed for the evolution of the reference test cycles. A total incoherency should lead to the cancellation of the corresponding data, while a systematic bias should enable a correction.
- Lastly, consider the coverage and the lacks of the cycles / emission data as regard fuels and vehicles categories. This should help assessing the stakes represented by certain cycles of lower quality but necessary to cover certain categories, or other ones associated with a high number of emission data. We should then envisage how the corresponding data can be used: correction if a systematic bias can be established, cancellation if not.

6.5.2. Analyses and results

From an initial set of 27700 data (hot emission vehicle x tests, passenger cars only), about 20000 were retained for which the driving cycles were known and analysable, and while all the

transition, pre, post, start phases, and parametric cycles were cancelled.

To illustrate the selection process, we present in Table 34 and Table 35, the initial set of cycles for 4 test patterns (1: urban, 7: congested, 8: rural and 15: motorway), their respective emissions values as well as the emissions measured throughout the whole set of cycles (in green) and on the only reference cycles (in yellow).

S	cycle	diesel					gasoline				
		EURO-1	EURO-2	EURO-3	pre- EURO-4	EURO-1	EURO-1	EURO-2	EURO-3	pre- EURO-4	EURO-1
1	<i>Artemis.HighMot_freurban</i>						0,284	0,203	0,186		
	Artemis.HighMot_urban						0,440	0,218	0,215		
	Artemis.HighMot_urbdense						1,180	0,294	0,413		
	<i>Artemis.LowMot_freurban</i>	0,747	0,862	0,796		0,725	0,207	0,500	0,040		
	Artemis.LowMot_urban	0,956	1,054	0,938		0,895	0,260	0,363	0,186		
	Artemis.LowMot_urbdense	1,033	1,221	1,096		0,987	0,343	0,392	0,059		
	Artemis.urban	1,083	1,163	0,967	0,704	0,978	0,733	0,270	0,148	0,104	1,765
2	<i>Artemis.HighMot_freurban_1</i>						0,539	0,333	0,350		
	Artemis.HighMot_urban_1						0,595	0,243	0,282		
	Artemis.HighMot_urbdense_1						1,757	0,416	0,520		
	<i>Artemis.LowMot_freurban_1</i>	1,041	1,252	1,158		1,026	0,383	0,669			
	Artemis.LowMot_urban_1	1,055	1,106	0,882		0,880	0,305	0,425	0,099		
	Artemis.LowMot_urbdense_1	0,864	1,071	1,043		0,881	0,468	0,256	0,070		
	Artemis.urban_1	0,981	1,126	1,055		1,250	0,702	0,346	0,134	0,060	1,493
1	EMPA.M2_I							0,370			
1	<i>Legislative.ECE</i>	0,878	0,712			0,895	0,142	0,218			0,858
	<i>Legislative.ECE_2000</i>	0,828	1,085	0,472	0,357	1,229	0,567	0,179	0,082	0,024	
2	Legislative.ECE_34							0,018			
	Legislative.ECE_4					1,467					
1	modem.MODEM_1					0,839	0,335	0,376			1,669
	modem.MODEM_2	1,150				0,850	0,347	0,439			2,617
	<i>modem.MODEM_5</i>					0,693	0,290	0,294			1,419
	<i>modem.MODEM_6</i>					0,722	0,374	0,448			1,618
	modem.urban5713	0,852	1,206	1,430				0,071	0,152		
2	modem.urban1					0,773	0,341	0,347			1,660
	<i>modem.urban12</i>					0,693	0,290	0,294			1,419
	modem.urban13					0,815	0,405	0,507			1,615
	modem.urban13b	1,019	1,338	1,496					0,096		
	modem.urban5					0,782	0,429	0,445			1,877
	modem.urban5b	0,883	1,218	1,466					0,102		
	modem.urban8					0,896	0,343	0,361			1,612
1	<i>modemHyzem.urban</i>	0,646	0,605			0,424	0,357	0,311			1,364
	<i>modemHyzem.urban1</i>	0,707	0,690			0,709	0,250	0,212			1,695
	<i>modemHyzem.urbanx2</i>	0,614	0,627			0,678	0,203	0,127			1,644
1	<i>modemIM.Urban_Free_Flow</i>	0,775				0,712	0,443	0,135			1,791
1	LDV_PVU.CommercialCars.urban_1	0,906	0,831			0,804					
	<i>LDV_PVU.lightvans-Empty.urban2</i>		0,859								
	<i>LDV_PVU.lightvans-Loaded.urban2</i>		0,904								
1	OSCAR.D2	1,102	0,823	1,027	0,454		0,055	0,205	0,058	0,084	
	OSCAR.E	1,144	0,931	0,713	0,519		0,087	0,242	0,082	0,121	
	OSCAR.G1	1,243	1,058	1,133	0,585		0,097	0,070	0,072	0,032	
1	TUV.TUV-A	0,522				0,491	0,309				1,804
	REF._TEST_CYCLES.1	1,058	1,148	0,978	0,700	1,067	0,716	0,285	0,137	0,082	1,624
	REF._TEST_PATTERN.1	0,840	1,071	0,822	0,524	0,867	0,247	0,279	0,135	0,068	1,210

Table 34: Illustration of the cycles selection as regards the emission coherency – Case of the test Pattern N°1, NOx emission -. All the cycles are considered. The 2 reference cycles and the combined reference test cycle are in yellow. Emissions for the whole set of cycles are in green. Italic figures highlight the deviating cycles and emissions.

S	cycle	Diesel					Gasoline				
		EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1
2	Artemis.HighMot_urbdense_3						0,434	0,235	0,381		
	Artemis.LowMot_urban_4	1,583	1,654	1,297		1,196	0,161	0,558	0,089		
	Artemis.LowMot_urbdense_3	1,333	1,618	1,695		1,547	0,208	0,602	0,012		
1	Handbook.R4_II	1,616	1,457	1,046			0,354	0,137	0,026		0,764
	Handbook.R4_III	2,715	2,494	1,757			0,316	0,185	0,030		1,316
	Handbook.S4_II						0,082	0,103			
	Handbook.S4_III						0,328	0,163			
1	Inrets.urbainlent2					1,444	0,678	0,208			0,856
2	modem.urban6					2,013	1,019	0,255			2,256
	modem.urban9					1,506	0,291	0,192			1,161
1	MTC.Essing_congested							0,012			
2	Napoli.18	3,200	2,574	2,211					0,024		
	Napoli.23	3,723	3,151	3,412					0,053		
1	TRL.WSL_CongestedTraffic		2,709			4,923	0,180	0,369			1,561
1	OSCAR.H1	1,724	1,341	1,746	0,565		0,052	0,080	0,019	0,027	
	OSCAR.H2	1,757	1,353	1,633	0,625		0,115	0,120	0,052	0,035	
	OSCAR.H3	1,596	1,376	1,838	0,709		0,060	0,255	0,155	0,060	
	REFERENCE_TEST_CYCLE.7	1,658	1,529	1,664	0,628	4,919	0,232	0,172	0,038	0,035	1,476
	REFER_TEST_PATTERN.7	2,137	1,846	1,768	0,633	3,884	0,406	0,189	0,055	0,041	1,366
2	Artemis.HighMot_rural_5							0,149	0,025		
	Artemis.LowMot_rural_5	0,543	0,631	0,610		0,691	0,164	0,065	0,495		
	Artemis.rural_5	0,523	0,505	0,618		0,569	0,402	0,136	0,041	0,021	1,327
1	EMPA.B3	0,737					0,327	0,032			
2	EMPA.B3_511						0,350				
	EMPA.B3_765						0,302				
1	Handbook.R2_I	0,504	0,550	0,783			0,658	0,168	0,035		2,076
	Handbook.S1_III						0,046	0,047			
	Handbook.S2_I						0,055	0,049			
1	Legislative.US_HWAY	1,001				0,564	0,264	0,110	0,028		1,079
2	Legislative.US_HWAY511							0,135	0,027		
	Legislative.US_HWAY765							0,130	0,022		
2	TRL.MotorwayM90		0,491	0,537		1,426	0,413	0,341	0,187		3,566
	REFERENCE_TEST_CYCLE.8	0,517	0,501	0,613		0,565	0,398	0,131	0,037	0,017	1,322
	REFER_TEST_PATTERN.8	0,732	0,521	0,609		1,098	0,335	0,158	0,047	0,021	1,287
1	EMPA.BAB	1,314	0,998	1,095		0,864	0,620	0,158	0,057	0,024	1,775
	EMPA.L2_III						1,056	0,366			
	EMPA.M2_II							0,286			
2	EMPA.BAB437						0,511	0,111	0,034		
1	Handbook.R1_I	0,752	0,781	1,022			1,127	0,348	0,060		3,420
	Handbook.R1_II	0,650	0,750	1,008			0,972	0,257	0,043		2,779
	Handbook.R1_III	0,580	0,598	0,854			0,724	0,181	0,044		2,421
	Handbook.S1_II						0,091	0,057			
1	Inrets.autoroute1					0,611	0,414	0,340			2,051
1	Legislative.US06							0,035			
1	modemHyzem.motorway	0,508	0,816			0,505	0,493	0,448			2,434
	modemHyzem.motorway1	1,225	0,761			0,467	0,542	0,441			2,659
	modemHyzem.motorway_part_1	0,565	0,580			0,775	0,352	0,134			2,639
1	modemIM.Motorway	0,673				0,582	0,690				2,502
	LDV_PVU.lightvans-Empty.motorway		0,640								
	LDV_PVU.lightvans-Loaded.motorway		0,635								
1	TRL.Motorway			0,729					0,034		
2	TRL.MotorwayM113		0,845	0,920		1,800	0,424	0,590	0,025		3,469
	REFERENCE_TEST_CYCLE.15	1,167	0,787	1,031		1,473	0,595	0,295	0,045	0,020	1,953
	REFER_TEST_PATTERN.15	1,012	0,740	0,973		1,389	0,633	0,278	0,049	0,024	2,077

Table 35: Cycles selection as regards the emission coherency – Test Pattern N°7, 8, 15, NOx emission - Reference cycles in yellow. Deviating cycles in Italic.

As shown, the variability of the emissions can be quite high within a test patterns. A systematic analysis of the ranges of variation was conducted for all the test patterns and all the pollutants. The “relative emissions” (around a reference value of 1) range frequently within intervals of 0.2 to 10 (NO_x, CO), or 0,4 to 2 (CO₂). Such variations are hardly acceptable. This indicates clearly that several cycles are too far from the average driving / test conditions within a given class or test pattern. These deviating cycles were systematically searched for and are highlighted in *Italic* in the previous tables.

As regards test pattern 1, the following cycles deviate significantly from the average figures: Artemis.HighMot_ and LowMot_freeurban, Legislative.ECE and ECE2000, modem.MODEM_5 and 6, modem.urban12, the modemHyzem.urban cycles, modemIM.Urban_FreeFlow, the short cycle TUV.TUV-A.

For test patterns 7 and 8, the deviating cycles are respectively Handbook.R4_III, MTC.Essing_Congested, Napoli.18 and 23 on one side, Handbook.S1_III, Handbook.S2_I on the other side. For the motorway test pattern 15, none cycle deviates significantly.

These deviating cycles were generally not of high importance because either they account for few data (their incidence on the results is indeed very low) or they are not necessary to enable a good coverage of the vehicle / fuel categories. These cycles (as well as the light duty vans specific measurement with / without load) were then cancelled.

The same process was applied for all the 15 test patterns, focusing first on the NO_x, and confirming the selection through the analysis of the CO₂. Within a reference test pattern, a cycle that presented an important and systematic gap for one pollutant was cancelled for all the pollutants. Important datasets were considered with caution (TRL, OSCAR, Handbook, modem, modemIM, Highway, FTP), as they represented a high number of tests, or have EURO4 emission data or particulate data.

Generally, one can say that when the RTC and RTP emissions were consistent, there was no need to go further in the analysis: considering all the data does not affect significantly the results. Some deviating cycles showed quasi-systematic under or over estimation. They were generally far away from the RTC in term of kinematic. When they did not represent a high quantity of tests, the corresponding data was cancelled in a first approach. When the difference was not at all systematic or understandable, the cancellation of the related data was unavoidable. The relative evolution observed between pre-EURO, EURO1, 2, 3 and 4 was also examined, as theoretically, this evolution observed for one given cycle should be consistent as it generally concerned one given experiment and one laboratory.

The analyses showed that the order of magnitude of the average emissions per RTP (including all the driving cycles selected in a first approach) and those of the corresponding RTC were in most cases very comparable, and the variability of the emissions between the most important cycles was generally low. We observed some important differences, but these differences were not systematic (for the different vehicles categories). Considering that the engine capacity was not a significant factor of the emissions (except CO₂) we have also neglected the vehicle size effect that could explain the differences.

From the 20000 initial data (hot emission vehicle x tests, passenger cars only), this selection process led to retain about 11000 coherent data (3100 diesel and 7700 petrol). Three

complementary cycles were considered to enlarge the coverage (vehicle categories), but this finally led to get only 200 complementary emissions data, which did not significantly affect the results.

6.6. Emission calculation and refinements

The resulting emissions are shown in Table 36 (Case of NO_x emissions) and in Annex 11.

NO _x g/km in NO ₂ equivalents				diesel					gasoline				
Reference	Test Patterns and speed (km/h)			EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1
7	Urban Stop&go	7		1,551	1,583	1,620	0,633	3,884	0,422	0,193	0,072	0,041	1,369
3	Urban Congested, stops	9		1,506	1,892	1,750	0,618	1,669	0,915	0,357	0,152	0,071	2,672
2	Urban Congested, low speeds	12		1,124	1,458	1,455	0,665	1,644	0,803	0,284	0,149	0,043	1,811
1	Urban Dense	17		1,049	1,143	0,991	0,566	0,862	0,483	0,300	0,146	0,085	1,858
4	Urban Free-flowing	22		0,877	0,981	1,009	0,339	1,938	0,326	0,233	0,117	0,049	1,652
5	Urban Free-flow, unsteady	32		0,807	0,854	0,939	0,441	1,076	0,398	0,274	0,112	0,044	1,790
6	Rural Low speed	43		0,550	0,568	0,644	0,386	0,691	0,331	0,111	0,045	0,024	0,798
11	Rural Unsteady	58		0,612	0,703	0,670	0,401	0,963	0,384	0,205	0,084	0,070	1,708
9	Rural Steady	66		0,519	0,554	0,608	0,364	0,629	0,347	0,106	0,043	0,015	1,243
10	Rural Main roads, unsteady	79		0,654	0,942	1,105	0,662	0,781	0,643	0,227	0,101	0,022	2,718
8	Rural Main roads	88		0,732	0,521	0,609	0,365	1,098	0,339	0,163	0,047	0,021	1,287
14	Motorway Unsteady	104		0,689	0,977	1,077	1,015	0,772	0,665	0,205	0,075	0,008	2,819
15	Motorway Stable	115		1,053	0,790	0,973	0,917	1,398	0,639	0,284	0,049	0,024	2,070
13	Motorway	119		0,825	1,049	0,785	0,740	1,013	0,613	0,226	0,068	0,018	3,418
12	Motorway High speed	125		0,872	1,316	1,248	1,176	1,038	0,856	0,133	0,104	0,087	3,930
Total				0,888	0,995	0,927	0,567	1,494	0,506	0,226	0,095	0,051	1,827

Table 36: NO_x emissions based on the cycles selection. In Bold and green, the extrapolated figures

As shown, a certain number of cases were not covered by the approach, and when examining in detail the results some inconsistencies were also observed.

Mechanisms of interpolation have then been implemented to cover these cases as follows:

- Extrapolation of the rate Euro4/Euro3, or Euro3/Euro2, or Euro1/Euro2 or pre-Euro-1/Euro1 observed on a similar test pattern (RTP1 for the urban cases, RTP 11 for the rural cases, RTP11 or 12 for the Motorway cases)
- Equivalence between close vehicle categories (i.e. Euro4 and Euro3, Euro3 and Euro2, Euro1 and Euro2, pre-Euro1 and Euro1) when they were too few data (case of the particulates).

A complementary correction according to the number of data (considering that a minimum number is required to establish an average emission) was also envisaged but was not implemented due to lack of time.

The whole set of corrected emission data is provided in Annex 12. This dataset was provided for further analyses to establish the various emissions functions and factors according to the different estimation approaches (average speed, microscopic and macroscopic traffic situations). One should note that some incoherencies or points to re-examine can remain at this stage such

the particulate emissions from pre-EURO1 petrol cars which seem higher than the Diesel ones.

6.7. Discussion

For the data harmonization, various issues have been initially envisaged and discussed which worth to be recapitulated here:

- To consider only the emissions measured on the RTC cycles (i.e. mainly the Artemis sub-cycles): the coverage would have been insufficient.
- To consider the Artemis measurement for EURO2 and EURO3 categories, to establish corrections rules for EURO1 and pre-EURO based on external results (a set of measurements using the Handbook cycles should enable this): This was very questionable. Indeed, such corrections (EURO1 = f(EURO3), etc.) would require an exhaustive synthesis of the question and an in-depth analysis, and a serious validation.
- To use corrected or harmonised data (from mileage and possibly other parameters effect identified in Artemis) before conducting the above analyses. This should have probably improved the results (decrease of the variability due to other factors), but was not possible as the harmonized data was not available. We can assume however that the results observed with the non-harmonised data are still valid after harmonisation.
- To use weighing factors (according to the quality of the cycles and to the number of data per vehicle): the second factor is quite complicated to implement. The first should finally have a low importance, as the selection of the cycles is already done according to their “importance” and quality.
- The analysis of the paired samples was finally of low help, because it concerned too few cases, and it would have hardly enabled to implement corrections and to gain significant a number of data.

6.8. Implications as regards the emissions modelling

The previous process (cartography of cycles and computation of the emission per driving pattern) can be considered to several aspects as a robust approach: indeed, prior to any interpolation, computation, it realizes a certain equilibrium between the different and contrasted driving conditions, considering the different cycles according to their quality. It seems then pertinent to build-up emissions functions (in particular the emission versus average speed functions) while starting from this basis.

Furthermore, the cartography of the driving cycles constitutes a good mapping of the driving conditions as regards the average speed level but also as regards the acceleration dimension, i.e. the dynamic of the traffic conditions (Figure 19). Indeed, we clearly identify two classes of driving along the speed scale, i.e. the stable or normal driving with low acceleration and stop frequencies on one side, and the unsteady driving on the opposite.

Considering this distinction could enable a more accurate analysis of the traffic dynamic at a later stage. Indeed, for certain pollutants (NO_x and CO₂) and vehicle categories, the influence

of this dynamic dimension appears clearly as shown in Figure 20.

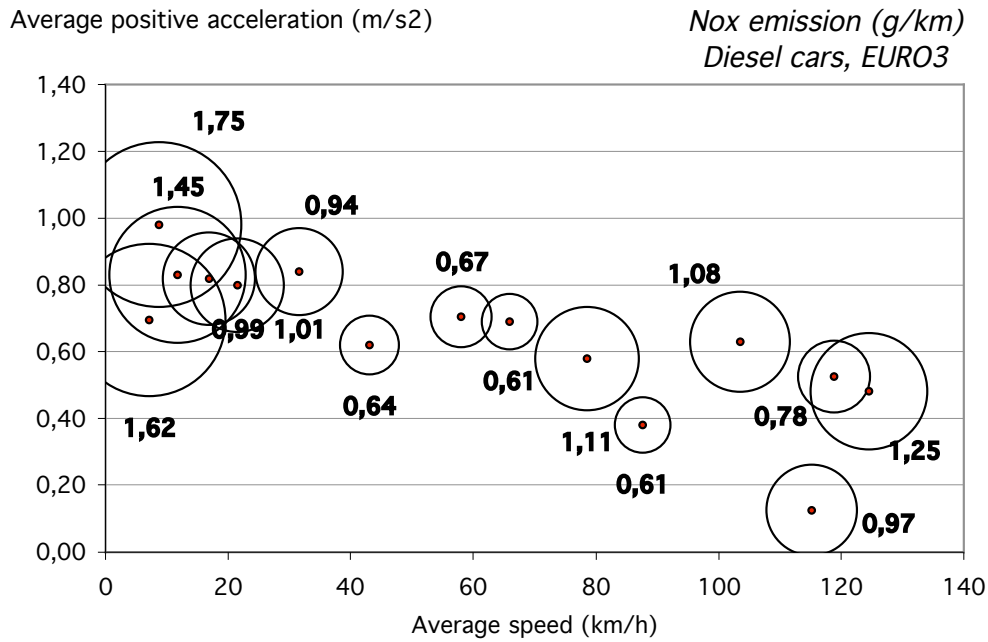


Figure 19: Typology in 15 test driving patterns and variation of the pollutant emissions (NOx emission from Diesel Cars EURO3)

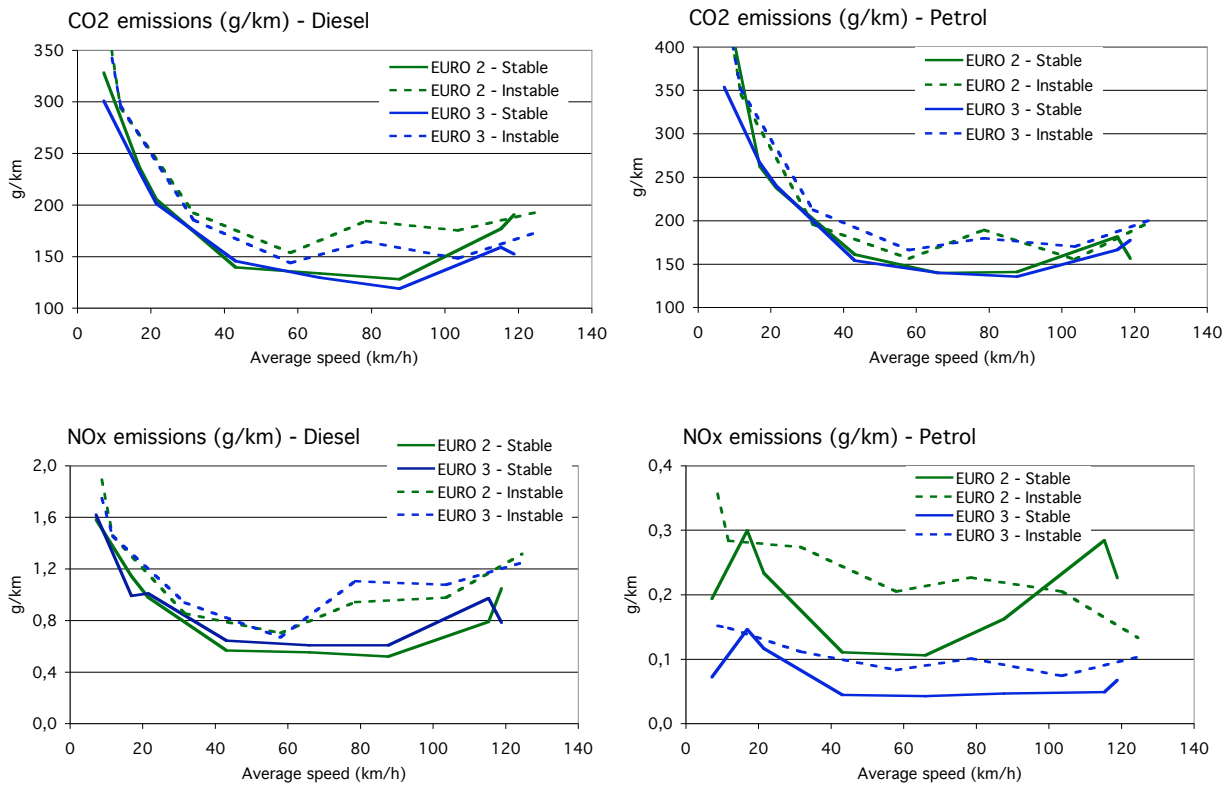


Figure 20: Dynamic influence on the CO₂ and NO_x pollutant emissions.

7. Approach for estimating the emissions at a traffic situation level

More and more, the estimation of the pollutant emissions from the road transport is needed at a low spatial scale (i.e. in one street, as a function of the traffic conditions), to enable detailed inventories or impact studies. Indeed pollutant emissions are generally quite sensitive to different "traffic situations", as the encountered driving conditions significantly vary. It was then agreed in the frame of the ARTEMIS and COST346 European research projects, that an approach - the so-called "Traffic situations approach" (by type of street and traffic conditions) - should be designed for estimating the pollutant emissions at this level.

A structure recapitulating the most important traffic situations encountered in the European context has then been elaborated (André et al. 2005b, Fantozzi et al. 2005).

The approach requires also appropriated emissions and driving related data. For the passenger cars, the emissions factors are mainly based on the Artemis driving cycles, but include also a high number of non-Artemis data. As developed in the Chapter 6, a typology of the numerous cycles has been built-up, that has enabled the definition of 15 reference tests patterns for which reference emissions are calculated.

To compute the emissions for a given traffic situation, it is proposed to develop an approach based on this cartography. A linear combination (in term of kinematic) between a representative speed curve and the 15 test patterns is proposed, so that we can estimate the emissions at the street level by a combination of the related emissions factors.

In this chapter, we recapitulate the principles and assumptions behind this approach.

7.1. Definition of traffic situations

The estimation of the pollutant emissions at a street level implies the definition of "traffic situations" which should be understandable across the different countries and users, and preferably close to the classifications usually implemented by traffic engineers (André et al. 2005b, Fantozzi et al. 2005).

It was proposed to adopt a road classification based on the urban / rural areas distinction and according to the road function (access / distribution / through). The distinction between motorway and normal road and the road characteristics were then considered according to the usual practices in Europe to propose an agreed urban and rural road typology (Table 37 and Table 38).

Main function	Characteristics	Speed limit (km/h)
National and regional network - Through-traffic	5a - Motorway	80 - 130
	5b - Non-motorway	70 - 100
Agglomeration primary network - Primary distributor	4a - Motorway (ring, etc.)	60 - 110
	4b - Non-motorway	50 - 90
Districts distributor	3 - Road	50 - 80
Local distributor- Inner exchange, local traffic	2 - Road	50 - 60
Access road - Local traffic.	1 - Road, side road, etc.	30 - 50

Table 37: Urban roads typology

Main function	Characteristics	Speed limit (km/h)
National and regional network - Through and distribution	5 - Motorway	80 - 150
	4 - Trunk road	60 - 110
Distributor	3 - Road	50 - 100
Local distributor - Inner exchange, local traffic	2 - Road	50 - 80
Access road - Local traffic	1 - Road, side road, etc.	30 - 50

Table 38: Rural roads typology

The road gradient and sinuosity were also considered with a qualitative approach for large scale application (Flat – sinuous / non-sinuuous, Hilly – ramps / sinuous, Mountainous).

For a good coverage of the actual traffic conditions, a structure in 4 levels was proposed, with free-flow traffic (average speed at 85-100% of the free speed), heavy traffic (constraint speed at 65-85% of the free speed), unsteady quite saturated traffic (variable speed with possible stops in the range of 30 to 60% of the free speed) and the stop-and-go (speed in the range of 10 km/h).

The combination of the above criteria led to the definition of several hundreds of traffic situations or cases for which speed data are required

7.2. Representative speed data

Therefore, representative speed data are required to characterize each traffic situation. Existing driving data were then collected (amongst the Artemis partners), providing that it was well documented, in order to affect a speed curve to each of the traffic situation. In parallel, a complementary experimentation was conducted to monitor one car in a certain number of cases clearly identified by the traffic situation scheme, of which hilly and mountainous roads. In all, more than 1500 speed versus time curves were collected, but most often, the information on the traffic condition was not available. On the other hand, very few data was available for rural and for hilly and mountainous situations, that can then hardly be considered with different road characteristics and traffic conditions.

The available speed data were affected to the different traffic situations according to the only background information and to a validation through the driving data (average speed, stop number, etc.). Furthermore, comparisons between the different situations, and from different data set enabled a certain validation of the choices (Figure 21).

However, this process enabled the direct coverage of about 70 cases amongst more than 400 needed. For the other cases, an affectation by similarity was done (i.e. congestion for 2 roads with close speed limits should be comparable, etc.). However, this lack of data remains the

main weakness of the approach. A similar process was conducted for heavy vehicles and 2-wheelers that led to a similar conclusion.

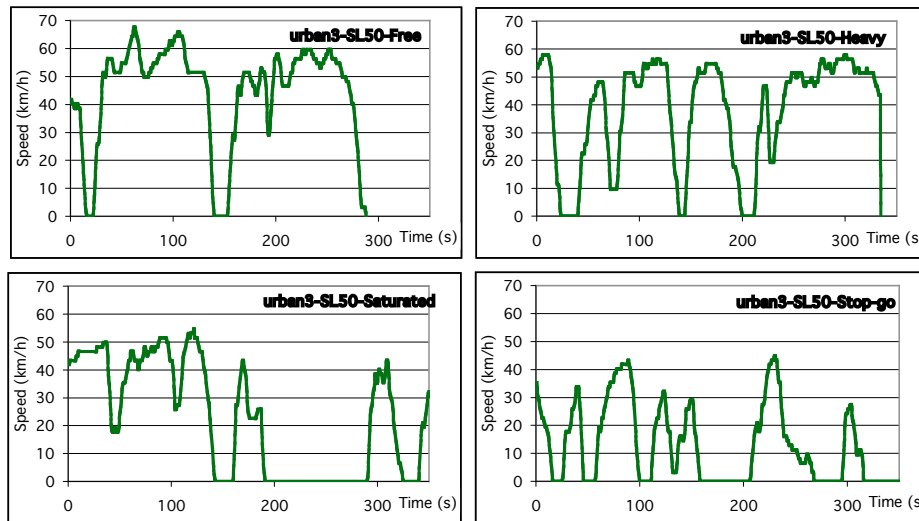


Figure 21: Speed curves corresponding to an urban road, speed limit 50 km/h, with 4 conditions of traffic

7.3. Emission estimation

The previously developed emission cartography is quite appropriated to compute emission for the different traffic situations, as the structure enables already the analysis at a relatively microscopic scale. The idea is then to “link” a given traffic situation as a function of the different sub-cycles for which emissions are known.

In this aim, the representative speed curves were analysed together with the test cycles as regards their speed and acceleration distribution. Binary Correspondences Analysis enabled to transform the time distribution into factorial coordinates and to compute distances between a speed curve (i.e a traffic situation) and the test cycles. These distances enabled identifying the closest test patterns and to consider the traffic situation as a linear combination proportional to the proximity – in term of kinematic – to the test patterns. We realise then a projection on the plan (when 3 reference points are selected), on the line (with 2 points), or on a hyper-plan (4 or 5 points) determined by the reference points. We got always an interpolation process, and never an extrapolation (Figure 22). We determine then a set of coefficients for each traffic situation. These coefficients are then used to compute their emissions. We obtain then a way to compute the emissions at the street level by combination of the reference emissions factors. Figure 23 highlights this calculation and the strong incidence of the traffic condition on the emissions.

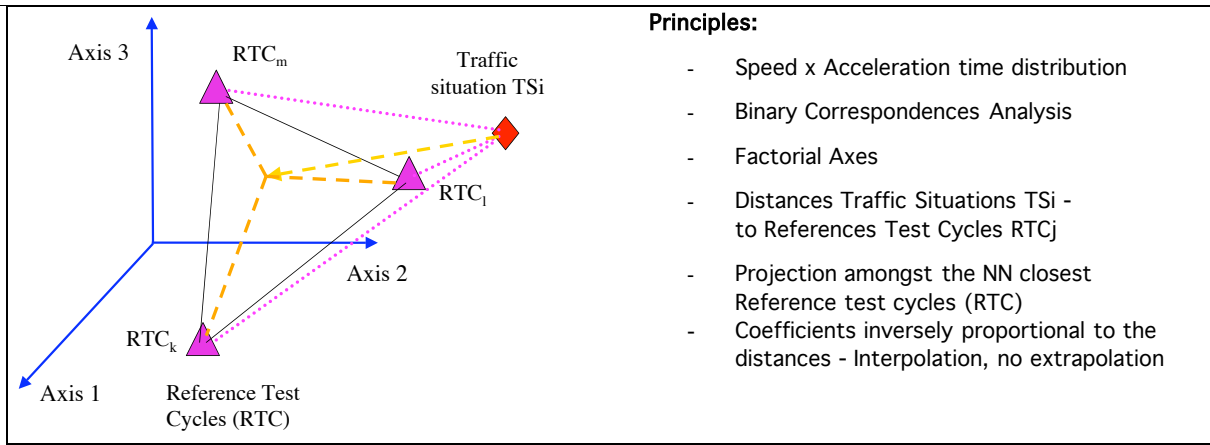


Figure 22: Positioning of a traffic situation as regards the reference test cycles

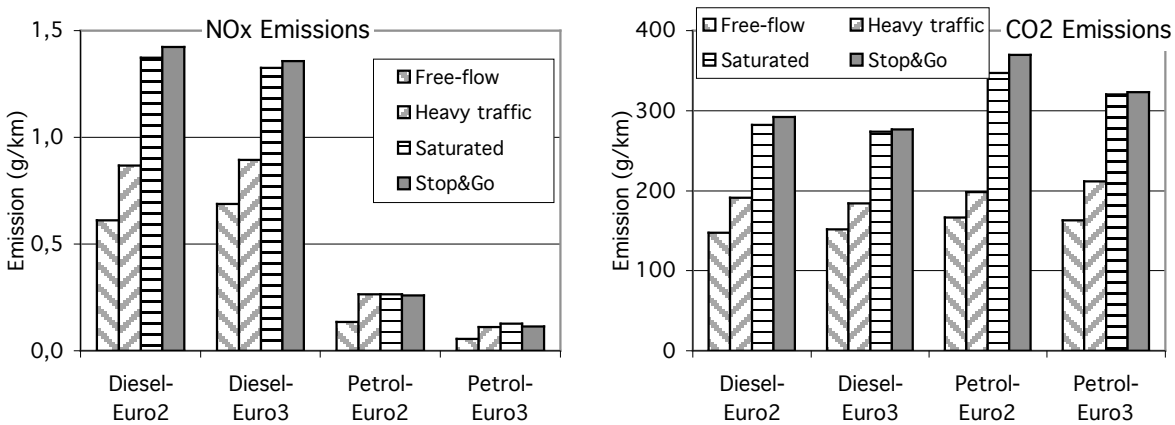


Figure 23: Emissions for an urban trunk road (4b), speed limit 50 km/h

7.4. Conclusions

An approach was designed for estimating the pollutant emissions from the passenger cars at the street level.

This approach required the provision of speed related data for a high number of traffic situations that were defined in road type and traffic conditions. The collection and analysis of the available driving data for passenger cars enabled covering partially this need.

This lack of speed data remains the main limitation and weakness of the traffic situation approach. For the time being, such an approach should be reserved for local applications, while regional or national inventories should rely on a more macroscopic and robust approach. However, the conceptual framework seems operational and ready for new data and new investigations.

A specific approach was developed to deal with the complex emission data set for the passenger cars (high number of test cycles). The emission cartography in 15 test driving patterns covering the European actual driving is used to compute in a simple way the emissions of the different traffic situations, using a representative speed curve.

Conclusions

This report recapitulates consequent works undertaken within the European research project ARTEMIS to analyse the influence of the driving cycles as regards the estimation of the emissions.

The review of a large range of cycles has enabled the building-up of a set of 14 contrasted cycles and 40 sub-cycles, and the measurement on chassis dynamometer of the pollutants emissions of 9 passenger cars. These data and of a complementary dataset of 30 vehicles tested using both the Artemis cycles and specific cycles for the high and low-powered cars, were analysed to characterize the influence of the cycles and of the kinematic parameters on the emission.

These analyses have demonstrated the significant and even preponderant influence of the driving cycles on the emissions. The analysis of the emissions should then necessarily be conducted by driving type (urban, rural, motorway), while the highly emitting cars should be analysed separately as they induce a large perturbation of the analyses. The analyses have also revealed quite contrasted emission behaviours for Diesel (rather sensitive to speed and stop parameters) and Petrol cars (rather sensitive to accelerations) and a certain similarity between urban and rural driving for both the categories of vehicles.

The occurrence of very high or very low speeds, of high accelerations at high speeds, the frequencies of stops, of accelerations and of strong accelerations, the occurrence of high acceleration / deceleration, the stop duration, and finally the acceleration level were identified as the most significant parameters of the emissions.

The analysis of the Artemis emissions data through a hierarchical approach combining both dynamic related parameters and the 2-dimensionnal distribution of the instantaneous speed and acceleration has also demonstrated the predominant influence of the driving cycle as regards for most emissions. Most often, the best fit between observed and predicted emissions can be obtained using the distribution of the instantaneous speed and acceleration, while a model based on the only average speed is unable to predict the emission behaviour induced by the dynamic of the cycles. However, the model fit is generally good for CO₂ but less or not satisfying for the other pollutants due to a large variability between the vehicles, and in particular to a low number of "high emitting" petrol cars.

The comparison between the emissions measured on specific driving cycles for the high- and low-powered cars respectively, and the emissions measured with only one common set of cycles for all the cars, has demonstrated that emissions estimations can be strongly affected by this purely methodological aspect, particularly for the recent vehicles. Although the induced complexity, the taking into account of the vehicles performances and of their specific uses should then become important to improve the quality of the emissions estimations.

The analysis the Artemis hot emission database for cars and its harmonization as regards test cycles have enabled the elaboration of reference emissions, through a “cartography” of the cycles. This approach constitutes certainly a good basis for the elaboration of emissions functions (in particular the emission versus average speed functions). The mapping of the driving conditions as regards speed and acceleration highlights well the influence of the traffic dynamic on the emissions and should then improve its taking into account.

These reference emissions were then used for the development of a specific method to compute the emissions at a low spatial scale, i.e. the so-called traffic situation approach. These results have been implemented in the European emission model Artemis for the light vehicles.

These works have certainly contributed to a better understanding of the link between the emissions and the driving cycles, kinematic parameters and driving conditions. The 2-dimensional time distribution of the speed and acceleration, largely used to characterize driving cycles, constitutes also a good basis for the emission modelling. It was successfully used to harmonize the Artemis emission database as regards the test cycles and to develop the emission estimation approach at a local scale.

The question of the highly emitting vehicles and the limitation of the emission estimation based on the only average speed emission dependency were raised-up and should require further investigations to improve the emission estimation.

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Annex 1. Driving cycles considered for selection (Chapter 1) and harmonization (Chapter 6)

Notes on the following tables:

- By convention, a cycle is named by its “family name” (giving information on its origin or its context), followed by a cycle name, which attempts to be as explicit as possible.
 - In the following tables, the specific phases such as pre-conditioning, post-cycle, transitions are not reported.
 - In the following tables, the “parametric cycles”, i.e. derived or adapted from other ones to study specifically the influence of parameters such as the gearshift strategy, the vehicle load, the road gradient, etc. are not reported.
1. The Artemis.urban_start phase is designed to measure the emission at the engine start (which is never estimated from other procedures and not included in the standard ones)
 2. A specific version of this motorway cycle, with a speed limit at 130 km/h, taking into account the possible limitation of the chassis dynamometer
 3. Artemis.URM130 and URM150 are composite cycles including the whole set of the Artemis cycles (i.e. urban, rural and motorway, self-weighted). These cycles were sometimes used in particular for Particulates measurements
 4. The characteristics of the Neapolitan sub-cycles are computed after their modification for the building-up of the 3 Neapolitan cycles
 5. Three composite cycles derived from the Neapolitan driving patterns
 6. Quasi steady speeds around the given speed
 7. Composite cycles grouping the 14 modem.urban sub-cycles into 6 main cycles
 8. Modified modem.urban sub-cycles (5,7 and 13) to derive 1 composite cycle (modem.urban5713) as indicated in Chapter 1

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

MAIN CYCLES FAMILIES USED IN CHAPTER 1 (WP3141 SELECTION OF CYCLES) AND ALSO IN CHAPTER 6 (ARTEMIS DATABASE HARMONISATION)																				WP3141 SELECTION			CARTOGRAPHY OF CYCLES			
Notes	IFAMI	Cycle_Family	Cycle_Name	Cycle/Sous-cycle	duration (s)	distance (m)	Average speed (km/h)	Running speed (km/h)	Maximum speed (km/h)	Stop number	Stop duration in %	Stops / km	Average negative acceleration (m/s ²)	Average Positive Acceleration (m/s ²)	Std-Dev Acceleration (m/s ²)	Acceleration number	Strong acceleration number	Accelerations / km	Strong Acceleration / km	Type of cycle	ID/CYL (Identifier Database ARTEMIS)	Active/Illustrative	Pre-Classification (1-motorway/2-main roads/3-rural/4-urban)	Detailed class. (1 to 8 of: 1 or 2-motorway-main roads/3-rural/4-urban)	Active/Illustrative	Affection to the 1/5 test patterns
INRETS cycles and short cycles (for cold start measurement, French data)	13	Inrets	Inrets.urbainlent1	1	806	846	3,8	5,8	14,7	37	35,0	43,7	-0,55	0,62	0,46	18	0	21,3	0,0	1	13100001	1	4	408	1	7
	13	Inrets	Inrets.urbainlent2	1	815	1671	7,4	9,8	22,5	20	25,0	12,0	-0,58	0,67	0,51	33	3	19,8	1,8	1	13070001	1	4	408	1	7
	13	Inrets	Inrets.urbainfluide1	1	681	1879	9,9	14,7	35,1	13	32,3	6,9	-0,84	0,74	0,71	32	8	17,0	4,3	1	13110001	1	4	404	1	2
	13	Inrets	Inrets.urbainfluide2	1	1055	5617	19,2	23,0	45,2	14	16,6	2,5	-0,84	0,71	0,70	54	10	9,6	1,8	1	13090001	1	4	403	1	4
	13	Inrets	Inrets.urbainfluide3	1	1068	7232	24,4	28,4	57,9	11	14,0	1,5	-0,80	0,76	0,73	57	16	7,9	2,2	1	13120001	1	4	401	1	1
	13	Inrets	Inrets.route1	1	889	7805	31,6	38,3	70,1	10	17,4	1,3	-0,87	1,01	0,94	53	22	6,8	2,8	1	13130001	1	3	303	1	5
	13	Inrets	Inrets.route2	1	810	9270	41,2	45,4	77,6	6	9,3	0,7	-0,95	0,70	0,76	39	7	4,2	0,8	1	13080001	1	3	301	1	11
	13	Inrets	Inrets.route3	1	997	15695	56,7	63,1	101,7	4	10,1	0,3	-0,78	0,63	0,53	32	5	2,0	0,3	1	13140001	1	3	302	1	11
	13	Inrets	Inrets.autoroute1	1	735	15125	74,1	76,0	113,9	3	2,6	0,2	-0,88	0,61	0,57	24	4	1,6	0,3	1	13150001	1	2	206	1	15
	13	Inrets	Inrets.autoroute2	1	1010	26489	94,4	95,0	131,5	2	0,6	0,1	-0,74	0,56	0,43	25	4	0,9	0,2	1	13160001	1	2	202	1	15
	13	Inrets	Inrets.lentcourt	0	209	420	7,2	10,7	22,5	6	32,5	14,3	-0,48	0,75	0,50	8	2	19,0	4,8	90	13180000	1	4	408	2	7
	13	Inrets	Inrets.routecourt	0	127	1439	40,8	45,4	74,9	2	10,2	1,4	-1,14	0,68	0,85	6	0	4,2	0,0	90	13030000	1	3	301	2	5
	13	Inrets	Inrets.urbainfluidecourt	0	190	999	18,9	22,8	44,0	3	16,8	3,0	-0,78	0,84	0,78	10	3	10,0	3,0	90	13050000	1	4	403	2	4
Cycles for cars with a professional use (French data, INRETS)	21	LDV_PVU	LDV_PVU.CommercialCars.urban_1	1	584	3320	20,5	27,7	66,3	11	26,2	3,3	-0,94	0,91	0,86	33	11	9,9	3,3	1	21150001	1	4	401	2	1
	21	LDV_PVU	LDV_PVU.CommercialCars.urban_2	1	477	3723	28,1	32,1	59,8	5	12,6	1,3	-0,96	0,87	0,89	34	10	9,1	2,7	1	21160001	1	4	401	2	5
	21	LDV_PVU	LDV_PVU.CommercialCars.urban_3	1	503	2481	17,8	20,1	48,9	8	11,7	3,2	-0,77	0,77	0,69	33	6	13,3	2,4	1	21170001	1	4	404	2	2
	21	LDV_PVU	LDV_PVU.CommercialCars.road	1	811	13513	60,0	62,8	113,6	4	4,4	0,3	-0,88	0,65	0,63	44	6	3,3	0,4	1	21180201	1	3	302	2	11
	21	LDV_PVU	LDV_PVU.CommercialCars.motorway_1	1	829	18755	81,4	82,5	128,6	2	1,3	0,1	-0,71	0,66	0,56	36	5	1,9	0,3	1	21190201	1	2	206	2	15
	21	LDV_PVU	LDV_PVU.CommercialCars.motorway_2	1	774	24661	114,7	116,5	140,5	2	1,6	0,1	-0,72	0,61	0,39	10	1	0,4	0,0	1	21200201	1	1	101	2	13
Legislative European and US cycles	14	Legislative	Legislative.ECE_2000	1	781	4058	18,7	27,7	50,0	13	32,4	3,2	-0,71	0,64	0,52	0	0	0,0	0,0	3	14020101	1	4	403	2	1
	14	Legislative	Legislative.EUDC	1	401	6955	62,4	69,7	120,0	2	10,5	0,3	-0,90	0,50	0,38	2	0	0,3	0,0	3	14010701	1	3	305	2	11
	14	Legislative	Legislative.NEDC_2000	0	1181	11013	33,6	44,7	120,0	14	24,9	1,3	-0,75	0,60	0,47	2	0	0,2	0,0	90	14020000	2	4	400	2	1
	14	Legislative	Legislative.US_FTP	0	1376	11990	31,4	38,9	91,2	18	19,3	1,5	-0,93	0,81	0,65	49	16	4,1	1,3	90	14030000	2	3	300	2	5
	14	Legislative	Legislative.US_FTP1	1	506	5779	41,1	51,2	91,2	6	19,8	1,0	-0,94	0,91	0,68	16	6	2,8	1,0	2	14030101	1	3	302	1	5
	14	Legislative	Legislative.US_FTP2	1	871	6211	25,7	31,7	55,2	13	19,1	2,1	-0,92	0,76	0,64	33	10	5,3	1,6	2	14030201	1	4	402	1	5
	14	Legislative	Legislative.US_HWAY	1	766	16502	77,6	78,2	96,4	2	0,8	0,1	-0,68	0,55	0,29	9	1	0,6	0,1	2	14040001	1	3	308	1	8
14	Legislative	Legislative.US06	1	601	12885	77,2	83,4	129,2	6	7,5	0,5	-1,18	1,26	0,94	20	7	1,6	0,5	2	14050001	1	2	206	2	15	
modem urban cycles (derived from the DRIVE-modem research project, European data)	15	modem	modem.urban1	2	636	3446	19,5	25,4	60,0	8	23,1	2,3	-0,80	0,77	0,70	31	7	9,0	2,0	2	15010102	1	4	401	1	1
	15	modem	modem.urban2	2	169	877	18,7	36,3	60,0	2	48,5	2,3	-0,93	0,95	0,87	5	1	5,7	1,1	2	15010202	1	4	401	1	3
	15	modem	modem.urban3	2	283	1082	13,8	19,0	39,1	5	27,6	4,6	-0,84	0,66	0,65	10	2	9,2	1,9	2	15010302	1	4	403	1	2
	15	modem	modem.urban4	2	133	405	11,0	13,8	31,0	2	20,3	4,9	-0,77	0,84	0,67	7	1	17,3	2,5	2	15010402	1	4	404	1	2
	15	modem	modem.urban5	2	1028	6332	22,2	31,3	73,5	18	29,2	2,8	-0,93	0,96	0,89	51	18	8,1	2,8	2	15020102	1	4	401	1	1
	15	modem	modem.urban6	2	92	131	5,1	6,4	26,1	3	19,6	23,0	-0,71	0,73	0,62	6	1	46,0	7,7	2	15020202	1	4	408	1	7
	15	modem	modem.urban7	2	101	840	29,9	36,9	82,4	3	18,8	3,6	-1,02	0,99	0,98	6	2	7,1	2,4	2	15020302	1	4	405	1	5
	15	modem	modem.urban8	2	251	1107	15,9	21,9	53,5	5	27,5	4,5	-0,70	0,73	0,64	9	2	8,1	1,8	2	15030102	1	4	403	1	1
	15	modem	modem.urban9	2	96	201	7,5	10,8	27,5	3	30,2	14,9	-0,71	0,50	0,47	5	0	24,9	0,0	2	15030202	1	4	408	1	7
	15	modem	modem.urban10	2	431	1867	15,6	21,0	44,4	9	25,8	4,8	-0,78	0,91	0,70	17	7	9,1	3,8	2	15030302	1	4	403	1	4
	15	modem	modem.urban11	2	963	11347	42,4	44,8	88,2	7	5,4	0,6	-0,81	0,64	0,60	56	8	4,9	0,7	2	15040102	1	3	302	1	11
	15	modem	modem.urban12	2	424	2443	20,7	25,3	49,9	8	18,2	3,3	-0,86	0,76	0,67	20	4	8,2	1,6	2	15050102	1	4	402	1	1
	15	modem	modem.urban13	2	527	2620	17,9	25,7	55,7	10	30,4	3,8	-0,81	0,90	0,82	21	5	8,0	1,9	2	15060102	1	4	401	1	1
	15	modem	modem.urban14	2	384	3413	32,0	38,5	67,0	5	16,9	1,5	-0,89	0,81	0,74	23	5	6,7	1,5	2	15060202	1	3	303	1	5

MAIN CYCLES FAMILIES USED IN CHAPTER 1 (WP3141 SELECTION OF CYCLES) AND ALSO IN CHAPTER 6 (ARTEMIS DATABASE HARMONISATION)																	WP3141 SELECTION			CARTOGRAPHY OF CYCLES							
Notes	IFAMI	Cycle_Family	Cycle_Name	Cycle/Sous-cycle	duration (s)	distance (m)	Average speed (km/h)	Running speed (km/h)	Maximum speed (km/h)	Stop number	Stop duration in %	Stops / km	Average negative acceleration (m/s ²)	Average Positive Acceleration (m/s ²)	Std-Dev Acceleration (m/s ²)	Acceleration number	Strong acceleration number	Accelerations / km	Strong Acceleration / km	Type of cycle	IDCYCL (identifier Database ARTEMIS)	Active/Illustrative	Pre-Classification (1- motorway/2-main roads/3-rural/4-urban)	Detailed class. (1 to 8 of: 1 or 2-motorway-main roads/3-rural/4-urban)	Active/Illustrative	Affection to the 15 test patterns	
modem-Hyzem cycles (derived from the DRIVE-modem and BRITE-EURAM research projects, European data)	16	modemHyzem	modemHyzem.urban	1	561	3470	22,3	29,6	57,2	6	24,8	1,7	-0,79	0,80	0,69	29	8	8,4	2,3	1	16010001	1	4	401	1	1	
	16	modemHyzem	modemHyzem.urban1	1	721	4185	20,9	28,6	59,0	14	27,0	3,4	-0,97	0,82	0,81	33	10	7,9	2,4	1	16040001	1	4	401	1	1	
	16	modemHyzem	modemHyzem.urban3	1	584	2914	18,0	22,9	61,6	12	21,4	4,1	-0,76	0,72	0,61	27	5	9,3	1,7	1	16050001	1	4	404	1	2	
	16	modemHyzem	modemHyzem.road_total	0	844	11224	47,9	53,5	103,4	6	10,5	0,5	-0,93	0,72	0,70	40	7	3,6	0,6	90	16020000	2	3	300	2	11	
	16	modemHyzem	modemHyzem.road	1	743	10682	51,8	57,1	103,4	4	9,3	0,4	-0,94	0,72	0,70	33	6	3,1	0,6	1	16020201	1	3	302	1	11	
	16	modemHyzem	modemHyzem.road1_total	0	701	7820	40,2	44,3	71,7	4	9,4	0,5	-0,77	0,83	0,66	39	10	5,0	1,3	90	16060000	2	3	300	2	5	
	16	modemHyzem	modemHyzem.road1	1	584	6957	42,9	46,1	71,7	3	7,0	0,4	-0,76	0,81	0,65	35	8	5,0	1,2	1	16060201	1	3	301	1	11	
	16	modemHyzem	modemHyzem.road2_total	0	1495	27327	65,8	68,0	125,8	5	3,3	0,2	-0,80	0,62	0,52	52	6	1,9	0,2	90	16070000	2	3	300	2	11	
	16	modemHyzem	modemHyzem.road2	1	1091	23107	76,2	77,7	125,8	1	1,9	0,0	-0,70	0,54	0,40	32	4	1,4	0,2	1	16070201	1	2	206	1	11	
	16	modemHyzem	modemHyzem.motorway_total	0	1805	46205	92,2	95,4	138,1	5	3,4	0,1	-0,92	0,73	0,53	49	9	1,1	0,2	90	16030000	2	2	200	2	15	
	16	modemHyzem	modemHyzem.motorway	1	1495	42902	103,3	104,4	138,1	2	1,0	0,1	-0,85	0,71	0,44	30	6	0,7	0,1	1	16030201	1	2	202	1	15	
	16	modemHyzem	modemHyzem.motorway1_total	0	1869	42702	82,3	89,0	149,9	8	7,6	0,2	-0,78	0,67	0,59	74	9	1,7	0,2	90	16080000	2	2	200	2	15	
	16	modemHyzem	modemHyzem.motorway1	1	1281	36939	103,8	106,2	149,9	1	2,3	0,0	-0,71	0,59	0,51	45	1	1,2	0,0	1	16080201	1	2	202	1	15	
	modemIM cycles and short cycle (Drive-modem and IM proj.)	17	modemIM	modemIM.Urban_Slow	1	429	1705	14,3	20,9	42,3	8	31,5	4,7	-0,69	0,73	0,65	18	5	10,6	2,9	1	17040001	1	4	403	1	2
17		modemIM	modemIM.Urban_Free_Flow	1	356	2248	22,7	28,5	62,3	7	20,2	3,1	-0,89	0,81	0,77	15	4	6,7	1,8	1	17030001	1	4	401	1	1	
17		modemIM	modemIM.Road	1	713	8485	42,8	49,6	109,2	5	13,6	0,6	-0,83	0,84	0,72	31	9	3,7	1,1	1	17020001	1	3	302	1	5	
17		modemIM	modemIM.Motorway	1	453	12683	100,8	103,5	128,7	2	2,6	0,2	-0,81	0,72	0,47	10	2	0,8	0,2	1	17010001	1	2	202	1	15	
17		modemIM	modemIM.Short	1	256	2246	31,6	39,6	69,7	5	20,3	2,2	-0,84	0,85	0,77	9	3	4,0	1,3	2	17050001	1	3	303	2	5	
Neapolitan driving patterns (by IM-CNR, Italy)	19	Napoli	Napoli.1	2	261	1061	14,6	18,0	37,9	6	18,8	5,7	-0,75	0,67	0,61	14	6	13,2	5,7			1	4	404			
	19	Napoli	Napoli.2	2	88	141	5,8	8,7	19,3	6	34,1	42,7	-0,57	0,77	0,59	4	2	28,5	14,2			1	4	408			
	19	Napoli	Napoli.3	2	21	6	1,0	2,9	4,0	3	66,7	525,4	-0,37	0,37	0,31	0	0	0,0	0,0			1	4	406			
	19	Napoli	Napoli.4	2	120	817	24,5	26,0	46,6	2	5,8	2,5	-0,49	0,54	0,42	9	0	11,0	0,0			1	4	402			
	19	Napoli	Napoli.5	2	47	82	6,3	9,2	16,3	3	31,9	36,8	-0,55	0,73	0,51	2	2	24,5	24,5			1	4	408			
	4	19	Napoli	Napoli.6 *	2	447	7160	57,7	60,2	105,5	2	4,3	0,3	-0,63	0,61	0,48	25	1	3,5	0,1	2	19010102	1	3	306	1	11
	19	Napoli	Napoli.7	2	39	14	1,3	5,6	9,1	3	76,9	213,4	-0,57	0,63	0,56	0	0	0,0	0,0			1	4	406			
	19	Napoli	Napoli.8	2	1404	1635	4,2	7,5	24,5	72	43,9	44,1	-0,58	0,65	0,52	34	17	20,8	10,4			1	4	408			
	19	Napoli	Napoli.9	2	57	184	11,6	15,7	26,7	2	26,3	10,9	-0,63	0,54	0,49	3	0	16,4	0,0			1	4	404			
	4	19	Napoli	Napoli.10 *	2	527	2895	19,8	22,1	50,0	5	10,6	1,7	-0,65	0,61	0,53	29	0	10,0	0,0	2	19020102	1	4	404	1	2
	19	Napoli	Napoli.11	2	240	1122	16,8	19,4	48,1	3	13,3	2,7	-0,69	0,62	0,52	14	3	12,5	2,7			1	4	404			
	19	Napoli	Napoli.12	2	407	193	1,7	4,8	10,4	20	64,4	103,7	-0,48	0,54	0,39	8	0	41,5	0,0			1	4	406			
	19	Napoli	Napoli.13	2	1451	582	1,4	4,8	14,1	67	69,9	115,2	-0,49	0,52	0,35	15	2	25,8	3,4			1	4	406			
	19	Napoli	Napoli.14	2	68	261	13,8	16,5	41,7	2	16,2	7,7	-0,83	0,76	0,63	3	2	11,5	7,7			1	4	404			
	4	19	Napoli	Napoli.15 *	2	179	1231	24,8	28,1	52,0	3	11,7	2,4	-1,15	0,62	0,67	6	0	4,9	0,0	2	19030102	1	4	402	1	5
	19	Napoli	Napoli.16	2	428	4310	36,3	38,0	82,7	3	4,7	0,7	-0,79	0,68	0,63	22	8	5,1	1,9			1	3	303			
	4	19	Napoli	Napoli.17 *	2	592	9309	56,6	58,1	90,2	2	2,5	0,2	-0,62	0,55	0,41	25	0	2,7	0,0	2	19010202	1	3	302	1	11
	4	19	Napoli	Napoli.18 *	2	372	347	3,4	6,9	14,7	14	51,3	40,4	-0,47	0,48	0,33	5	0	14,4	0,0	2	19030202	1	4	408	1	7
	19	Napoli	Napoli.19	2	192	332	6,2	9,3	21,9	9	33,3	27,1	-0,58	0,6	0,5	9	2	27,1	6,0			1	4	408			
	19	Napoli	Napoli.20	2	1407	19360	49,5	49,6	89,9	2	0,2	0,1	-0,6	0,52	0,38	54	6	2,8	0,3			1	3	302			
	19	Napoli	Napoli.21 *	2	520	2890	20,0	22,7	42,0	5	11,7	1,7	-0,80	0,61	0,57	28	2	9,7	0,7	2	19030302	1	4	403	1	4	
19	Napoli	Napoli.22	2	1731	33489	69,6	70,1	117,9	1	0,6	0,0	-0,59	0,5	0,4	116	4	3,5	0,1			1	3	306				
4	19	Napoli	Napoli.23 *	2	555	467	3,0	7,3	17,4	20	58,6	42,8	-0,57	0,66	0,49	7	0	15,0	0,0	2	19020202	1	4	406	1	7	
Neapolitan driving cycles from the above	5	19	Napoli	Napoli.10_23	1	1082	3362	11,2	17,3	50,0	24	35,2	7,1	-0,62	0,62	0,52	36	0	10,7	0,0	2	19020001				2	2
	19	Napoli	Napoli.15_18_21	1	1071	4468	15,0	20,2	52,0	20	25,5	4,5	-0,79	0,59	0,55	39	2	8,7	0,5	2	19030001				2	2	
	19	Napoli	Napoli.6_17	1	1039	16470	57,1	59,0	105,5	3	3,3	0,2	-0,62	0,58	0,44	50	1	3,0	0,1	2	19010001				2	11	
TUV short cycle	28	TUV	TUV.TUV-A	1	201	1970	35,3	47,6	90,0	3	25,9	1,5	-1,01	0,55	0,59	2	0	1,0	0,0	3	28010001	1	3	303	2	1	

Analysis of the cars pollutant emissions as regards driving cycles and kinematic parameters

MAIN AND COMPLEMENTARY CYCLES FAMILIES ANALYSED IN CHAPTER 6 (ARTEMIS DATABASE HARMONISATION)																								WP9141 SELECTION			CARTOGRAPHY OF CYCLES	
Notes	IFAMI	Cycle_Family	Cycle_Name	Cycle/Sous-cycle	duration (s)	distance (m)	Average speed (km/h)	Running speed (km/h)	Maximum speed (km/h)	Stop number	Stop duration in %	Stops / km	Average negative acceleration (m/s ²)	Average Positive Acceleration (m/s ²)	Std-Dev Acceleration (m/s ²)	Acceleration number	Strong acceleration number	Accelerations / km	Strong Acceleration / km	Type of cycle	IDCYCL (Identifier Database ARTEMIS)	Active/illustrative	Pre-Classification (1-motorway/2-main roads/3-rural/4-urban)	Detailed class. (1 to 8 of 1 or 2-motorway-main roads/3-rural/4-urban)	Active/illustrative	Affection to the 15 test patterns		
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.A	0	1376	11990	31,4	38,9	91,2	18	19,3	1,5	-0,93	0,81	0,65	49	16	4,1	1,3	90	11010000				2	5		
	11	EMPA	EMPA.A1	1	506	5779	41,1	51,2	91,2	6	19,8	1,0	-0,94	0,91	0,68	16	6	2,8	1,0	92	11010101				2	5		
	11	EMPA	EMPA.A2	1	871	6211	25,7	31,7	55,2	13	19,1	2,1	-0,92	0,76	0,64	33	10	5,3	1,6	92	11010201				2	5		
	11	EMPA	EMPA.A3	1	506	5779	41,1	51,2	91,2	6	19,8	1,0	-0,94	0,91	0,68	16	6	2,8	1,0	92	11010301				2	5		
	11	EMPA	EMPA.B	0	2025	27519	48,9	59,1	120,0	15	17,3	0,6	-0,71	0,59	0,39	10	1	0,4	0,0	90	11020000				2	11		
	11	EMPA	EMPA.B1	1	820	4058	17,8	26,5	50,0	13	32,7	3,2	-0,68	0,64	0,51	0	0	0,0	0,0	92	11020101				2	1		
	11	EMPA	EMPA.B2	1	400	6955	62,6	69,4	120,0	2	9,8	0,3	-0,88	0,49	0,38	1	0	0,1	0,0	92	11020201				2	11		
	11	EMPA	EMPA.B3	1	764	16506	77,8	78,0	96,4	1	0,3	0,1	-0,67	0,54	0,29	9	1	0,6	0,1	92	11020301				2	8		
	11	EMPA	EMPA.B3_255	2	256	4841	68,1	68,6	79,7	1	0,8	0,2	-0,52	0,61	0,28	5	1	1,0	0,2	92	11020402				2	9		
	11	EMPA	EMPA.B3_511	2	256	6061	85,2	85,2	96,4	0	0,0	0,0	-0,48	0,51	0,20	2	0	0,3	0,0	92	11020502				2	8		
	11	EMPA	EMPA.B3_765	2	250	5556	80,0	80,0	95,3	0	0,0	0,0	-0,80	0,36	0,34	2	0	0,4	0,0	92	11020602				2	8		
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.BAB	1	1001	32646	117,4	117,5	160,9	1	0,1	0,0	-0,38		0,15	0	0	0,0	0,0	2	11030001				1	15		
	11	EMPA	EMPA.BAB1000	2	30	1150	138,0	138,0	141,9	0	0,0	0,0			0,17	0	0	0,0	0,0	2	11030302				2	12		
	11	EMPA	EMPA.BAB437	2	438	12962	106,5	106,8	120,8	1	0,2	0,1	-0,36		0,11	0	0	0,0	0,0	2	11030102				2	15		
	11	EMPA	EMPA.BAB736	2	300	9557	114,7	114,7	137,7	0	0,0	0,0	-0,40		0,20	0	0	0,0	0,0	2	11030202				2	13		
	11	EMPA	EMPA.BeschI.	0	964	5375	20,1	36,9	60,0	17	45,6	3,2	-0,98	0,99	1,11	19	10	3,5	1,9	90	11040000				2	3		
	11	EMPA	EMPA.BeschI_1	1	188	1544	29,6	34,5	60,0	8	14,4	5,2	-1,33	1,39	1,48	7	7	4,5	4,5	3	11040101				2	5		
	11	EMPA	EMPA.BeschI_II	1	210	1935	33,2	37,5	60,0	7	11,4	3,6	-1,06	1,05	1,10	6	0	3,1	0,0	3	11040201				2	5		
	11	EMPA	EMPA.BeschI_III	1	189	1896	36,1	38,6	60,0	4	6,3	2,1	-0,56	0,55	0,62	6	3	3,2	1,6	3	11040301				2	5		
	11	EMPA	EMPA.C-1	0	1349	1197	3,2	5,9	19,3	36	45,4	30,1	-0,50	0,63	0,39	25	0	20,9	0,0	90	11060000				2	7		
	11	EMPA	EMPA.C-1_I	1	259	219	3,0	5,7	19,3	7	46,7	31,9	-0,51	0,63	0,40	5	0	22,8	0,0	91	11060101				2	7		
	11	EMPA	EMPA.C-1_II	1	259	220	3,1	5,7	19,3	7	46,7	31,8	-0,50	0,63	0,40	5	0	22,7	0,0	91	11060201				2	7		
11	EMPA	EMPA.C-1_III	1	259	220	3,1	5,7	19,3	7	46,7	31,8	-0,50	0,63	0,40	5	0	22,7	0,0	91	11060301				2	7			
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.C-2	0	829	17314	75,2	76,2	88,4	1	1,3	0,1	-0,42	0,54	0,24	14	1	0,8	0,1	90	11070000				2	9		
	11	EMPA	EMPA.C-2_I	1	259	5552	77,2	77,2	88,4	0	0,0	0,0	-0,42	0,35	0,18	4	0	0,7	0,0	91	11070101				2	9		
	11	EMPA	EMPA.C-2_II	1	259	5553	77,2	77,2	88,4	0	0,0	0,0	-0,42	0,35	0,18	4	0	0,7	0,0	91	11070201				2	9		
	11	EMPA	EMPA.C-2_III	1	259	5553	77,2	77,2	88,4	0	0,0	0,0	-0,42	0,35	0,18	4	0	0,7	0,0	91	11070301				2	9		
	11	EMPA	EMPA.C-3	0	856	27393	115,2	116,4	127,2	1	1,1	0,0	-0,33	0,70	0,23	8	1	0,3	0,0	90	11080000				2	15		
	11	EMPA	EMPA.C-3_I	1	259	8530	118,6	118,6	127,2	0	0,0	0,0	-0,33	0,34	0,12	2	0	0,2	0,0	91	11080101				2	15		
	11	EMPA	EMPA.C-3_II	1	259	8530	118,6	118,6	127,2	0	0,0	0,0	-0,33	0,34	0,12	2	0	0,2	0,0	91	11080201				2	15		
	11	EMPA	EMPA.C-3_III	1	259	8530	118,6	118,6	127,2	0	0,0	0,0	-0,33	0,34	0,12	2	0	0,2	0,0	91	11080301				2	15		
	11	EMPA	EMPA.C-4	0	1095	9395	30,9	31,8	53,9	5	3,0	0,5	-0,78	0,70	0,61	39	8	4,2	0,9	90	11090000				2	4		
	11	EMPA	EMPA.C-4_I	1	259	2302	32,0	32,8	53,9	1	2,3	0,4	-0,78	0,70	0,63	9	2	3,9	0,9	91	11090101				2	4		
	11	EMPA	EMPA.C-4_II	1	259	2302	32,0	32,8	53,9	1	2,3	0,4	-0,78	0,70	0,63	9	2	3,9	0,9	91	11090201				2	4		
	11	EMPA	EMPA.C-4_III	1	259	2302	32,0	32,8	53,9	1	2,3	0,4	-0,78	0,69	0,62	9	2	3,9	0,9	91	11090301				2	4		
	11	EMPA	EMPA.C-5	0	984	18184	66,5	72,3	88,4	4	7,9	0,2	-0,94	0,70	0,44	18	3	1,0	0,2	90	11100000				2	9		
	11	EMPA	EMPA.C-5_I	1	293	5854	71,9	74,5	88,4	1	3,4	0,2	-0,43	0,69	0,32	6	1	1,0	0,2	91	11100101				2	9		
	11	EMPA	EMPA.C-5_II	1	293	5854	71,9	74,5	88,4	1	3,4	0,2	-0,42	0,71	0,32	6	1	1,0	0,2	91	11100201				2	9		
	11	EMPA	EMPA.C-5_III	1	293	5855	71,9	74,5	88,4	1	3,4	0,2	-0,43	0,70	0,32	6	1	1,0	0,2	91	11100301				2	9		
	11	EMPA	EMPA.C-6	0	1041	29866	103,3	108,3	127,2	4	4,6	0,1	-1,17	0,83	0,49	12	3	0,4	0,1	90	11110000				2	15		
	11	EMPA	EMPA.C-6_I	1	312	9477	109,4	112,6	127,2	1	2,9	0,1	-0,32	0,83	0,33	4	1	0,4	0,1	91	11110101				2	15		
	11	EMPA	EMPA.C-6_II	1	312	9477	109,4	112,6	127,2	1	2,9	0,1	-0,33	0,83	0,33	4	1	0,4	0,1	91	11110201				2	15		
	11	EMPA	EMPA.C-6_III	1	312	9478	109,4	112,6	127,2	1	2,9	0,1	-0,33	0,82	0,33	4	1	0,4	0,1	91	11110301				2	15		

MAIN AND COMPLEMENTARY CYCLES FAMILIES ANALYSED IN CHAPTER 6 (ARTEMIS DATABASE HARMONISATION)

Notes	IFAM	Cycle_Family	Cycle_Name	Cycle/Sous-cycle	duration (s)	distance (m)	Average speed (km/h)	Running speed (km/h)	Maximum speed (km/h)	Stop number	Stop duration in %	Stops / km	Average negative acceleration (m/s ²)	Average Positive Acceleration (m/s ²)	Std-Dev Acceleration (m/s ²)	Acceleration number	Strong acceleration number	Accelerations / km	Strong Acceleration / km	Type of cycle	ID/CYCL (identifier Database ARTEMIS)	WP3141 SELECTION		CARTOGRAPHY OF CYCLES	
																						Active/Illustrative	Pre-Classification (1- motorway/2-main roads/3-rural/4-urban)	Detailed class. (1 to 8 of: 1 or 2-motorway-main roads/ 3-rural/4-urban)	Active/Illustrative
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.EL1.1	0	1229	34692	101,6	102,4	127,2	1	0,7	0,0	-0,40	0,48	0,20	11	0	0,3	0,0	90	11120000			2	15
	11	EMPA	EMPA.EL1.1_I	1	529	17385	118,3	118,3	127,2	0	0,0	0,0	-0,40	0,37	0,12	3	0	0,2	0,0	91	11120101			2	15
	11	EMPA	EMPA.EL1.1_II	1	258	7191	100,3	100,3	115,0	0	0,0	0,0	-0,35	0,46	0,20	3	0	0,4	0,0	91	11120201			2	15
	11	EMPA	EMPA.EL1.1_III	1	259	5554	77,2	77,2	88,4	0	0,0	0,0	-0,41	0,35	0,18	4	0	0,7	0,0	91	11120301			2	9
	11	EMPA	EMPA.EL1.2	0	1229	34692	101,6	102,4	127,2	1	0,7	0,0	-0,40	0,48	0,20	11	0	0,3	0,0	90	11130000			2	15
	11	EMPA	EMPA.EL1.2_I	1	529	17385	118,3	118,3	127,2	0	0,0	0,0	-0,40	0,37	0,12	3	0	0,2	0,0	91	11130101			2	15
	11	EMPA	EMPA.EL1.2_II	1	258	7191	100,3	100,3	115,0	0	0,0	0,0	-0,35	0,46	0,20	3	0	0,4	0,0	91	11130201			2	15
	11	EMPA	EMPA.EL1.2_III	1	259	5554	77,2	77,2	88,4	0	0,0	0,0	-0,41	0,35	0,18	4	0	0,7	0,0	91	11130301			2	9
	11	EMPA	EMPA.EL2.1	0	1732	15258	31,7	34,7	79,1	10	8,6	0,7	-0,59	0,57	0,43	63	4	4,1	0,3	90	11140000			2	5
	11	EMPA	EMPA.EL2.1_I	1	529	7776	52,9	52,9	79,1	0	0,0	0,0	-0,52	0,53	0,39	23	1	3,0	0,1	91	11140101			2	11
	11	EMPA	EMPA.EL2.1_II	1	529	4933	33,6	34,8	60,9	2	3,6	0,4	-0,70	0,64	0,54	22	3	4,5	0,6	91	11140201			2	5
	11	EMPA	EMPA.EL2.1_III	1	529	605	4,1	5,3	19,3	7	22,9	11,6	-0,45	0,54	0,29	12	0	19,8	0,0	91	11140301			2	7
	11	EMPA	EMPA.EL2.2	0	1732	15258	31,7	34,7	79,1	10	8,6	0,7	-0,59	0,57	0,43	63	4	4,1	0,3	90	11150000			2	5
	11	EMPA	EMPA.EL2.2_I	1	529	7776	52,9	52,9	79,1	0	0,0	0,0	-0,52	0,53	0,39	23	1	3,0	0,1	91	11150101			2	11
	11	EMPA	EMPA.EL2.2_II	1	529	4933	33,6	34,8	60,9	2	3,6	0,4	-0,70	0,64	0,54	22	3	4,5	0,6	91	11150201			2	5
11	EMPA	EMPA.EL2.2_III	1	529	605	4,1	5,3	19,3	7	22,9	11,6	-0,45	0,54	0,29	12	0	19,8	0,0	91	11150301			2	7	
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.K1	0	2191	53226	87,5	87,9	131,5	1	0,5	0,0	-0,50	0,50	0,25	32	1	0,6	0,0	90	11160000			2	11
	11	EMPA	EMPA.K1_I	1	776	21383	99,2	99,2	131,5	0	0,0	0,0	-0,37	0,38	0,18	13	0	0,6	0,0	92	11160101			2	15
	11	EMPA	EMPA.K1_II	1	540	13218	88,1	88,1	131,1	0	0,0	0,0	-0,61	0,60	0,37	10	1	0,8	0,1	92	11160201			2	11
	11	EMPA	EMPA.K1_III	1	523	10261	70,6	70,6	94,2	0	0,0	0,0	-0,41	0,43	0,22	8	0	0,8	0,0	92	11160301			2	9
	11	EMPA	EMPA.K2	0	2046	19698	34,7	38,2	81,4	12	9,2	0,6	-0,68	0,63	0,44	62	6	3,2	0,3	90	11170000			2	5
	11	EMPA	EMPA.K2_I	1	488	6841	50,5	50,5	70,9	0	0,0	0,0	-0,76	0,57	0,48	19	1	2,8	0,2	92	11170101			2	6
	11	EMPA	EMPA.K2_II	1	556	5942	38,5	38,7	81,4	1	0,5	0,2	-0,65	0,68	0,49	23	4	3,9	0,7	92	11170201			2	5
	11	EMPA	EMPA.K2_III	1	633	2386	13,6	17,6	60,3	9	22,7	3,8	-0,65	0,63	0,46	18	1	7,5	0,4	92	11170301			2	7
	11	EMPA	EMPA.Kreisel	1	514	4882	34,2	34,9	65,0	2	1,9	0,4	-1,05	0,78	0,71	25	8	5,1	1,6	2	11180001			2	5
	11	EMPA	EMPA.L1	0	1376	11990	31,4	38,9	91,2	18	19,3	1,5	-0,93	0,81	0,65	49	16	4,1	1,3	90	11190000			2	5
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.L1_I	1	506	5779	41,1	51,2	91,2	6	19,8	1,0	-0,94	0,91	0,68	16	6	2,8	1,0	92	11190101			2	5
	11	EMPA	EMPA.L1_II	1	871	6211	25,7	31,7	55,2	13	19,1	2,1	-0,92	0,76	0,64	33	10	5,3	1,6	92	11190201			2	5
	11	EMPA	EMPA.L1_III	1	506	5779	41,1	51,2	91,2	6	19,8	1,0	-0,94	0,91	0,68	16	6	2,8	1,0	92	11190301			2	5
	11	EMPA	EMPA.L2	0	2291	44639	70,1	81,0	160,9	14	13,4	0,3	-0,67	0,55	0,34	1	0	0,0	0,0	90	11200000			2	15
	11	EMPA	EMPA.L2_I	1	820	4058	17,8	26,5	50,0	13	32,7	3,2	-0,68	0,64	0,51	0	0	0,0	0,0	92	11200101			2	1
	11	EMPA	EMPA.L2_II	1	400	6955	62,6	69,4	120,0	2	9,8	0,3	-0,88	0,49	0,38	1	0	0,1	0,0	92	11200201			2	11
	11	EMPA	EMPA.L2_III	1	1001	32673	117,5	117,5	160,9	0	0,0	0,0	-0,38		0,15	0	0	0,0	0,0	92	11200301			2	15
	11	EMPA	EMPA.L2_III1000	2	264	10155	138,5	138,5	160,9	0	0,0	0,0	-0,34		0,15	0	0	0,0	0,0	92	11200602			2	12
	11	EMPA	EMPA.L2_III1437	2	428	12702	106,8	106,8	120,8	0	0,0	0,0	-0,34		0,11	0	0	0,0	0,0	92	11200402			2	15
	11	EMPA	EMPA.L2_III736	2	299	9529	114,7	114,7	137,7	0	0,0	0,0	-0,40		0,20	0	0	0,0	0,0	92	11200502			2	13
	11	EMPA	EMPA.LSA	1	771	6065	28,3	39,7	60,9	11	28,7	1,8	-1,15	0,75	0,82	27	9	4,5	1,5	2	11210001			2	5
Driving cycles derived or adapted by EMPA, Switzerland	11	EMPA	EMPA.M1	0	1141	10191	32,2	40,3	109,2	12	20,2	1,2	-0,78	0,80	0,70	49	14	4,8	1,4	90	11220000			2	1
	11	EMPA	EMPA.M1_I	1	429	1705	14,3	20,9	42,3	8	31,5	4,7	-0,69	0,73	0,65	18	5	10,6	2,9	92	11220101			2	2
	11	EMPA	EMPA.M1_II	1	713	8485	42,8	49,6	109,2	5	13,6	0,6	-0,83	0,84	0,72	31	9	3,7	1,1	92	11220201			2	5
	11	EMPA	EMPA.M2	0	808	14930	66,5	74,2	128,7	7	10,4	0,5	-0,86	0,77	0,60	25	6	1,7	0,4	90	11230000			2	15
	11	EMPA	EMPA.M2_I	1	356	2248	22,7	28,5	62,3	7	20,2	3,1	-0,89	0,81	0,77	15	4	6,7	1,8	92	11230101			2	1
	11	EMPA	EMPA.M2_II	1	453	12683	100,8	103,5	128,7	2	2,6	0,2	-0,81	0,72	0,47	10	2	0,8	0,2	92	11230201			2	15

MAIN AND COMPLEMENTARY CYCLES FAMILIES ANALYSED IN CHAPTER 6 (ARTEMIS DATABASE HARMONISATION)																				WP9141 SELECTION			CARTOGRAPHY OF CYCLES					
Notes	IFAMI	Cycle_Family	Cycle_Name	Cycle/Sous-cycle	duration (s)	distance (m)	Average speed (km/h)	Running speed (km/h)	Maximum speed (km/h)	Stop number	Stop duration in %	Stops / km	Average negative acceleration (m/s ²)	Average Positive Acceleration (m/s ²)	Std-Dev Acceleration (m/s ²)	Acceleration number	Strong acceleration number	Accelerations / km	Strong Acceleration / km	Type of cycle	IDCYCL (Identificateur Database ARTEMIS)	Active/Illustrative	Pre-Classification (1-motorway/2-main roads/3-rural/4-urban)	Detailed class. (1 to 8 of: 1 or 2-motorway-main roads/3-rural/4-urban)	Active/Illustrative	Affection to the 1 5 test patterns		
	14	Legislative	Legislative.ECE	1	821	4058	17,8	27,7	50,0	13	35,7	3,2	-0,71	0,64	0,52	0	0	0,0	0,0	3	14010101				2	1		
	14	Legislative	Legislative.NEDC	0	1221	11013	32,5	44,7	120,0	14	27,4	1,3	-0,75	0,60	0,47	2	0	0,2	0,0	90	14010000				2	1		
Composite cycles derived from the basic moderm.urban sub-cycles	7	15	modem	modem.MODEM_1	1	1218	5810	17,2	23,6	60,0	15	27,2	2,6	-0,82	0,77	0,70	53	11	9,1	1,9	2	15010001				2	1	
		15	modem	modem.MODEM_2	1	1219	7302	21,6	29,7	82,4	22	27,5	3,0	-0,93	0,94	0,88	64	22	8,8	3,0	2	15020001				2	1	
		15	modem	modem.MODEM_3	1	776	3176	14,7	20,1	53,5	15	26,7	4,7	-0,75	0,79	0,66	31	9	9,8	2,8	2	15030001				2	2	
		15	modem	modem.MODEM_4	1	963	11347	42,4	44,8	88,2	7	5,4	0,6	-0,81	0,64	0,60	56	8	4,9	0,7	2	15040001				2	11	
		15	modem	modem.MODEM_5	1	424	2443	20,7	25,3	49,9	8	18,2	3,3	-0,86	0,76	0,67	20	4	8,2	1,6	2	15050001				2	1	
		15	modem	modem.MODEM_6	1	910	6033	23,9	31,7	67,0	15	24,6	2,5	-0,84	0,86	0,78	44	10	7,3	1,7	2	15060001				2	1	
		8	15	modem	modem.urban13b	2	526	2620	17,9	25,7	55,7	11	30,2	4,2	-0,80	0,90	0,82	21	5	8,0	1,9	2	15070302				1	1
			15	modem	modem.urban2x7	2	200	1680	30,2	36,9	82,4	5	18,0	3,0	-1,02	0,99	0,99	14	6	8,3	3,6	2	15070202				1	5
			15	modem	modem.urban5713	1	1427	9078	22,9	30,8	82,4	25	25,7	2,8	-0,89	0,93	0,88	75	25	8,3	2,8	2	15070001				2	1
			15	modem	modem.urban5b	2	701	4779	24,5	32,5	73,5	11	24,5	2,3	-0,91	0,94	0,88	40	14	8,4	2,9	2	15070102				1	1
From MTC, Sweden	18	MTC	MTC.Essing_congested	1	1050	1427	4,9	6,3	16,4	24	22,3	16,8	-0,41	0,56	0,27	20	0	14,0	0,0	2	18010001				2	7		
	18	MTC	MTC.Essing_freeflow	1	507	9610	68,2	70,5	79,1	2	3,2	0,2	-0,80	0,79	0,39	11	1	1,1	0,1	2	18020001				2	9		
Cycles from the OSCAR European research Project	27	OSCAR	OSCAR.C	1	402	3974	35,6	40,4	70,8	7	11,9	1,8	-0,99	0,88	0,77	15	4	3,8	1,0	2	27010001				1	5		
	27	OSCAR	OSCAR.D1	1	430	2691	22,5	28,6	46,7	7	21,2	2,6	-0,83	0,76	0,60	16	2	5,9	0,7	2	27020001				1	4		
	27	OSCAR	OSCAR.D2	1	364	2326	23,0	28,9	54,7	6	20,3	2,6	-0,86	0,81	0,71	15	3	6,5	1,3	2	27030001				1	1		
	27	OSCAR	OSCAR.E	1	372	2051	19,8	29,5	54,7	4	32,8	2,0	-1,00	0,80	0,76	20	6	9,8	2,9	2	27040001				1	1		
	27	OSCAR	OSCAR.F	1	424	1595	13,5	26,8	49,0	7	49,5	4,4	-0,96	0,82	0,81	11	2	6,9	1,3	2	27050001				1	3		
	27	OSCAR	OSCAR.G1	1	456	1553	12,3	19,6	40,2	12	37,5	7,7	-0,87	0,96	0,73	15	5	9,7	3,2	2	27060001				1	1		
	27	OSCAR	OSCAR.G2	1	351	1123	11,5	16,8	51,5	9	31,6	8,0	-0,71	0,97	0,76	16	6	14,3	5,3	2	27070001				1	2		
	27	OSCAR	OSCAR.H1	1	371	799	7,8	11,8	31,0	11	34,2	13,8	-0,60	0,60	0,47	11	0	13,8	0,0	2	27080001				1	7		
	27	OSCAR	OSCAR.H2	1	425	947	8,0	13,9	30,6	13	42,1	13,7	-0,79	0,81	0,68	15	3	15,9	3,2	2	27090001				1	7		
	27	OSCAR	OSCAR.H3	1	375	854	8,2	14,0	38,6	16	41,3	18,7	-0,78	1,00	0,76	13	5	15,2	5,9	2	27100001				1	7		
Cycles from works from Transport Research Laboratory, and Warren Spring Lab., UK	22	TRL	TRL.Motorway	1	587	16642	102,1	102,1	118,6	0	0,0	0,0	-0,35	0,46	0,12	2	0	0,1	0,0	2	22050001				1	15		
	22	TRL	TRL.MotorwayM113	2	257	8003	112,1	112,1	118,6	0	0,0	0,0	-0,38	0,32	0,11	1	0	0,1	0,0	2	22050202				2	15		
	22	TRL	TRL.MotorwayM90	2	308	7993	93,4	93,4	99,2	0	0,0	0,0	-0,32		0,10	0	0	0,0	0,0	2	22050102				2	8		
	22	TRL	TRL.Rural	2	589	10933	66,8	67,4	95,0	2	0,8	0,2	-0,97	0,81	0,47	16	4	1,5	0,4	2	22040202				1	11		
	22	TRL	TRL.Suburban	2	482	5513	41,2	42,0	64,5	2	1,9	0,4	-1,01	0,74	0,67	18	5	3,3	0,9	2	22040102				1	5		
	22	TRL	TRL.Suburban&Rural	1	1080	16445	54,8	56,0	95,0	4	2,1	0,2	-1,00	0,77	0,57	34	9	2,1	0,6	2	22040001				1	11		
	22	TRL	TRL.Urban	1	1208	6145	18,3	23,5	47,7	18	22,2	2,9	-0,79	0,70	0,62	51	9	8,3	1,5	2	22030001				1	4		
	22	TRL	TRL.WSL_CongestedTraffic	1	1030	1915	6,7	10,0	44,9	32	33,4	16,7	-0,67	0,64	0,50	16	2	8,4	1,0	2	22060001				1	7		
From TUG, Austria	23	TUG	TUG.Ries_RoadGradient	1	511	6842	48,2	55,6	87,6	2	13,3	0,3	-0,54	0,52	0,42	27	0	4,0	0,0	3	23010001				2	11		

Annex 3. Classification of driving cycles as motorway / main roads /rural / urban

Active cycles									
Class 1: Motorway cycles		Class 2: Main roads (highways) cycles		Class 3: Rural/suburban cycles		Class 4: Urban cycles			
ID	Cycle name	ID	Cycle name	ID	Cycle name	ID	Cycle name	ID	Cycle name
1	Artemis.motorway_150_1	2	Artemis.motorway_150_2	9	Artemis.rural_1	14	Artemis.urban_1	102	modem.urban4
3	Artemis.motorway_150_3	6	Artemis.motorway_150_2	10	Artemis.rural_2	16	Artemis.urban_3	103	modem.urban5
4	Artemis.motorway_150_4	12	Artemis.rural_4	11	Artemis.rural_3	17	Artemis.urban_4	104	modem.urban6
5	Artemis.motorway_150_1	13	Artemis.rural_5	15	Artemis.urban_2	18	Artemis.urban_5	105	modem.urban7
7	Artemis.motorway_130_3	20	Artemis.HighMot_motorway_2	23	Artemis.HighMot_rural_1	28	Artemis.HighMot_urbdense_1	106	modem.urban8
8	Artemis.motorway_130_4	26	Artemis.HighMot_rural_4	24	Artemis.HighMot_rural_2	29	Artemis.HighMot_urbdense_2	107	modem.urban9
19	Artemis.HighMot_motorway_1	27	Artemis.HighMot_rural_5	25	Artemis.HighMot_rural_3	30	Artemis.HighMot_urbdense_3	113	modemHyzem.urban
21	Artemis.HighMot_motorway_3	40	Artemis.LowMot_motorway_2	32	Artemis.HighMot_freurban_2	31	Artemis.HighMot_freurban_1	114	modemHyzem.urban1
22	Artemis.HighMot_motorway_4	46	Artemis.LowMot_rural_4	35	Artemis.HighMot_urban_2	33	Artemis.HighMot_freurban_3	115	modemHyzem.urban3
39	Artemis.LowMot_motorway_1	47	Artemis.LowMot_rural_5	43	Artemis.LowMot_rural_1	34	Artemis.HighMot_urban_1	116	Napoli.1
41	Artemis.LowMot_motorway_3	62	Handbook.R1_II	44	Artemis.LowMot_rural_2	36	Artemis.HighMot_urban_3	117	Napoli.2
42	Artemis.LowMot_motorway_4	63	Handbook.R1_III	45	Artemis.LowMot_rural_3	37	Artemis.HighMot_urban_4	118	Napoli.3
61	Handbook.R1_I	64	Handbook.R2_I	52	Artemis.LowMot_freurban_2	38	Artemis.HighMot_urban_5	119	Napoli.4
142	LDV_PVU.CommercialCars.motorway_2	73	Inrets.autoroute1	55	Artemis.LowMot_urban_2	48	Artemis.LowMot_urbdense_1	120	Napoli.5
		74	Inrets.autoroute2	59	Legislative.US_FTP1	49	Artemis.LowMot_urbdense_2	122	Napoli.7
		88	modemIM.Motorway	65	Handbook.R2_II	50	Artemis.LowMot_urbdense_3	123	Napoli.8
		108	modemHyzem.motorway	66	Handbook.R2_III	51	Artemis.LowMot_freurban_1	124	Napoli.9
		109	modemHyzem.motorway1	67	Handbook.R3_I	53	Artemis.LowMot_freurban_3	125	Napoli.10
		112	modemHyzem.road2	68	Handbook.R3_II	54	Artemis.LowMot_urban_1	126	Napoli.11
		141	LDV_PVU.CommercialCars.motorway_1	70	Handbook.R4_I	56	Artemis.LowMot_urban_3	127	Napoli.12
		150	Legislative.US06	75	Inrets.route1	57	Artemis.LowMot_urban_4	128	Napoli.13
				76	Inrets.route2	58	Artemis.LowMot_urban_5	129	Napoli.14
				77	Inrets.route3	60	Legislative.US_FTP2	130	Napoli.15
				83	Inrets.routecourt	69	Handbook.R3_III	133	Napoli.18
				86	Inrets.routecourt	71	Handbook.R4_II	134	Napoli.19
				89	modemIM.Road	72	Handbook.R4_III	136	Napoli.21
				90	modemIM.Short	78	Inrets.urbainfluide1	138	Napoli.23
				92	TUV.TUV-A	79	Inrets.urbainfluide2	139	Legislative.ECE_2000
				96	modem.urban11	80	Inrets.urbainfluide3	144	LDV_PVU.CommercialCars.urban_1
				99	modem.urban14	81	Inrets.urbainlent1	145	LDV_PVU.CommercialCars.urban_2
				110	modemHyzem.road	82	Inrets.urbainlent2	146	LDV_PVU.CommercialCars.urban_3
				111	modemHyzem.road1	84	Inrets.urbainfluidecourt	148	US.NYCC
				121	Napoli.6	85	Inrets.lentcourt		
				131	Napoli.16	87	modemIM.Urban_Free_Flow		
				132	Napoli.17	91	modemIM.Urban_Slow		
				135	Napoli.20	93	modem.EVAP		
				137	Napoli.22	94	modem.urban1		
				140	Legislative.EUDC	95	modem.urban10		
				143	LDV_PVU.CommercialCars.road	97	modem.urban12		
				147	US.IM240	98	modem.urban13		
				149	US.SC03	100	modem.urban2		
				151	Legislative.US_HWAY	101	modem.urban3		
Illustrative cycles									
Class 1: Motorway cycles		Class 2: Main roads (highways) cycles		Class 3: Rural/suburban cycles		Class 4: Urban cycles			
ID	Cycle name	ID	Cycle name	ID	Cycle name	ID	Cycle name	ID	Cycle name
1	Artemis.motorway_150	17	modemHyzem.motorway_total	3	Artemis.rural	4	Artemis.urban		
2	Artemis.motorway_130	18	modemHyzem.motorway1_total	6	Artemis.HighMot_rural	7	Artemis.HighMot_urbdense_total		
5	Artemis.HighMot_motorway	24	LDV_PVU.CommercialCars.motorway_1_total	11	Artemis.LowMot_rural	8	Artemis.HighMot_freurban_total		
10	Artemis.LowMot_motorway			15	Legislative.US_FTP	9	Artemis.HighMot_urban		
25	LDV_PVU.CommercialCars.motorway_2_total			16	Handbook.R1_to_R4	12	Artemis.LowMot_urbdense_total		
				19	modemHyzem.road_total	13	Artemis.LowMot_freurban_total		
				20	modemHyzem.road1_total	14	Artemis.LowMot_urban		
				21	modemHyzem.road2_total	22	Napoli.All		
				26	LDV_PVU.CommercialCars.road_total	23	Legislative.NEDC_2000		

Annex 4. Experimental protocol

The overall list of cycles is as follows:

1. Artemis.motorway (alternatively Artemis.motorway_130)
2. Artemis.rural
3. Artemis.urban
4. Artemis.LowMot_Motorway
5. LDV-PVU.CommercialCars_motorway1
6. modemHyzem.road
7. modem.urban5713
8. Handbook.R1
9. Handbook.R2
10. Handbook.R3
11. Handbook.R4
12. Napoli.6_17
13. Napoli.15-18-21
14. Napoli.10-23

A planning in 3 days is proposed hereafter for the tests. The order of the 3 days can be changed. The succession is roughly defined in days / half days and sequences of test. Depending on the possibilities, it is possible to manage differently these half-days / days / sequences of cycles, as a pre-conditioning phase is generally foreseen before a sequence of cycles.

A.6.1. First day (or half day) - The ARTEMIS Cycles

- Warm-up preconditioning - various possibilities can be used, such as a NEDC cycle (cold or not), or any procedure to warm-up the vehicle, for instance 15 minutes at 70 km/h (INRETS), followed by an eventual pause 5-20 minutes (engine off)

- 1- Artemis.urban,
- 2- Artemis.rural,
- 3- Artemis.motorway cycles.

If the cycles are conducted in a same test sequence, a 5 minutes pause engine off, between the 3 cycles, and that can be extended to 20 minutes.

A.6.2. Second day - Neapolitan D.C. and other ones

- Warm-up preconditioning - as above - followed by an eventual pause 5-20 minutes (engine off)

- 4- Naples.15_18_21,
- 5- Naples.6_17,
- 6- Naples.10_23.

If these 3 cycles are conducted in a same test sequence, it should be a 5 minutes pause engine off, between the 3 cycles, pause that can be extended to 20 minutes.

- Preconditioning phase if necessary (as above) before going on with the following cycles :
- 7- modem.urban5713,
- 8- LDV-PVU.CommercialCars_Motorway_1,
- 9- Artemis.LowMot_Motorway.

These cycles can be conducted in a same sequence. In that case it should be a 5 minutes pause, engine off, between the 3 cycles, pause that can be extended to 20 minutes.

A.6.3. Third day - Handbook D.C. and last cycle

- Warm-up preconditioning - as above - followed by an eventual pause 5-20 minutes (engine off)
- 10- Handbook.R1,
- 11- Handbook.R2,
- 12- Handbook.R3,
- 13- Handbook.R4,
- 14- modem-Hyzem.road.

If the Handbook cycles are in the same sequence, it should be a 5 minutes pause engine off, between the 3 cycles, and this pause can be extended to 20 minutes or even up to 40 minutes (according to the rules of EMPA). If the cycles are not in the same sequence (for instance 2 cycles, and later the 2 remaining cycles), a preconditioning can be necessary before conducting the remaining cycles.

After the Handbook R4 cycle, a pause of 20-40 minutes is needed before the last cycle. If this last cycle is conducted separately from the previous ones, a pre-conditioning phase (as above) should be necessary.

Annex 5. Rules of usage of the cycles

A.5.1. Rules of usage

For all the cycles, the sampling of the emissions in the bags and the continuous emissions measurements are necessary to assess the emissions at the sub-cycle level.

A5.1.1. *Artemis and Artemis.LowMot cycles*

For the Artemis cycles and Artemis.LowMot_motorway the rules of usage are defined in the note produced during their elaboration (André, 2004b, annex). This note defines the preconditioning, start conditions, and the points determining the useful parts of the cycles, the sub-cycles, and the parts to be sampled in the bags.

For LDV-PVU.CommercialCars_motorway_1, modemHyzem.road that include also preconditioning and post parts, the sampling in the bag should start at the beginning of the useful part of the cycle and finish at the end of this useful part, as indicated in the corresponding data sheets. The continuous measurements can start and end with the cycle.

A5.1.2. *Modem and Neapolitan cycles*

For modem and Neapolitan cycles, the sampling starts and ends with the cycle. The sub-cycles limits are given in the data-sheets.

A5.1.3. *Handbook cycles*

The Handbook cycles ².consist in 4 tests corresponding to the 4 cycles (named R1 to R4), each one being measured in 3 bags (sampling of the emission). *A single bag per driving cycle combined with continuous measurements to determine the, and calculate the sub-cycle emission can be envisaged. The emission sampling into the bag should start with the first sub-cycle and end with the last one. The continuous measurements can start and end with the cycle.*

Usually the cycles are run after a cold start test (NEDC or FTP-75) or one after the other with stop times of about 20 to 40 min.

In the former version of the cycles, a constant speed phase (average speed of the cycle) was observed to warm up the vehicles right before the test. The criterion to be warm was 80 °C oil temperature. Furthermore a dynamic pre-conditioning consisting in the first 80 to 100 s of the cycle is performed just before cycle to initiate the correct driving conditions.

Within a cycle and between the bags and sub-cycles, there are always some seconds of interruption (transition).

At EMPA, the tests are run with closed bonnet and speed dependent cooling (up to 150 km/h) with a fan surface of .72 m² (0.6*1.2m). Ambient conditions are 23°C and 50 -70% relative Humidity. Driver tolerances are as in NEDC.

Gearbox use: The ECE-Gearshift- rules were applied for the Handbook cycles, since these ones were derived from car following tests, which did not enable the development of a realistic

² These instructions have been provided by the EMPA laboratory, Duebendorf, Switzerland, and commented by the Artemis working group

gearshift strategy. For compatibility with the Artemis emission data and to be closer to the real driving, a common strategy based on actual driving data is proposed in the next section.

A.5.2. Gear box ratio changes

For the Artemis cycles, the corresponding procedure should obviously be used (see Andre 2004b). For all the other cycles in WP3141 (except the Artemis), a simple procedure was developed taking into account the actual European driving data recorded in the DRIVE-modem and BRITE/EURAM Hyzem research projects.

This simple but realistic approach consists in the definition of engine speed levels to change from one gear ratio to another one, based on the observed statistics (modem data base). Engine speed levels have been determined to increase and to decrease the gear ratio. These engine speed levels are provided in % of the engine speed at the maximum power, and the actual engine speed levels are calculated for each car tested.

For a vehicle to be tested, we consider then the actual gear ratios (vehicle speeds in km/h at 1000 rev/min for each gear ratio) and the engine speed at maximum power (rev/min at kW) that are specifications of the vehicle. We determine then the speed levels to increase and to decrease the different gear ratios. This procedure seems practically satisfying and quite easy to implement. The figures and example of calculation are provided in Annex 6. This procedure was finally extended to the case of cars with 6 gears.

Other gearshift strategies (such as ECE-gearshift rules or gearshift as the driver feels) can be used, but should be clearly indicated with the emission data.

Annex 6. Gearshift statistics and test strategy

For a realistic gear shifting within realistic cycles, a simplified gearshift procedure was developed, from the observation of the gearshifts. It was also extended to vehicles with 6 gear ratios. This approach consists in the definition of engine speed levels to change from one gear ratio to another one, based on the observed statistics (modem data base, Table A6.1). Engine speeds are provided in % of the engine speed at maximum power. The actual engine speed levels can be calculated for each car tested according to its specifications.

To determine the gearshift for a car to be tested, its technical specifications should be considered (vehicle speeds in km/h at 1000 rev/min for each gear ratio, and engine speed at maximum power, in rev/min at kW). We determine then the engine and vehicle speed levels to shift up or down the gear ratio (Tables A6.2 and A6.3).

Notes :

- 0->1 means a change from neutral to the first gear, 1->2 from the first to the second, etc.
- Optimal engine speeds are currently in the order of 4500 – 5500 rev/min for gasoline vehicles. They can be lowered for diesel vehicles

Table A6.1: Statistics regarding the gear ratio changes based on the DRIVE-modem data, urban and non-urban (03/1995, 12/2001)

Vehicles with 4 gear ratios					
Change : from -> to	0->1	1->2	2->3	3->4	
Relative Engine speed at the change (in % of the optimal engine speed)	NA	50	55	50	
Change : from -> to	1->0	2->1	3->2	4->3	
Relative Engine speed at the change (in % of the optimal engine speed)	10	20	35	37	
Vehicles with 5 gear ratios					
Change : from -> to	0->1	1->2	2->3	3->4	4->5
Relative Engine speed at the change (in % of the optimal engine speed)	NA	48	55	50	50
Change : from -> to	1->0	2->1	3->2	4->3	5->4
Relative Engine speed at the change (in % of the optimal engine speed)	10	18	35	35	40

Extrapolation

Vehicles with 6 gear ratios						
Change : from -> to	0->1	1->2	2->3	3->4	4->5	5->6
Relative Engine speed at the change (in % of the optimal engine speed)	NA	48	55	50	50	50
Change : from -> to	1->0	2->1	3->2	4->3	5->4	6->5
Relative Engine speed at the change (in % of the optimal engine speed)	10	18	35	35	35	40

Table A6.2: Engine speeds at the gear shifting (example of calculation)

EXAMPLE OF CALCULATION	PUT IN THE YELLOW CASE THE VALUE OF THE ENGINE SPEED (in REV./MN) AT MAXIMUM POWER= 5000					
	Vehicles with 4 gear ratios					
Change : from -> to	0->1	1->2	2->3	3->4		
Engine speed (rev/mn) at the change	NA	2500	2750	2500		
Change : from -> to	1->0	2->1	3->2	4->3		
Engine speed (rev/mn) at the change	500	1000	1750	1850		
Vehicles with 5 gear ratios						
Change : from -> to	0->1	1->2	2->3	3->4	4->5	
Engine speed (rev/mn) at the change	NA	2400	2750	2500	2500	
Change : from -> to	1->0	2->1	3->2	4->3	5->4	
Engine speed (rev/mn) at the change	500	900	1750	1750	2000	
Vehicles with 6 gear ratios						
Change : from -> to	0->1	1->2	2->3	3->4	4->5	5->6
Engine speed (rev/mn) at the change	NA	2400	2750	2500	2500	2500
Change : from -> to	1->0	2->1	3->2	4->3	5->4	6->5
Engine speed (rev/mn) at the change	500	900	1750	1750	1750	2000

Table A6.3: Vehicle speeds at the gear shifting (example of calculation)

PUT IN THE YELLOW CASE THE VALUE OF THE ENGINE SPEED (in REV./MN) AT MAXIMUM POWER	AND THE GEAR RATIO Gear ratio (km/h at 1000 rev/min)						
	5000	1	2	3	4	5	6
		8,2	14,5	22,7	30,8	37,6	43,0
Vehicles with 4 gear ratios							
Change : from -> to	0->1	1->2	2->3	3->4			
Speed (km/h) to change from :	NA	20,5	39,9	56,8			
Change : from -> to	1->0	2->1	3->2	4->3			
Speed (km/h) to change from :	4,1	14,5	39,7	57,0			
Vehicles with 5 gear ratios							
Change : from -> to	0->1	1->2	2->3	3->4	4->5		
Speed (km/h) to change from :	NA	19,7	39,9	56,8	77,0		
Change : from -> to	1->0	2->1	3->2	4->3	5->4		
Speed (km/h) to change from :	4,1	13,1	39,7	53,9	75,2		
Vehicles with 6 gear ratios							
Change : from -> to	0->1	1->2	2->3	3->4	4->5	5->6	
Speed (km/h) to change from :	NA	19,7	39,9	56,8	77,0	94,0	
Change : from -> to	1->0	2->1	3->2	4->3	5->4	6->5	
Speed (km/h) to change from :	4,1	13,1	39,7	53,9	65,8	86,0	

Annex 7. Vehicles tested in the frame of WP3141

Laboratory	Make, model	Emission Standard	Fuel Type	Vehicle Mass (kg)	Mileage (km)	Registration Date	Engine capacity (cm ³)	Max Power (kW)
INRETS	Peugeot 307 HDI	EURO-3	Diesel	1260	23774	2001	1997	66
INRETS	Ford Fiesta 1.8 L	EURO-1	Diesel	925	135000	1995	1753	44
INRETS	Peugeot 206 XR	EURO-3	Gasoline	910	17400	2000	1124	44
INRETS	Volkswagen Passat TDI	EURO-2	Diesel	1437	74000	2000	1896	85
INRETS	Peugeot 206 D	EURO-2	Diesel	1009		1999	1868	51
INRETS	Fiat Brava 1.9L D	EURO-1	Diesel	1130	113700	1996	1929	48
KTI	SUZUKI Swift 1.3 GLX	EURO-2	Gasoline	830	3000	2001	1298	50
TNO-AUTOMOTIVE	Alfa Romeo 147 1.6	EURO-3	Gasoline	1234	19200	2001	1598	77
IM-CNR	LANCIA Y	EURO-3	Gasoline	920	81000	2000	1242	59

Annex 8. The French PNR-Ademe complementary emission dataset

Lab.	Vehicle Lab	Make model	European Emission Standard	Fuel Type	Vehicle Mass (kg)	Mileage (km)	Registration Date	Engine capacity (cm3)	Max power (kW)
INRETS	396	Volkswagen Polo 1.4	EURO-2	Gasoline	967	15000	1999/11	1390	44
INRETS	397	HYUNDAI Pony 5	EURO-1	Gasoline	930	95000	1995/5	1341	62
INRETS	398	Renault Laguna RXE	EURO-2	Gasoline	1255	61570	1995/10	1783	66
INRETS	399	Renault 19 1.9D	EURO-1	Diesel	1030	135000	1995/5	1870	48
INRETS	400	Fiat Punto TD Cult	EURO-2	Diesel	1025	59346	1999/3	1698	46
INRETS	401	Peugeot 306 HDI	EURO-2	Diesel	1155	10900	2000/10	1997	66
INRETS	402	Peugeot 309 GLD	pre-EURO-1 (ECE 1504)	Diesel	950	212000	1990/5	1905	48
INRETS	403	Peugeot 206 XS16S	EURO-3	Gasoline	1013	3200	2001/5	1587	80
INRETS	404	Opel Astra DTI16V	EURO-2	Diesel	1239	70000	1999/11	1995	60
INRETS	405	Volkswagen Sharan TDI	EURO-2	Diesel	1691	110000	1998/7	1896	81
INRETS	407	Renault Espace 2.2DT	EURO-2	Diesel	1630	15000	2000/7	2188	83
INRETS	408	Ford Fiesta 1.2	EURO-2	Gasoline	989	10200	2000/9	1242	55
INRETS	409	Citroen ZX TD Break	EURO-2	Diesel	1150	64500	1997/7	1905	66
INRETS	410	Audi A4 1.8Turbo	EURO-2	Gasoline	1283	24000	1998/8	1781	110
INRETS	411	Renault Lagunall 1.6 16V	EURO-3	Gasoline	1270	6500	2001/5	1598	79
INRETS	412	Renault Megane 1.9D	EURO-2	Diesel	1115	30400	2000/4	1870	55
INRETS	413	Renault MeganeScen DCI	EURO-3	Diesel	1290	5000	2001/4	1870	75
INRETS	414	Citroen AX 1.0	EURO-1	Gasoline	706	33000	1995/6	954	37
INRETS	416	Renault Clio 1.4RXT	EURO-2	Gasoline	980	24000	2000/9	1390	70
INRETS	417	Rover 414 I	EURO-2	Gasoline	1100	50500	1997/9	1396	76
INRETS	418	Renault Clio 1.2L	EURO-1	Gasoline	845	112000	1995/3	1171	43
INRETS	419	Mercedes 190D 2.5I	pre-EURO-1 (ECE 1504)	Diesel	1175	220000	1988/12	2497	66
INRETS	420	Renault Scenic1.6 16s	EURO-3	Gasoline	1250	3600	2001/11	1598	79
INRETS	421	Peugeot 307 HDI	EURO-3	Diesel	1260	23774	2001/8	1997	66
INRETS	422	Ford Fiesta 1.8 L	EURO-1	Diesel	925	135000	1995/10	1753	44
INRETS	423	Peugeot 206 XR	EURO-3	Gasoline	910	17400	2001/2	1124	44
INRETS	424	Peugeot 406 HDI	EURO-2	Diesel	1410	26000	2000/9	1997	80
INRETS	425	Volkswagen Passat TDI	EURO-2	Diesel	1437	74000	2000/6	1896	85
INRETS	426	Peugeot 206 D	EURO-2	Diesel	1009	-	1999/8	1868	51
INRETS	427	Fiat Brava 1.9L D	EURO-1	Diesel	1130	113700	1996/11	1929	48

Annex 9. Pollutant emissions per driving cycle

CO emission (g/km), all vehicles:

- Urban

Driving type (U/R/M)	Urban															
Statut/Emitter	(Tous)															
Moyenne sur CO (g/km)	CodeEx	Fuel Ty	High md	Eu Standard												
	ART3141															
	Diesel		Gasoline							Gasoline						
	Indet.		Indet.							Low mot.						
										High mot.						
										Low mot.						
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	
Artemis.HighMot_freeurban_1											0,77	0,02				
Artemis.HighMot_freeurban_3											0,03	0,00				
Artemis.HighMot_freeurban_total										0,47	0,22	0,03				
Artemis.HighMot_urban										0,55	0,20	0,02				
Artemis.HighMot_urban_1																
Artemis.HighMot_urban_3																
Artemis.HighMot_urban_4																
Artemis.HighMot_urban_5																
Artemis.HighMot_urbdense_1										3,84	1,03					
Artemis.HighMot_urbdense_2										1,70	1,06					
Artemis.HighMot_urbdense_3										1,44	0,58					
Artemis.HighMot_urbdense_total										2,81	0,65	0,03				
Artemis.LowMot_freeurban_1						1,15	0,66	0,76							3,05	
Artemis.LowMot_freeurban_3						0,69	0,51	0,44							1,36	
Artemis.LowMot_freeurban_total						0,74	0,32	0,23	0,01						2,12	0,01
Artemis.LowMot_urban						0,84	0,42	0,24	0,02						3,55	0,07
Artemis.LowMot_urban_1						1,11	0,91	0,62							3,58	0,06
Artemis.LowMot_urban_3						1,30	1,13	0,59							5,76	0,17
Artemis.LowMot_urban_4						1,66	1,67	0,70							5,77	0,07
Artemis.LowMot_urban_5						0,87	0,67	0,50							3,64	0,03
Artemis.LowMot_urbdense_1						0,63	0,65	0,77							4,38	
Artemis.LowMot_urbdense_2						0,94	1,20	1,03							4,37	
Artemis.LowMot_urbdense_3						1,07	0,99	0,76							11,37	
Artemis.LowMot_urbdense_total						0,89	0,39	0,32	0,09						5,57	0,03
Artemis.urban	0,20	0,56	0,05	2,94	0,34	0,89	0,36	0,36	0,07	0,75	0,46	0,04	5,74	0,25	0,18	
Artemis.urban_1		0,48			0,17	0,87	1,05	0,83		1,27	0,96	0,07	5,14			
Artemis.urban_3		1,65			0,29	1,35	1,38	1,31		0,83	2,19	0,10	8,98			
Artemis.urban_4		0,61	0,00		0,06	0,91	1,07	0,58	0,00	1,33	2,17	0,04	7,50			
Artemis.urban_5		0,69	0,00		0,26	0,66	0,68	0,51	0,00	0,60	1,16	0,03	6,95			
Handbook.R3_III	0,55	0,13		1,25	0,24											
Handbook.R4	0,25	0,18	0,04		0,28											
Handbook.R4_II				1,08	0,68											
Handbook.R4_III				1,55	1,62											
modem.urban13b		1,68			1,26											
modem.urban2x7		2,16			5,97											
modem.urban5713	0,26	0,94	0,02	8,67	3,20											
modem.urban5b		1,82			2,03											
Napoli.10		0,79			0,65											
Napoli.10_23	0,27	0,42	0,02	1,35	0,55											
Napoli.15					0,24											
Napoli.15_18_21	0,28	0,25	0,02	0,99	0,21											
Napoli.18					0,49											
Napoli.21					0,30											
Napoli.23		1,66			0,81											
Total	0,28	0,82	0,02	2,55	1,16	0,95	0,67	0,50	0,04	1,41	0,63	0,04	5,22	0,08	0,22	

CO emission (g/km), all vehicles:

- Rural

Driving type (U/R/M)	Rural/Suburb.																
StatutEmitter	(Tous)																
Moyenne sur CO (g/km)	CodeEx	Fuel Ty	High mc	Eu_Standard													
	ART3141			PNR													
	Diesel			Gasoline			Diesel			Gasoline							
	Indet.			Indet.			Low mot.			High mot.			Low mot.				
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3		
Artemis.HighMot_freeurban_2														0,17	0,00		
Artemis.HighMot_rural													1,54	0,54	0,34		
Artemis.HighMot_rural_1													1,85	0,81	0,24		
Artemis.HighMot_rural_2													0,78	0,16	0,18		
Artemis.HighMot_rural_3													0,26	0,10	0,08		
Artemis.HighMot_urban_2																	
Artemis.LowMot_freeurban_2						0,68	0,41	0,38							2,29		
Artemis.LowMot_rural						0,45	0,23	0,12	0,01						2,23	0,44	1,52
Artemis.LowMot_rural_1						0,40	0,32	0,64							1,83	0,25	0,30
Artemis.LowMot_rural_2						0,45	0,32	0,49							0,84	0,23	0,03
Artemis.LowMot_rural_3						0,43	0,39	0,52							1,10	0,16	0,05
Artemis.LowMot_urban_2						0,72	0,48	0,37							2,29	0,07	
Artemis.rural	0,16	0,19	0,01	6,02	0,74	0,52	0,22	0,13	0,01	0,56	0,34	0,10	2,05	0,33	1,11		
Artemis.rural_1	0,32	0,21			0,93	0,64	0,36	0,25		1,77	1,40	0,09	2,91	0,83	0,65		
Artemis.rural_2	0,24	0,05			0,10	0,51	0,30	0,14		0,12	0,21	0,05	1,28	0,32	0,12		
Artemis.rural_3	0,27	0,21			0,15	0,60	0,38	0,21		0,22	0,25	0,06	1,28	0,35	0,24		
Artemis.urban_2		1,06			0,12	0,78	0,46	0,73		0,64	0,82	0,02	3,21				
Handbook.R2	0,14	0,10	0,00		0,08												
Handbook.R2_II	0,19	0,04		0,67	0,05												
Handbook.R2_III	0,26	0,24		1,27	0,14												
Handbook.R3	0,20	0,19	0,01		0,30												
Handbook.R3_I	0,34	0,57		1,48	0,50												
Handbook.R3_II	0,31	0,13		0,69	0,08												
Handbook.R4_I				0,58	0,10												
modemHyzem.road	0,23	0,39	0,00	1,87	0,55												
Napoli.17	0,28	0,53			0,20												
Napoli.6	0,28	0,54			1,41												
Napoli.6_17	0,17	0,29	0,05	4,12	0,95												
Total	0,22	0,29	0,01	2,09	0,41	0,56	0,33	0,25	0,01	0,86	0,45	0,13	1,94	0,32	0,50		

- Motorway / main roads

Driving type (U/R/M)	Motorway/Main road																
StatutEmitter	(Tous)																
Moyenne sur CO (g/km)	CodeEx	Fuel Ty	High mc	Eu_Standard													
	ART3141			PNR													
	Diesel			Gasoline			Diesel			Gasoline							
	Indet.			Indet.			Low mot.			High mot.			Low mot.				
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3		
Artemis.HighMot_motorway													6,13	1,58	1,21		
Artemis.HighMot_motorway_1													0,69	0,38	0,33		
Artemis.HighMot_motorway_2													2,63	0,57	0,68		
Artemis.HighMot_motorway_3													9,63	0,61	0,92		
Artemis.HighMot_motorway_4													14,32	0,73	2,46		
Artemis.HighMot_rural_4													2,89	1,37	0,98		
Artemis.HighMot_rural_5													0,76	0,54	0,54		
Artemis.LowMot_motorway	0,14	0,17	0,01	7,96	2,45	0,43	0,24	0,07	0,01						2,95	1,84	4,26
Artemis.LowMot_motorway_1	0,19				1,29	0,43	0,24	0,08							0,34	0,21	2,17
Artemis.LowMot_motorway_2	0,25				2,98	0,45	0,33	0,11							1,37	1,02	4,74
Artemis.LowMot_motorway_3	0,19				2,12	0,41	0,32	0,08							3,46	2,38	4,15
Artemis.LowMot_motorway_4	0,25				5,55	0,41	0,66	0,09							9,28	5,31	10,20
Artemis.LowMot_rural_4						0,40	0,34	0,53							5,11	2,82	5,12
Artemis.LowMot_rural_5						0,27	0,31	0,36							0,54	0,13	0,02
Artemis.motorway_130				9,73	0,31												
Artemis.motorway_130_3					0,08												
Artemis.motorway_130_4					0,23												
Artemis.motorway_150	0,14	0,17	0,01		2,28	0,45	0,22	0,07	0,01	1,87	1,16	0,47	3,86	3,66	2,92		
Artemis.motorway_150_1	0,18	0,05	0,01		1,16	0,42	0,23	0,07	0,01	0,03	0,51	0,22	1,83	0,52	1,96		
Artemis.motorway_150_2	0,22	0,07	0,01		1,59	0,45	0,29	0,10	0,01	0,09	0,81	0,30	2,70	2,89	2,63		
Artemis.motorway_150_3	0,20	0,05	0,00		2,76	0,40	0,33	0,08	0,00	2,63	1,25	0,34	4,89	5,14	2,76		
Artemis.motorway_150_4	0,25	0,06	0,00		3,44	0,40	0,41	0,08	0,00	5,41	2,58	1,25	6,01	7,23	3,44		
Artemis.rural_4	0,28	0,08			1,44	0,50	0,33	0,12		0,37	0,71	0,36	2,46	1,02	2,66		
Artemis.rural_5	0,20	0,04			0,06	0,42	0,24	0,08		0,19	0,08	0,10	0,96	0,25	0,02		
Handbook.R1	0,12	0,06	0,00		0,07												
Handbook.R1_I	0,18	0,05		2,72	0,15												
Handbook.R1_II	0,20	0,04		4,60	0,52												
Handbook.R1_III	0,19	0,03		5,05	0,43												
Handbook.R2_I	0,19	0,04		3,54	0,08												
LDV_PVU.CommercialCars.motorw	0,27	0,21	0,01	12,49	3,01												
Total	0,19	0,09	0,01	6,58	1,57	0,42	0,31	0,09	0,01	3,40	0,99	0,71	3,27	2,69	3,36		

CO2 emission (g/km), all vehicles:

- Urban

Driving type (U/R/M)	Urban																		
StatutEmitter	(Tous)																		
Moyenne sur CO2 (g/km)	CodeEx	Fuel Ty	High md	Eu_ Standard															
	ART3141																		
	Diesel			Gasoline										Gasoline					
	Indet.			Indet.										High mot.					
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	
Artemis.HighMot_freeurban_1													245	299	294				
Artemis.HighMot_freeurban_3													173	202	197				
Artemis.HighMot_freeurban_total													190	221	222				
Artemis.HighMot_urban													217	264	246				
Artemis.HighMot_urban_1													227	283	263				
Artemis.HighMot_urban_3													288	383	357				
Artemis.HighMot_urban_4													292	358	328				
Artemis.HighMot_urban_5													197	233	219				
Artemis.HighMot_urbdense_1													198	245	250				
Artemis.HighMot_urbdense_2													293	364	367				
Artemis.HighMot_urbdense_3													299	359	362				
Artemis.HighMot_urbdense_total													239	287	295				
Artemis.LowMot_freeurban_1							248	247	261	235							219	257	268
Artemis.LowMot_freeurban_3							173	164	171	161							160	177	194
Artemis.LowMot_freeurban_total							192	187	202	183							172	190	209
Artemis.LowMot_urban							207	219	235	207							191	215	222
Artemis.LowMot_urban_1							270	234	248	217							204	234	227
Artemis.LowMot_urban_3							382	344	363	328							275	346	330
Artemis.LowMot_urban_4							376	313	326	294							305	338	340
Artemis.LowMot_urban_5							218	182	195	174							171	186	193
Artemis.LowMot_urbdense_1							210	202	219	195							174	209	212
Artemis.LowMot_urbdense_2							316	314	329	298							273	328	335
Artemis.LowMot_urbdense_3							291	286	316	276							263	320	328
Artemis.LowMot_urbdense_total							247	243	255	234							212	254	261
Artemis.urban	234	254	223	217	260		238	235	252	225	241	297	275	211	240	247			
Artemis.urban_1	231	249	210		268		241	233	245	215	233	292	266	214	241	237			
Artemis.urban_3	379	405	358		416		369	378	398	358	369	473	437	319	388	369			
Artemis.urban_4	292	326	285		362		293	290	320	288	317	383	357	280	324	325			
Artemis.urban_5	196	222	189		240		201	195	216	192	212	266	244	186	205	224			
Handbook.R3_III	159	153	150	154	178														
Handbook.R4	202	202	183		188														
Handbook.R4_II	295	293	267	322	346														
Handbook.R4_III	524	514	422	398	565														
modem.urban13b	235	241	213		255														
modem.urban2x7	211	220	202		226														
modem.urban5713	220	228	206	198	253														
modem.urban5b	234	219	198		230														
Napoli.10	208	204	186		223														
Napoli.10_23	266	275	250	236	332														
Napoli.15	194	198	178		195														
Napoli.15_18_21	248	239	214	197	269														
Napoli.18	640	633	547		694														
Napoli.21	218	210	189		218														
Napoli.23	712	713	645		781														
Total	295	300	266	246	330		257	251	268	240	249	307	293	225	262	266			

CO2 emission (g/km), all vehicles:

- Rural

Driving type (U/R/M)	Rural/Suburb.																
StatutEmitter	(Tous)																
Moyenne sur CO2 (g/km)	CodeEx	Fuel Ty	High mq	Eu_Standard													
	ART3141			PNR													
	Diesel			Gasoline			Diesel			Gasoline							
	Indet.			Indet.			Low mot.			High mot.			Low mot.				
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3		
Artemis.HighMot_freeurban_2													177	213	211		
Artemis.HighMot_rural													143	172	166		
Artemis.HighMot_rural_1													158	192	184		
Artemis.HighMot_rural_2													139	161	158		
Artemis.HighMot_rural_3													139	169	162		
Artemis.HighMot_urban_2													172	210	198		
Artemis.LowMot_freeurban_2						187	189	193	182						165	185	227
Artemis.LowMot_rural						160	164	162	150						131	143	161
Artemis.LowMot_rural_1						180	160	189	168						145	163	178
Artemis.LowMot_rural_2						141	124	138	124						113	120	140
Artemis.LowMot_rural_3						152	131	152	134						132	138	150
Artemis.LowMot_urban_2						200	171	189	165						153	173	180
Artemis.rural	143	151	136	127	161	157	147	154	143	140	171	161	128	137	168		
Artemis.rural_1	163	167	156		191	179	165	176	161	151	189	181	138	155	184		
Artemis.rural_2	128	135	122		160	142	131	139	127	129	153	143	116	123	154		
Artemis.rural_3	132	144	125		176	148	134	145	131	135	169	157	127	131	170		
Artemis.urban_2	191	207	183		221	193	191	208	185	200	238	224	170	187	206		
Handbook.R2	117	119	122		133												
Handbook.R2_II	113	116	121	105	118												
Handbook.R2_III	113	116	120	110	122												
Handbook.R3	128	123	124		149												
Handbook.R3_I	124	121	123	123	179												
Handbook.R3_II	116	114	117	120	128												
Handbook.R4_I	152	154	146	152	174												
modernHyzem.road	148	156	149	137	165												
Napoli.17	128	138	129		147												
Napoli.6	144	152	144		154												
Napoli.6_17	136	145	137	127	160												
Total	136	141	135	125	157	166	157	168	152	153	184	177	138	150	174		

- Motorway / main roads

Driving type (U/R/M)	Motorway/Main road																
StatutEmitter	(Tous)																
Moyenne sur CO2 (g/km)	CodeEx	Fuel Ty	High mq	Eu_Standard													
	ART3141			PNR													
	Diesel			Gasoline			Diesel			Gasoline							
	Indet.			Indet.			Low mot.			High mot.			Low mot.				
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3		
Artemis.HighMot_motorway													185	202	199		
Artemis.HighMot_motorway_1													201	208	210		
Artemis.HighMot_motorway_2													145	169	161		
Artemis.HighMot_motorway_3													206	226	229		
Artemis.HighMot_motorway_4													178	198	193		
Artemis.HighMot_rural_4													151	184	178		
Artemis.HighMot_rural_5													134	151	148		
Artemis.LowMot_motorway	187	181	189	143	190	223	196	200	190						164	177	190
Artemis.LowMot_motorway_1	187	181	191		177	218	197	203	193						172	182	201
Artemis.LowMot_motorway_2	172	167	170		159	200	179	184	171						148	163	169
Artemis.LowMot_motorway_3	206	199	205		195	236	219	222	208						178	195	199
Artemis.LowMot_motorway_4	191	186	200		179	229	207	209	200						165	176	182
Artemis.LowMot_rural_4										198	184	204	187		147	172	187
Artemis.LowMot_rural_5										136	127	136	126		117	120	166
Artemis.motorway_130				145	193												
Artemis.motorway_130_3					193												
Artemis.motorway_130_4					182												
Artemis.motorway_150	183	178	185		159	187	194	195	194	181	201	191	164	175	187		
Artemis.motorway_150_1	186	179	183		199	218	196	195	194	185	202	192	170	177	196		
Artemis.motorway_150_2	166	163	168		179	198	175	179	172	165	184	177	151	158	173		
Artemis.motorway_150_3	206	196	204		199	237	219	216	213	200	222	213	177	192	199		
Artemis.motorway_150_4	191	177	195		183	222	205	202	202	182	201	193	168	173	183		
Artemis.rural_4	172	173	166		189	185	176	184	174	163	195	189	142	161	184		
Artemis.rural_5	112	122	107		147	124	117	120	112	119	138	128	114	109	148		
Handbook.R1	156	155	164		163												
Handbook.R1_I	169	168	179	140	157												
Handbook.R1_II	150	152	159	130	144												
Handbook.R1_III	138	141	145	120	134												
Handbook.R2_I	131	133	133	118	131												
LDV_PVU.CommercialCars.motorv	150	158	153	128	185												
Total	170	167	172	132	169	193	186	189	181	171	191	186	155	166	183		

HC emission (g/km), all vehicles:

- Urban

Driving type (U/R/M)	Urban																			
StatutEmitter	(Tous)																			
Moyenne sur HC (g/km)	CodeEx	Fuel Ty	High md	Eu	Standard															
	ART3141																			
	Diesel			Gasoline		Diesel				Gasoline										
	Indet.			Indet.		Low mot.				High mot.										
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	Low mot.	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	
Artemis.HighMot_freeurban_1														0,097	0,069					
Artemis.HighMot_freeurban_3														0,027	0,062					
Artemis.HighMot_freeurban_total														0,041	0,027	0,005				
Artemis.HighMot_urban														0,057	0,043	0,015				
Artemis.HighMot_urban_1															0,089	0,034				
Artemis.HighMot_urban_3															0,071	0,015				
Artemis.HighMot_urban_4															0,053	0,011				
Artemis.HighMot_urban_5															0,034	0,006				
Artemis.HighMot_urbdense_1														1,116	0,106					
Artemis.HighMot_urbdense_2														0,235	0,040					
Artemis.HighMot_urbdense_3														0,126	0,031					
Artemis.HighMot_urbdense_total														0,678	0,081	0,011				
Artemis.LowMot_freeurban_1							0,176	0,069	0,059	0,021							0,260			
Artemis.LowMot_freeurban_3							0,094	0,055	0,036	0,011							0,085			
Artemis.LowMot_freeurban_total							0,111	0,049	0,038	0,013							0,133	0,043	0,010	
Artemis.LowMot_urban							0,143	0,071	0,054	0,032							0,200	0,024	0,040	
Artemis.LowMot_urban_1							0,166	0,096	0,086	0,055							0,244	0,060	0,090	
Artemis.LowMot_urban_3							0,221	0,128	0,066	0,044							0,368	0,032	0,040	
Artemis.LowMot_urban_4							0,220	0,134	0,069	0,041							0,273	0,022	0,053	
Artemis.LowMot_urban_5							0,115	0,051	0,031	0,016							0,185	0,011	0,027	
Artemis.LowMot_urbdense_1							0,104	0,056	0,042	0,026							0,807			
Artemis.LowMot_urbdense_2							0,175	0,096	0,065	0,033							0,249			
Artemis.LowMot_urbdense_3							0,178	0,087	0,060	0,018							0,424			
Artemis.LowMot_urbdense_total							0,134	0,065	0,049	0,026							0,424	0,068	0,033	
Artemis.urban	0,059	0,035	0,025	0,100	0,015		0,152	0,068	0,047	0,021	0,061	0,059	0,010	0,294	0,083	0,022				
Artemis.urban_1	0,065	0,046	0,031		0,018		0,147	0,088	0,065	0,026		0,088		0,359	0,088					
Artemis.urban_3	0,097	0,057	0,048		0,015		0,309	0,120	0,074	0,040		0,221		0,660	0,025					
Artemis.urban_4	0,078	0,044	0,030		0,000		0,172	0,098	0,058	0,023		0,114		0,421	0,016					
Artemis.urban_5	0,041	0,026	0,016		0,013		0,126	0,057	0,038	0,013		0,077		0,305	0,008					
Handbook.R3_III	0,045	0,020	0,009	0,021	0,011															
Handbook.R4	0,056	0,029	0,013		0,056															
Handbook.R4_II	0,091	0,053	0,020	0,056	0,048															
Handbook.R4_III	0,164	0,135	0,032	0,116	0,161															
modem.urban13b	0,055	0,016	0,009		0,044															
modem.urban2x7	0,040	0,011	0,006		0,132															
modem.urban5713	0,048	0,018	0,018	0,353	0,057															
modem.urban5b	0,052	0,021	0,028		0,063															
Napoli.10	0,054	0,029	0,020		0,035															
Napoli.10_23	0,065	0,040	0,022	0,048	0,046															
Napoli.15	0,037	0,034	0,009		0,012															
Napoli.15_18_21	0,068	0,043	0,013	0,034	0,020															
Napoli.18	0,203	0,176	0,029		0,030															
Napoli.21	0,057	0,032	0,015		0,006															
Napoli.23	0,149	0,129	0,033		0,047															
Total	0,076	0,049	0,021	0,104	0,048		0,159	0,082	0,055	0,027	0,271	0,064	0,012	0,319	0,041	0,039				

HC emission (g/km), all vehicles:

- Rural

Driving type (U/R/M)	Rural/Suburb.																									
StatutEmitter	(Tous)																									
Moyenne sur HC (g/km)	CodeEx	Fuel Ty	High mq	Eu_Standard			PNR																			
							Diesel			Gasoline																
							Indet.			Low mot.			High mot.			Low mot.										
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3											
Artemis.HighMot_freurban_2													0,042	0,044												
Artemis.HighMot_rural													0,108	0,032	0,018											
Artemis.HighMot_rural_1													0,299	0,048	0,019											
Artemis.HighMot_rural_2													0,055	0,014	0,027											
Artemis.HighMot_rural_3													0,037	0,017	0,010											
Artemis.HighMot_urban_2														0,032	0,011											
Artemis.LowMot_freurban_2							0,090	0,044	0,030	0,012													0,132			
Artemis.LowMot_rural							0,059	0,024	0,017	0,012													0,108	0,025	0,034	
Artemis.LowMot_rural_1							0,062	0,024	0,019	0,016													0,218		0,019	
Artemis.LowMot_rural_2							0,053	0,020	0,019	0,011													0,040		0,010	
Artemis.LowMot_rural_3							0,060	0,028	0,023	0,013													0,085		0,007	
Artemis.LowMot_urban_2							0,103	0,051	0,034	0,020													0,159	0,018	0,039	
Artemis.rural	0,025	0,009	0,009	0,135	0,023	0,077	0,026	0,016	0,009	0,082	0,026	0,010	0,083	0,036	0,033											
Artemis.rural_1	0,029	0,011	0,012		0,023	0,093	0,032	0,022	0,011	0,306	0,055	0,012	0,158	0,028	0,034											
Artemis.rural_2	0,021	0,010	0,009		0,011	0,059	0,023	0,015	0,008	0,032	0,015	0,006	0,038	0,029	0,018											
Artemis.rural_3	0,026	0,014	0,011		0,009	0,075	0,034	0,022	0,010	0,028	0,022	0,004	0,034	0,006	0,013											
Artemis.urban_2	0,036	0,021	0,016		0,005	0,108	0,043	0,031	0,014				0,066									0,166	0,014			
Handbook.R2	0,017	0,005	0,002		0,013																					
Handbook.R2_II	0,016	0,005	0,002	0,014	0,011																					
Handbook.R2_III	0,018	0,007	0,002	0,030	0,011																					
Handbook.R3	0,028	0,010	0,005		0,020																					
Handbook.R3_I	0,024	0,011	0,004	0,021	0,016																					
Handbook.R3_II	0,021	0,010	0,004	0,008	0,007																					
Handbook.R4_I	0,039	0,018	0,012	0,012	0,009																					
modernHyzem.road	0,027	0,010	0,005	0,034	0,017																					
Napoli.17	0,023	0,007	0,004		0,008																					
Napoli.6	0,030	0,011	0,013		0,054																					
Napoli.6_17	0,024	0,008	0,008	0,088	0,034																					
Total	0,025	0,010	0,007	0,043	0,017	0,075	0,032	0,022	0,012	0,110	0,030	0,012	0,110	0,023	0,023											

- Motorway / main roads

Driving type (U/R/M)	Motorway/Main road																									
StatutEmitter	(Tous)																									
Moyenne sur HC (g/km)	CodeEx	Fuel Ty	High mq	Eu_Standard			PNR																			
							Diesel			Gasoline																
							Indet.			Low mot.			High mot.			Low mot.										
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3											
Artemis.HighMot_motorway													0,135	0,064	0,017											
Artemis.HighMot_motorway_1													0,032	0,035	0,021											
Artemis.HighMot_motorway_2													0,068	0,018	0,023											
Artemis.HighMot_motorway_3													0,256	0,032	0,023											
Artemis.HighMot_motorway_4													0,309	0,020	0,027											
Artemis.HighMot_rural_4													0,114	0,054	0,071											
Artemis.HighMot_rural_5													0,042	0,025	0,031											
Artemis.LowMot_motorway	0,020	0,007	0,006	0,095	0,113	0,043	0,024	0,011	0,008													0,114	0,033	0,113		
Artemis.LowMot_motorway_1	0,021	0,007	0,007		0,037	0,040	0,023	0,012	0,008													0,058	0,006	0,073		
Artemis.LowMot_motorway_2	0,023	0,007	0,007		0,059	0,051	0,027	0,010	0,008													0,111	0,006	0,122		
Artemis.LowMot_motorway_3	0,022	0,007	0,005		0,050	0,040	0,026	0,010	0,006													0,117	0,003	0,098		
Artemis.LowMot_motorway_4	0,024	0,008	0,007		0,135	0,041	0,040	0,012	0,008													0,309	0,033	0,268		
Artemis.LowMot_rural_4							0,071	0,028	0,014	0,008												0,309		0,110		
Artemis.LowMot_rural_5							0,040	0,015	0,013	0,011												0,041		0,021		
Artemis.motorway_130				0,123																						
Artemis.motorway_130_3					0,002																					
Artemis.motorway_130_4					0,003																					
Artemis.motorway_150	0,017	0,008	0,005		0,055	0,047	0,020	0,010	0,006	0,043	0,057	0,016	0,139	0,069	0,067											
Artemis.motorway_150_1	0,018	0,008	0,004		0,033	0,043	0,020	0,010	0,005	0,014	0,046	0,020	0,096		0,062											
Artemis.motorway_150_2	0,021	0,009	0,004		0,035	0,055	0,023	0,009	0,006	0,013	0,042	0,015	0,135		0,066											
Artemis.motorway_150_3	0,016	0,008	0,005		0,076	0,046	0,022	0,009	0,005	0,066	0,075	0,013	0,191		0,076											
Artemis.motorway_150_4	0,016	0,011	0,008		0,091	0,047	0,023	0,011	0,007	0,121	0,091	0,015	0,222		0,091											
Artemis.rural_4	0,025	0,009	0,008		0,042	0,085	0,027	0,014	0,007	0,049	0,038	0,032	0,124	0,045	0,076											
Artemis.rural_5	0,020	0,009	0,006		0,018	0,067	0,020	0,011	0,006	0,015	0,010	0,009	0,039	0,014	0,018											
Handbook.R1	0,020	0,012	0,005		0,011																					
Handbook.R1_I	0,022	0,015	0,007	0,047	0,008																					
Handbook.R1_II	0,021	0,011	0,003	0,061	0,013																					
Handbook.R1_III	0,021	0,010	0,003	0,053	0,009																					
Handbook.R2_I	0,016	0,005	0,002	0,065	0,018																					
LDV_PVU.CommercialCars.motorv	0,025	0,005	0,006	0,213	0,064																					
Total	0,020	0,008	0,005	0,094	0,041	0,053	0,024	0,011	0,007	0,091	0,045	0,021	0,141	0,031	0,090											

NOx emission (g/km), all vehicles:

- Urban

Driving type (U/R/M)	Urban														
Statut Emitter	(Tous)														
Moyenne sur NOx (g/km)	CodeEx	Fuel Ty	High mq	Eu_Standard											
	ART3141				PNR										
	Diesel			Gasoline			Diesel			Gasoline					
	Indet.			Indet.			Low mot.			High mot.			Low mot.		
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3
Artemis.HighMot_freeurban_1										0,539	0,333	0,350			
Artemis.HighMot_freeurban_3										0,171	0,172	0,154			
Artemis.HighMot_freeurban_total										0,284	0,203	0,186			
Artemis.HighMot_urban										0,440	0,218	0,215			
Artemis.HighMot_urban_1										0,595	0,243	0,282			
Artemis.HighMot_urban_3										0,488	0,237	0,189			
Artemis.HighMot_urban_4										0,361	0,262	0,297			
Artemis.HighMot_urban_5										0,282	0,236	0,310			
Artemis.HighMot_urbdense_1										1,757	0,416	0,520			
Artemis.HighMot_urbdense_2										0,417	0,229	0,307			
Artemis.HighMot_urbdense_3										0,434	0,235	0,381			
Artemis.HighMot_urbdense_total										1,180	0,294	0,413			
Artemis.LowMot_freeurban_1						1,026	1,041	1,252	1,158				0,383	0,669	
Artemis.LowMot_freeurban_3						0,793	0,707	0,751	0,713				0,134	0,433	
Artemis.LowMot_freeurban_total						0,725	0,747	0,862	0,796				0,207	0,500	0,040
Artemis.LowMot_urban						0,895	0,956	1,054	0,938				0,260	0,363	0,186
Artemis.LowMot_urban_1						0,880	1,055	1,106	0,882				0,305	0,425	0,099
Artemis.LowMot_urban_3						1,266	1,563	1,848	1,640				0,461	0,257	0,208
Artemis.LowMot_urban_4						1,196	1,583	1,654	1,297				0,161	0,558	0,089
Artemis.LowMot_urban_5						0,728	0,832	0,963	0,870				0,221	0,461	0,173
Artemis.LowMot_urbdense_1						0,881	0,864	1,071	1,043				0,468	0,256	0,070
Artemis.LowMot_urbdense_2						1,734	1,481	1,652	1,197				0,211	0,061	0,086
Artemis.LowMot_urbdense_3						1,547	1,333	1,618	1,695				0,208	0,602	0,012
Artemis.LowMot_urbdense_total						0,987	1,033	1,221	1,096				0,343	0,392	0,059
Artemis.urban	0,902	1,088	1,124	0,065	0,068	0,978	0,894	1,132	1,103	0,272	0,248	0,261	0,262	0,508	0,094
Artemis.urban_1	0,999	1,097	0,884		0,106	1,250	0,981	1,133	0,894	0,321	0,204	0,406	0,247	0,220	0,130
Artemis.urban_3	1,571	1,939	1,966		0,061	2,071	1,547	1,999	1,907	0,353	0,407	0,280	0,371	0,825	0,074
Artemis.urban_4	1,257	1,537	1,476		0,121	1,644	1,228	1,578	1,576	0,364	0,459	0,201	0,338	0,606	0,198
Artemis.urban_5	0,807	1,005	1,343		0,044	1,054	0,796	1,095	1,279	0,225	0,308	0,293	0,178	0,593	0,061
Handbook.R3_III	0,636	0,631	0,711	0,061	0,044										
Handbook.R4	0,898	0,807	0,666		0,048										
Handbook.R4_II	1,616	1,402	1,046	0,017	0,010										
Handbook.R4_III	2,715	2,259	1,757	0,012	0,035										
modem.urban13b	1,019	1,338	1,496		0,096										
modem.urban2x7	0,848	1,338	1,775		0,185										
modem.urban5713	0,852	1,206	1,430	0,071	0,152										
modem.urban5b	0,883	1,218	1,466		0,102										
Napoli.10	0,909	0,889	0,935		0,099										
Napoli.10_23	1,209	1,133	1,185	0,061	0,134										
Napoli.15	0,855	0,781	0,641		0,155										
Napoli.15_18_21	1,044	0,907	0,860	0,066	0,124										
Napoli.18	3,200	2,574	2,211		0,024										
Napoli.21	0,999	0,840	0,868		0,077										
Napoli.23	3,723	3,151	3,412		0,053										

NOx emission (g/km), all vehicles:

- Rural

Driving type (U/R/M)	Rural/Suburb.														
StatutEmitter	(Tous)														
Moyenne sur NOx (g/km)	CodeEx	Fuel Ty	High m	Eu_Standard											
	ART3141			PNR											
	Diesel			Gasoline			Diesel			Gasoline					
	Indet.			Indet.			Low mot.			High mot.			Low mot.		
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3
Artemis.HighMot_freurban_2													0,257	0,254	0,166
Artemis.HighMot_rural													0,428	0,165	0,124
Artemis.HighMot_rural_1														0,219	0,286
Artemis.HighMot_rural_2														0,158	0,060
Artemis.HighMot_rural_3														0,138	0,118
Artemis.HighMot_urban_2													0,459	0,222	0,179
Artemis.LowMot_freurban_2						0,778	0,784	0,943	0,881						
Artemis.LowMot_rural						0,699	0,693	0,749	0,728						
Artemis.LowMot_rural_1						0,780	0,664	0,808	0,844						
Artemis.LowMot_rural_2						0,668	0,563	0,567	0,504						
Artemis.LowMot_rural_3						0,715	0,578	0,594	0,582						
Artemis.LowMot_urban_2						0,634	0,718	0,852	0,856						
Artemis.rural	0,541	0,653	0,710	0,044	0,175	0,609	0,552	0,735	0,714	0,373	0,119	0,129	0,258	0,314	0,368
Artemis.rural_1	0,600	0,820	0,915		0,168	0,688	0,598	0,848	0,906	0,695	0,181	0,344	0,285	0,386	0,262
Artemis.rural_2	0,527	0,494	0,499		0,255	0,589	0,535	0,610	0,482	0,233	0,115	0,050	0,172	0,147	0,446
Artemis.rural_3	0,579	0,575	0,564		0,213	0,667	0,577	0,692	0,582	0,212	0,100	0,099	0,241	0,133	0,326
Artemis.urban_2	0,772	0,954	1,140		0,081	0,926	0,756	0,954	1,064	0,219	0,192	0,220	0,308	0,537	0,094
Handbook.R2	0,455	0,486	0,626		0,086										
Handbook.R2_II	0,452	0,458	0,588	0,060	0,067										
Handbook.R2_III	0,461	0,495	0,651	0,012	0,043										
Handbook.R3	0,482	0,544	0,550		0,061										
Handbook.R3_I	0,497	0,631	0,644	0,021	0,063										
Handbook.R3_II	0,484	0,398	0,432	0,018	0,050										
Handbook.R4_I	0,659	0,606	0,565	0,028	0,050										
modernHyzem.road	0,582	0,759	0,830	0,051	0,098										
Napoli.17	0,558	0,710	0,720		0,097										
Napoli.6	0,579	0,940	1,120		0,152										
Napoli.6_17	0,537	0,776	0,846	0,044	0,166										
Total	0,547	0,643	0,713	0,035	0,108	0,693	0,642	0,763	0,740	0,360	0,167	0,162	0,240	0,281	0,262

- Motorway / main roads

Driving type (U/R/M)	Motorway/Main road														
StatutEmitter	(Tous)														
Moyenne sur NOx (g/km)	CodeEx	Fuel Ty	High m	Eu_Standard											
	ART3141			PNR											
	Diesel			Gasoline			Diesel			Gasoline					
	Indet.			Indet.			Low mot.			High mot.			Low mot.		
Cycle Name	EURO1	EURO2	EURO3	EURO2	EURO3	antEUR	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3	EURO1	EURO2	EURO3
Artemis.HighMot_motorway													0,984	0,185	0,057
Artemis.HighMot_motorway_1													1,361	0,031	0,056
Artemis.HighMot_motorway_2													0,595	0,064	0,052
Artemis.HighMot_motorway_3													0,920	0,025	0,069
Artemis.HighMot_motorway_4													0,839	0,096	0,074
Artemis.HighMot_rural_4														0,178	0,102
Artemis.HighMot_rural_5														0,149	0,025
Artemis.LowMot_motorway	0,833	1,023	1,316	0,040	0,252	1,087	0,817	1,226	1,387						
Artemis.LowMot_motorway_1	0,856	0,982	1,203		0,164	0,971	0,845	1,213	1,272					0,399	0,360
Artemis.LowMot_motorway_2	0,720	0,960	1,260		0,129	0,825	0,716	1,055	1,194					0,363	0,331
Artemis.LowMot_motorway_3	0,909	1,138	1,435		0,313	1,115	0,902	1,387	1,589					0,448	0,396
Artemis.LowMot_motorway_4	0,918	1,361	2,027		0,331	1,218	0,897	1,711	2,301					0,508	0,060
Artemis.LowMot_rural_4						0,850	0,672	1,075	1,221					0,447	0,484
Artemis.LowMot_rural_5						0,691	0,543	0,631	0,610					0,164	0,065
Artemis.motorway_130				0,032	0,120										
Artemis.motorway_130_3					0,080										
Artemis.motorway_130_4					0,141										
Artemis.motorway_150	0,779	1,038	1,379		0,253	0,845	0,771	1,157	1,420	0,967	0,191	0,043	0,335	0,297	0,474
Artemis.motorway_150_1	0,836	0,987	1,121		0,382	0,908	0,817	1,124	1,171	1,041	0,131	0,025	0,328	0,529	0,610
Artemis.motorway_150_2	0,677	1,015	1,364		0,231	0,719	0,662	1,013	1,220	0,349	0,210	0,036	0,397	0,262	0,374
Artemis.motorway_150_3	0,920	1,168	1,652		0,552	1,055	0,892	1,359	1,754	1,057	0,277	0,049	0,388	0,183	0,552
Artemis.motorway_150_4	0,925	1,288	2,098		0,332	1,153	0,901	1,552	2,281	1,677	0,261	0,099	0,333	0,056	0,332
Artemis.rural_4	0,636	0,883	1,095		0,318	0,711	0,642	0,967	1,071	0,346	0,116	0,104	0,393	0,548	0,419
Artemis.rural_5	0,500	0,481	0,427		0,289	0,569	0,523	0,597	0,550	0,321	0,103	0,061	0,163	0,185	0,524
Handbook.R1	0,658	0,701	0,934		0,210										
Handbook.R1_I	0,752	0,828	1,022	0,023	0,174										
Handbook.R1_II	0,650	0,727	1,008	0,017	0,139										
Handbook.R1_III	0,580	0,583	0,854	0,060	0,180										
Handbook.R2_I	0,504	0,574	0,783	0,007	0,097										
LDV_PVU.CommercialCars.motorw	0,597	0,838	1,219	0,065	0,170										
Total	0,736	0,921	1,233	0,035	0,217	0,873	0,765	1,156	1,360	0,871	0,151	0,061	0,361	0,303	0,457

Annex 10. Classification of the driving cycles from the Artemis emission database

The 98 active cycles are shown here and grouped into 15 test patterns

Classes	Number of cycles	Cycles (ranked by representativity)	Average Speed (km/h)	Running Speed (km/h)	Stop duration (%)	Stop Frequency (1/km)	Accelerations / km	Strong accelerations / km	Average positive acceleration (m/s ²)
1	16	Artemis.urban, modemHyzem.urban1, modem.urban1, modem.urban5, modem.urban13b, modem.urban13, OSCAR.D2, modem.urban5b, OSCAR.E, modemHyzem.urban, modemIM.Urban_Free_Flow, modem.urban12, Inrets.urbainfluide3, Artemis.urban_1, modem.urban8, OSCAR.G1	20,4	27,4	25,6	3,06	8,11	2,31	0,83
2	8	modemHyzem.urban3, Inrets.urbainfluide1, modemIM.Urban_Slow, modem.urban4, modem.urban3, OSCAR.G2, Artemis.urban_4, Napoli.10	14,3	19,1	24,9	4,91	11,75	2,33	0,76
3	3	Artemis.urban_3, OSCAR.F, modem.urban2	13,2	27,4	51,8	4,89	6,53	1,96	0,92
4	7	Inrets.urbainfluide2, TRL.Urban, OSCAR.D1, modem.urban10, Napoli.21, Artemis.urban_5, Handbook.R3_III	19,9	24,3	18,0	2,57	8,24	1,58	0,74
5	12	modem.urban14, Artemis.urban_2, OSCAR.C, Legislative.US_FTP1, Inrets.route1, Legislative.US_FTP2, modemIM.Road, Handbook.R4_I, TRL.Suburban, Napoli.15, modem.urban7, modem.urban2x7	34,1	39,5	13,8	1,26	4,77	1,45	0,84
6	2	Handbook.R3_II, Artemis.rural_3	48,5	49,1	1,1	0,17	2,01	0,17	0,51
7a	10	OSCAR.H1, Inrets.urbainlent1, TRL.WSL_CongestedTraffic, Inrets.urbainlent2, modem.urban9, OSCAR.H2, Napoli.18, modem.urban6, Napoli.23, OSCAR.H3	6,0	9,6	37,5	20,65	15,77	1,71	0,67
7b	2	Handbook.R4_III, Handbook.R4_II	5,1	6,0	15,4	6,29	15,26	0,00	0,49
8	3	Handbook.R2_I, Artemis.rural_5, Legislative.US_HWAY	81,2	81,6	0,5	0,08	0,64	0,04	0,45
9	2	Artemis.rural_2, Handbook.R2_II	72,7	72,7	0,0	0,00	0,69	0,00	0,52
10	1	Artemis.rural_4	78,5	78,5	0,0	0,00	1,29	0,00	0,58
11	14	Napoli.17, Artemis.rural, modemHyzem.road, modem.urban11, TRL.Suburban&Rural, Inrets.route3, modemHyzem.road1, Inrets.route2, Artemis.rural_1, TRL.Rural, modemHyzem.road2, Handbook.R2_III, Napoli.6, Handbook.R3_I	56,0	58,6	4,5	0,26	2,63	0,38	0,66
12	4	Artemis.motorway_150, Artemis.motorway_150_3, Artemis.motorway_130_4, Artemis.motorway_150_4	122,3	122,3	0,0	0,00	0,54	0,03	0,41
13	3	Artemis.motorway_130, Artemis.motorway_130_3, Artemis.motorway_150_1	117,9	117,9	0,0	0,00	0,46	0,03	0,46
14	1	Artemis.motorway_150_2	103,5	103,5	0,0	0,00	1,80	0,20	0,63
15	10	modemHyzem.motorway, Inrets.autoroute2, modemIM.Motorway, Handbook.R1_II, Inrets.autoroute1, EMPA.BAB, Handbook.R1_III, modemHyzem.motorway1, Handbook.R1_I, TRL.Motorway	102,3	103,4	1,0	0,05	0,67	0,08	0,55
All together			46,5	54,6	14,8	0,89	2,75	0,55	0,69

Annex 11. Reference emissions according to the driving cycles

Reference Test Patterns	Aver. Speed km/h	Diesel					Gasoline				
		pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4
NOx g/km in NO2 equiv.											
7 Stop and go	7	3,884	1,551	1,583	1,620	0,633	1,369	0,422	0,193	0,072	0,041
3 Congested urban, stops	9	1,669	1,506	1,892	1,750	0,618	2,672	0,915	0,357	0,152	0,071
2 Congested urban, low speeds	12	1,644	1,124	1,458	1,455	0,665	1,811	0,803	0,284	0,149	0,043
1 Urban dense	17	0,862	1,049	1,143	0,991	0,566	1,858	0,483	0,300	0,146	0,085
4 Free-flowing urban	22	1,938	0,877	0,981	1,009	0,339	1,652	0,326	0,233	0,117	0,049
5 Free-flow urban, unsteady	32	1,076	0,807	0,854	0,939	0,441	1,790	0,398	0,274	0,112	0,044
6 Rural	43	0,691	0,550	0,568	0,644		0,798	0,331	0,111	0,045	0,024
11 Rural unsteady	58	0,963	0,612	0,703	0,670	0,401	1,708	0,384	0,205	0,084	0,070
9 Rural steady	66	0,629	0,519	0,554	0,608		1,243	0,347	0,106	0,043	0,015
10 Main roads, unsteady	79	0,781	0,654	0,942	1,105		2,718	0,643	0,227	0,101	0,022
8 Main roads	88	1,098	0,732	0,521	0,609		1,287	0,339	0,163	0,047	0,021
14 Motorway, unsteady	104	0,772	0,689	0,977	1,077		2,819	0,665	0,205	0,075	0,008
15 Motorway, stable	115	1,398	1,053	0,790	0,973		2,070	0,639	0,284	0,049	0,024
13 Motorway	119	1,013	0,825	1,049	0,785	0,740	3,418	0,613	0,226	0,068	0,018
12 Motorway, high speed	125	1,038	0,872	1,316	1,248		3,930	0,856	0,133	0,104	0,087
CO2 g/km											
7 Stop and go	7	432	276	328	301	269	431	448	462	354	378
3 Congested urban, stops	9	373	334	364	356	219	523	378	424	420	451
2 Congested urban, low speeds	12	293	250	295	296	233	406	350	346	351	384
1 Urban dense	17	236	219	236	232	205	249	240	263	267	288
4 Free-flowing urban	22	247	190	205	201	151	249	238	238	240	270
5 Free-flow urban, unsteady	32	189	190	192	186	156	220	188	196	213	238
6 Rural	43	150	128	140	146		160	160	161	154	157
11 Rural unsteady	58	183	147	154	144	128	157	158	157	166	174
9 Rural steady	66	142	124	134	130		143	173	140	140	144
10 Main roads, unsteady	79	192	179	185	165		189	168	189	180	185
8 Main roads	88	188	192	128	119		141	171	141	136	140
14 Motorway, unsteady	104	199	177	175	148		182	161	156	170	187
15 Motorway, stable	115	246	239	177	159		176	199	182	167	177
13 Motorway	119	221	173	191	153	162	196	177	157	178	197
12 Motorway, high speed	125	216	209	193	173		212	188	199	201	195
PM mass g/km											
7 Stop and go	7	0,369	0,086	0,075	0,044	0,046			0,012		
3 Congested urban, stops	9		0,078	0,051	0,051	0,038					
2 Congested urban, low speeds	12		0,099	0,061	0,042	0,038					
1 Urban dense	17	0,113	0,090	0,089	0,043	0,041	0,151	0,004	0,002	0,006	0,002
4 Free-flowing urban	22	0,506	0,040	0,064	0,044	0,024		0,004	0,002	0,001	
5 Free-flow urban, unsteady	32	0,457	0,081	0,068	0,044	0,044		0,005	0,002	0,002	
6 Rural	43			0,029							
11 Rural unsteady	58	0,394	0,066	0,068	0,030	0,033	0,305	0,004	0,003	0,003	0,002
9 Rural steady	66			0,031							
10 Main roads, unsteady	79										
8 Main roads	88	0,168	0,090	0,047	0,035			0,004	0,005	0,002	
14 Motorway, unsteady	104										
15 Motorway, stable	115	0,289	0,176	0,069	0,049			0,018	0,010	0,003	
13 Motorway	119	0,095	0,089	0,085	0,037	0,105	0,537	0,002	0,006	0,004	
12 Motorway, high speed	125	0,208	0,226	0,089	0,096					0,009	0,006

Reference Test Patterns	Aver. Speed km/h	Diesel					Gasoline				
		pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4
CO g/km											
7 Stop and go	7	2,055	0,889	0,903	0,239	0,251	50,244	7,759	1,942	0,326	0,204
3 Congested urban, stops	9	1,326	0,994	1,045	0,485	0,057	32,667	3,924	1,172	1,071	0,287
2 Congested urban, low speeds	12	0,912	0,451	0,688	0,289	0,128	26,065	2,858	1,971	0,811	0,247
1 Urban dense	17	1,048	0,467	0,544	0,213	0,342	21,438	3,666	1,147	0,662	0,141
4 Free-flowing urban	22	1,307	0,570	0,545	0,201	0,076	25,209	4,533	1,379	0,677	0,227
5 Free-flow urban, unsteady	32	0,858	0,535	0,518	0,180	0,072	16,034	2,618	0,825	0,466	0,101
6 Rural	43	0,546	0,370	0,301	0,122		8,682	0,951	0,294	0,281	0,068
11 Rural unsteady	58	0,649	0,237	0,183	0,047	0,005	10,804	1,943	0,846	0,736	0,719
9 Rural steady	66	0,491	0,287	0,208	0,069		6,487	1,149	0,258	0,306	0,098
10 Main roads, unsteady	79	0,467	0,333	0,152	0,027		10,741	2,482	0,872	1,159	0,648
8 Main roads	88	0,484	1,661	0,088	0,013		4,168	1,741	0,398	0,360	0,180
14 Motorway, unsteady	104	0,446	0,309	0,085	0,015		13,285	1,895	0,710	2,765	0,656
15 Motorway, stable	115	0,769	0,396	0,087	0,012		11,964	6,363	2,041	1,997	0,348
13 Motorway	119	0,425	0,162	0,067	0,013	0,011	15,439	1,400	1,257	3,066	0,529
12 Motorway, high speed	125	0,420	0,370	0,063	0,028		13,133	4,031	2,240	3,898	5,276
HC g/km in C3H8 equivalents											
7 Stop and go	7	0,127	0,069	0,251	0,108	0,036	4,782	0,225	0,242	0,008	0,012
3 Congested urban, stops	9		0,058	0,207	0,050	0,028	3,028	0,006	0,152	0,028	0,003
2 Congested urban, low speeds	12		0,073	0,197	0,047	0,024	2,333	0,010	0,210	0,022	0,006
1 Urban dense	17	0,143	0,090	0,105	0,022	0,030	2,486	0,198	0,084	0,021	0,004
4 Free-flowing urban	22	0,270	0,037	0,141	0,030	0,009	2,676	0,524	0,099	0,019	0,004
5 Free-flow urban, unsteady	32	0,242	0,052	0,106	0,022	0,015	1,402	0,358	0,058	0,011	0,002
6 Rural	43			0,101	0,015		0,800	0,044	0,036	0,006	0,000
11 Rural unsteady	58	0,185	0,051	0,050	0,011	0,008	1,291	0,160	0,037	0,012	0,003
9 Rural steady	66			0,078	0,012		0,650	0,055	0,034	0,008	0,002
10 Main roads, unsteady	79			0,061	0,012		0,959		0,065	0,019	0,014
8 Main roads	88	0,084	0,074	0,042	0,009		0,400	0,076	0,034	0,011	0,004
14 Motorway, unsteady	104			0,030	0,007		0,979			0,018	0,011
15 Motorway, stable	115	0,096	0,047	0,031	0,015		0,576	0,183	0,070	0,021	0,010
13 Motorway	119		0,028	0,032	0,005	0,007	0,748	0,023	0,028	0,026	0,017
12 Motorway, high speed	125			0,025	0,006		0,795		0,020	0,036	0,002

Annex 12. Reference emissions according to the driving patterns – Extrapolations

Reference Test Patterns	Aver. Speed km/h	Diesel					Gasoline				
		pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4
NOx g/km in NO2 equiv.											
1 Urban dense	17	0,862	1,049	1,143	0,991	0,566	1,858	0,483	0,300	0,146	0,085
2 Congested urban, low speeds	12	1,644	1,124	1,458	1,455	0,665	1,811	0,803	0,284	0,149	0,043
3 Congested urban, stops	9	1,669	1,506	1,892	1,750	0,618	2,672	0,915	0,357	0,152	0,071
4 Free-flowing urban	22	1,938	0,877	0,981	1,009	0,339	1,652	0,326	0,233	0,117	0,049
5 Free-flow urban, unsteady	32	1,076	0,807	0,854	0,939	0,441	1,790	0,398	0,274	0,112	0,044
6 Rural	43	0,691	0,550	0,568	0,644	0,386	0,798	0,331	0,111	0,045	0,024
7 Stop and go	7	3,884	1,551	1,583	1,620	0,633	1,369	0,422	0,193	0,072	0,041
8 Main roads	88	1,098	0,732	0,521	0,609	0,365	1,287	0,339	0,163	0,047	0,021
9 Rural steady	66	0,629	0,519	0,554	0,608	0,364	1,243	0,347	0,106	0,043	0,015
10 Main roads, unsteady	79	0,781	0,654	0,942	1,105	0,662	2,718	0,643	0,227	0,101	0,022
11 Rural unsteady	58	0,963	0,612	0,703	0,670	0,401	1,708	0,384	0,205	0,084	0,070
12 Motorway, high speed	125	1,038	0,872	1,316	1,248	1,176	3,930	0,856	0,133	0,104	0,087
13 Motorway	119	1,013	0,825	1,049	0,785	0,740	3,418	0,613	0,226	0,068	0,018
14 Motorway, unsteady	104	0,772	0,689	0,977	1,077	1,015	2,819	0,665	0,205	0,075	0,008
15 Motorway, stable	115	1,398	1,053	0,790	0,973	0,917	2,070	0,639	0,284	0,049	0,024
CO2 g/km											
1 Urban dense	17	236	219	236	232	205	249	240	263	267	288
2 Congested urban, low speeds	12	293	250	295	296	233	406	350	346	351	384
3 Congested urban, stops	9	373	334	364	356	219	523	378	424	420	451
4 Free-flowing urban	22	247	190	205	201	151	249	238	238	240	270
5 Free-flow urban, unsteady	32	189	190	192	186	156	220	188	196	213	238
6 Rural	43	150	128	140	146	130	160	160	161	154	157
7 Stop and go	7	432	276	328	301	269	431	448	462	354	378
8 Main roads	88	188	192	128	119	106	141	171	141	136	140
9 Rural steady	66	142	124	134	130	116	143	173	140	140	144
10 Main roads, unsteady	79	192	179	185	165	147	189	168	189	180	185
11 Rural unsteady	58	183	147	154	144	128	157	158	157	166	174
12 Motorway, high speed	125	216	209	193	173	183	212	188	199	201	195
13 Motorway	119	221	173	191	153	162	196	177	157	178	197
14 Motorway, unsteady	104	199	177	175	148	157	182	161	156	170	187
15 Motorway, stable	115	246	239	177	159	169	176	199	182	167	177
PM mass g/km											
1 Urban dense	17	0,113	0,090	0,089	0,043	0,041	0,151	0,004	0,002	0,006	0,002
2 Congested urban, low speeds	12	0,125	0,099	0,061	0,042	0,038	0,170	0,004	0,002	0,003	0,001
3 Congested urban, stops	9	0,098	0,078	0,051	0,051	0,038	0,170	0,004	0,002	0,003	0,001
4 Free-flowing urban	22	0,506	0,040	0,064	0,044	0,024	0,159	0,004	0,002	0,001	0,001
5 Free-flow urban, unsteady	32	0,457	0,081	0,068	0,044	0,044	0,199	0,005	0,002	0,002	0,001
6 Rural	43	0,052	0,028	0,029	0,013	0,014	0,305	0,004	0,003	0,003	0,002
7 Stop and go	7	0,369	0,086	0,075	0,044	0,046	0,910	0,021	0,012	0,035	0,015
8 Main roads	88	0,168	0,090	0,047	0,035	0,039	0,305	0,004	0,005	0,002	0,001
9 Rural steady	66	0,055	0,030	0,031	0,014	0,015	0,305	0,004	0,003	0,003	0,002
10 Main roads, unsteady	79	0,122	0,066	0,068	0,030	0,033	0,305	0,004	0,003	0,003	0,002
11 Rural unsteady	58	0,394	0,066	0,068	0,030	0,033	0,305	0,004	0,003	0,003	0,002
12 Motorway, high speed	125	0,208	0,226	0,089	0,096	0,271	6,634	0,026	0,014	0,009	0,006
13 Motorway	119	0,095	0,089	0,085	0,037	0,105	0,537	0,002	0,006	0,004	0,002
14 Motorway, unsteady	104	0,146	0,089	0,089	0,037	0,105	2,702	0,011	0,006	0,004	0,002
15 Motorway, stable	115	0,289	0,176	0,069	0,049	0,138	4,549	0,018	0,010	0,003	0,002

Yellow: urban cases and corresponding extrapolations

Green: rural cases and corresponding extrapolations

Blue: motorway cases and corresponding extrapolations

In red: other extrapolation by similarity between close vehicle categories

Reference Test Patterns	Aver. Speed km/h	Diesel					Gasoline				
		pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4	pre-EURO-1	EURO-1	EURO-2	EURO-3	EURO-4
CO g/km											
1 Urban dense	17	1,048	0,467	0,544	0,213	0,342	21,438	3,666	1,147	0,662	0,141
2 Congested urban, low speeds	12	0,912	0,451	0,688	0,289	0,128	26,065	2,858	1,971	0,811	0,247
3 Congested urban, stops	9	1,326	0,994	1,045	0,485	0,057	32,667	3,924	1,172	1,071	0,287
4 Free-flowing urban	22	1,307	0,570	0,545	0,201	0,076	25,209	4,533	1,379	0,677	0,227
5 Free-flow urban, unsteady	32	0,858	0,535	0,518	0,180	0,072	16,034	2,618	0,825	0,466	0,101
6 Rural	43	0,546	0,370	0,301	0,122	0,012	8,682	0,951	0,294	0,281	0,068
7 Stop and go	7	2,055	0,889	0,903	0,239	0,251	50,244	7,759	1,942	0,326	0,204
8 Main roads	88	0,484	1,661	0,088	0,013	0,001	4,168	1,741	0,398	0,360	0,180
9 Rural steady	66	0,491	0,287	0,208	0,069	0,007	6,487	1,149	0,258	0,306	0,098
10 Main roads, unsteady	79	0,467	0,333	0,152	0,027	0,003	10,741	2,482	0,872	1,159	0,648
11 Rural unsteady	58	0,649	0,237	0,183	0,047	0,005	10,804	1,943	0,846	0,736	0,719
12 Motorway, high speed	125	0,420	0,370	0,063	0,028	0,024	13,133	4,031	2,240	3,898	5,276
13 Motorway	119	0,425	0,162	0,067	0,013	0,011	15,439	1,400	1,257	3,066	0,529
14 Motorway, unsteady	104	0,446	0,309	0,085	0,015	0,013	13,285	1,895	0,710	2,765	0,656
15 Motorway, stable	115	0,769	0,396	0,087	0,012	0,010	11,964	6,363	2,041	1,997	0,348
HC g/km in C3H8 equivalents											
1 Urban dense	17	0,143	0,090	0,105	0,022	0,030	2,486	0,198	0,084	0,021	0,004
2 Congested urban, low speeds	12	0,116	0,073	0,197	0,047	0,024	2,333	0,010	0,210	0,022	0,006
3 Congested urban, stops	9	0,093	0,058	0,207	0,050	0,028	3,028	0,006	0,152	0,028	0,003
4 Free-flowing urban	22	0,270	0,037	0,141	0,030	0,009	2,676	0,524	0,099	0,019	0,004
5 Free-flow urban, unsteady	32	0,242	0,052	0,106	0,022	0,015	1,402	0,358	0,058	0,011	0,002
6 Rural	43	0,376	0,104	0,101	0,015	0,011	0,800	0,044	0,036	0,006	0,000
7 Stop and go	7	0,127	0,069	0,251	0,108	0,036	4,782	0,225	0,242	0,008	0,012
8 Main roads	88	0,084	0,074	0,042	0,009	0,007	0,400	0,076	0,034	0,011	0,004
9 Rural steady	66	0,290	0,080	0,078	0,012	0,009	0,650	0,055	0,034	0,008	0,002
10 Main roads, unsteady	79	0,226	0,063	0,061	0,012	0,009	0,959	0,285	0,065	0,019	0,014
11 Rural unsteady	58	0,185	0,051	0,050	0,011	0,008	1,291	0,160	0,037	0,012	0,003
12 Motorway, high speed	125	0,045	0,022	0,025	0,006	0,008	0,795	0,017	0,020	0,036	0,002
13 Motorway	119	0,057	0,028	0,032	0,005	0,007	0,748	0,023	0,028	0,026	0,017
14 Motorway, unsteady	104	0,053	0,026	0,030	0,007	0,010	0,979	0,009	0,010	0,018	0,011
15 Motorway, stable	115	0,096	0,047	0,031	0,015	0,021	0,576	0,183	0,070	0,021	0,010

Yellow: urban cases and corresponding extrapolations

Green: rural cases and corresponding extrapolations

Blue: motorway cases and corresponding extrapolations

In red: other extrapolation by similarity between close vehicle categories