LAT / AUTh

TÜV Rheinland

TRANSPORT RESEARCH LABORATORY

The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency

Detailed Report N° 2 :

Development of short driving cycles

- **Short driving cycles for the inspection of in-use cars**
- **Representative European driving cycles for the assessment of the I/M schemes**

INRETS Report LEN 9809

May 1998

Project funded by the European Commission
Directorate Generals for Environment (DGXI), Transport (DG VII) and Energy (XVII)

INSTITUT NATIONAL DE RECHERCHE
SUR LES TRANSPORTS ET LEUR SÉCURITÉ

Michel ANDRÉ

Dieter HASSEL, Franz-Josef WEBER

Development of short driving cycles

- *Short driving cycles for the inspection of in-use cars*
- *Representative European driving cycles for the assessment of the I/M schemes*

INRETS Report N° LEN9809
May 1998

Research project : *The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency*
Sponsored by the European Commission
Directorate Generals for Environment (DGXI), Transport (DG VII) and Energy (XVII)

Authors :

Michel ANDRÉ, INRETS

Dieter HASSEL, TÜV-Rheinland

Franz-Josef WEBER, TÜV-Rheinland

Research units:

INRETS - LEN, Laboratoire Énergie Nuisances
25 avenue François Mitterrand, case 24, 69675 BRON cedex - France.

TÜV Rheinland - Zentralabteilung Verkehrs- und Transporttechnik,
PF 101750, 5000 Köln 1 - FRG - Germany

with the participation (DRIVE-modem project) of

TRL - Vehicles & Envir. Div.,
Crowthorne, Berkshire - RG 116AU - United Kingdom

INRETS INSTITUT NATIONAL DE RECHERCHE SUR LES TRANSPORTS ET LEUR SÉCURITÉ

INRETS - 25, Avenue F. Mitterrand - Case 24 - 69675 - BRON - Cedex - France
Tél. : +33 4 72 14 23 00 - Fax : +33 4 72 37 68 37

Fiche bibliographique

1 UR (1er auteur) Laboratoire Énergie Nuisances	2 Projet n°	3 Rapport INRETS n° LEN 9809
4 Titre Développement de cycles de conduite courts		
5 Sous-titre Cycles de conduite courts pour le contrôle des véhicules -Cycles représentatifs européens pour l'évaluation de procédures d'inspection / maintenance		6 Langue E
7 Auteur(s) Michel ANDRÉ Dieter HASSEL Franz-Josef WEBER		8 Rattachement ext. INRETS - LEN TÜV-Rheinland TÜV-Rheinland
9 Nom adresse financeur, co-éditeur Commission Européenne - DG XI		10 N° contrat, conv.
		11 Date de publication Mai 1998
12 Remarques Projet de recherche : The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency		

13 Résumé

On construit des cycle de conduite transitoires courts qui pourraient être utilisés dans le cadre d'un programme de contrôle technique des véhicules en ce qui concerne leurs émissions de polluants. De manière à obtenir une certaine corrélation entre les résultats d'émissions mesurés lors d'une telle procédure et ceux obtenus lors de l'homologation des véhicules, un premier cycle est proposé à partir du cycle réglementaire européen (NEDC). Des mesures d'émissions ont permis de valider le cycle retenu.

Dans le but de mieux correspondre aux émissions de pollutant émises par les véhicules en circulation, un second cycle de conduite est construit à partir des données mesurées à bord de véhicules en usage normal lors du projet de recherche européen DRIVE-modem.

L'analyse permet de déterminer différents paramètres statistiques tels que : durée, distance; vitesse moyenne, fréquence et durée des arrêts et de construire par simulation un cycle court représentatif de la circulation Européenne et dérivé de données réelles de conduite.

Afin de caractériser les émissions réelles de polluants, les mêmes données et méthodes sont utilisées pour construire un ensemble de cycles de référence correspondant à quatre situations types : circulation urbaine congestionnée et fluide, sur route et sur autoroute. Un logiciel de simulation permet de déterminer les rapports de boîte à utiliser sur ces cycles, selon les caractéristiques du véhicule et le comportement de conduite observé lors du suivi des véhicules. Les cycles d'essai et le logiciel de détermination des rapports de boîte constituent une base d'évaluation de différentes procédures de contrôle des véhicules, parmi lesquelles les cycles courts développés précédemment.

14 Mots clés : Cycle de conduite, émissions de polluants, voitures particulières, usages réels, conditions de fonctionnement, inspection		15 Diffusion libre	
16 Nombre de pages 63 pages	17 Prix ———— F	18 Confidentiel jusqu'au	19 Bibliographie oui

Publication data form

1 UR (1st author) Laboratoire Energie Nuisances	2 Project n° 13	3 INRETS report n° LEN9809
4 Title Development of short driving cycles		
5 Subtitle Short driving cycles for the inspection of in-use cars - Representative European driving cycles for the assessment of the I/M schemes		6 Language E
7 Author(s) Michel ANDRÉ Dieter HASSEL Franz-Josef WEBER		8 Affiliation INRETS - LEN TÜV-Rheinland TÜV-Rheinland
9 Sponsor, co-editor, name and address European Commission - DG XI		10 Contract, conv. n° 11 Publication date May 1998
12 Notes Research project : The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency		
13 Summary Short transient driving cycles are built-up that could be used within a procedure of inspection of the in-use vehicles as regards their pollutant emissions. In order to obtain a sufficient correlation between the emissions measured during such a procedure and those measured during the European approval test (vehicle homologation), a first driving cycle is based on the European standard driving cycle (NEDC). Preliminary emissions measurement have allowed to validate on a certain extent this cycle. Dedicated to correlate more accurately with the on-the-road pollutant emissions, a second driving cycle is built-up using the in-actual use data collected within the DRIVE-modem European Research. The analysis of distributions derived from this data allows to determine statistically various parameters such as : duration, length, average speed, stop rate, and idling relative duration. Simulations enable the construction of a short driving cycle, representative of the European traffic and derived from real driving data. The same data and method are used to derive a set of reference driving cycles to characterise the actual on-the-road pollutant emissions, and correspond to four typical driving situations : congested and free-flowing driving in urban areas, road and motorway driving. A simulation software allows to determine realistically the gears to be used during the tests as a function of the vehicles characteristics and the observed driving behaviour. Driving cycles and simulation software constitute a very representative test basis, for the assessment of various inspection procedures, of which the transient tests using the previous short driving cycles.		
14 Key Words : Driving cycle, passenger cars, pollutant emissions, actual uses, operating conditions, inspection programme	15 Distribution statement free	

16 Nb of pages 63 pages	17 Price ———— F	18 Declassification date	19 Bibliography yes

Contents

INTRODUCTION 7

1. DEVELOPMENT OF A SHORT CYCLE BASED ON THE TYPE APPROVAL TEST (TÜV SHORT CYCLE) 9

1.1. Introduction 9

1.2. Short driving cycles based on the type approval driving cycle 9

1.3. Test programme for TÜV short cycle selection 12

2. SHORT DRIVING CYCLE BASED ON THE EUROPEAN REAL DRIVING (*MODEM* SHORT CYCLE) 19

2.1 -Introduction 19

2.2 - Preliminary considerations for the construction of a short driving cycle 19
2.2.1 - Representativity 19
2.2.2 - Main orientations 20
2.2.3 - First criteria 20
2.2.4 - Other aspects 20

2.3 - Average parameters that a short driving cycle should meet 21

2.4 - Representativity of a short driving cycle 23

2.5 - Simulation of a short Driving Cycle 24

2.6 - Other considerations 25

3. PRELIMINARY COMPARISON BETWEEN THE SHORT CYCLES 27

4. REFERENCE DRIVING CYCLES BASED ON THE EUROPEAN REAL DRIVING (*MODEM* CYCLES) 29

4.1 - Introduction 29

4.2 - Urban driving 29

4.3 - Extra-urban driving 30

4.4 - Method 30

4.5 - Gear use software for automatic determination 31

4.6. Average characteristics of the real driving cycles and weighing 31

CONCLUSIONS 33

REFERENCES 35

APPENDICES 37

Appendix 1 - The DRIVE-*modem* data base 39

Appendix 2 - Characterisation of the European Driving - basic elements 41

Appendix 3 - Kinematic parameters of simulated short driving cycles 45

Appendix 4 - Typical simulated short trips 48

Appendix 5 - Proposal for a short transient driving cycle, derived from real driving data (modem short cycle) 51

Appendix 6 - Short transient driving cycle (*modem*) - second by second form 53

Appendix 7 -Average characteristics of the different trip groups and simulation parameters 55

Appendix 8 - Proposal for reference transient driving cycles, derived from real driving data (modem cycles) 57

Appendix 9 - Reference driving cycles - second by second form 59

Introduction

This report concerns the development of short driving cycles to be used for transient loaded testing in the framework of an enhanced Inspection and Maintenance programme. The report concerns also the development of reference (or long) driving cycles in order to assess the different test procedures that could be envisaged for Inspection purpose.

The works undertaken by TÜV Rheinland mainly concentrated on the development of a transient short test cycle representative of the European type approval driving cycle. The objective was to develop a short cycle that displays a good correlation between the short test emissions with the emissions as measured according to the type approval test.

Three short cycles are derived from the type approval driving cycles, and assessed through a programme of pollutant emissions measurements on three vehicles. The most satisfying cycle (as regards the correlation of the resulting emissions with the emissions measured on the approval test).

The works conducted by INRETS aimed mainly at the development of a cycle based on actual driving conditions, which should be as representative as possible. For that, a database was used, that was built-up within a previous European research project (DRIVE[1] - *modem*[2]) with the aim of defining typical vehicle real-world operating conditions. This experimental study has allowed on-board data recording on 60 privately-owned vehicles, from 3 European countries.

This database and the method allowing the characterisation of the driving conditions are used firstly to derive a representative short driving cycle for Inspection purpose.

They are used also to build-up a set of representative driving cycles - urban and extra-urban -, in order to measure the actual pollutant emissions of the passenger cars, and so, to constitute a reference basis for the assessment of various Inspection procedures, of which the transient loaded testing using the previous short driving cycles.

The methodology aspects of both approaches - based on the type approval test and based on the actual driving data - are addressed in this report. Preliminary comparison between the short driving cycles is conducted.

[1] DRIVE: Dedicated Road Infrastructure for Vehicle Safety in Europe - EEC research programme- DG XIII

[2] modem : Modelling of Emissions and Fuel Consumption in Urban Areas - DRIVE Project V1053.- by TRRL (UK), TÜV-Rheinland (FRG), CEDIA (B), INRETS (F)

1. Development of a short cycle based on the type approval test (TÜV short cycle)

1.1. Introduction

The objective was to develop a short cycle that displays a good correlation between the short test emissions with the emissions as measured according to the type approval test. In this connection the following aspects are of principle importance:

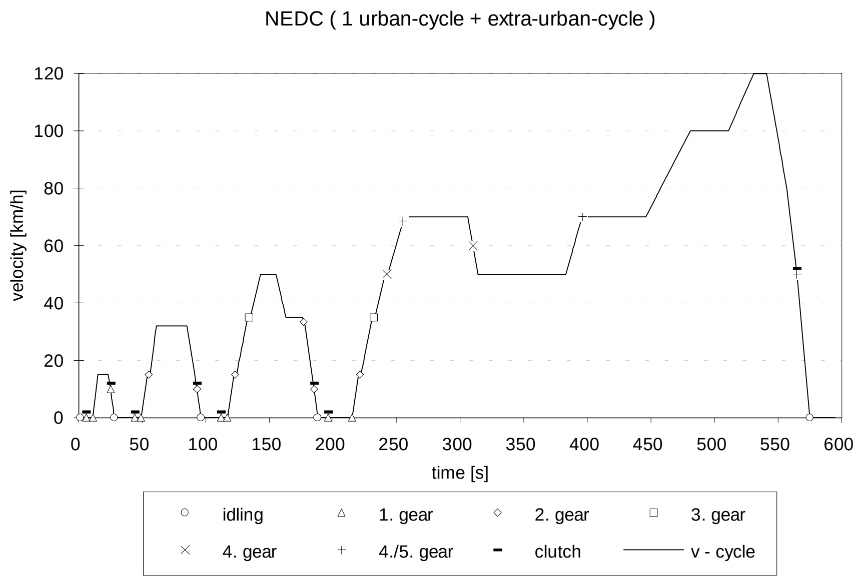
- The exhaust emission level of a vehicle is mainly determined by the average speed of a cycle. That means that the average speed of the short test should be similar to that of the type approval test.
- In former projects (see ref. [1], [2], [3]), it has been demonstrated that emission behaviour is not only influenced by mean speed, but also by acceleration and deceleration. This influence can be characterised by the parameter "speed times acceleration (v · a)", which is explained in [3]. The average and the standard deviation of the parameter (v · a) should be similar for the short test and for the type approval test in order to attain a good correlation of the emission results.

The duration of the cycle, which also influences the results, was limited for the short cycle to round about 200 s. Because of noise emissions and to avoid tyre problems the maximum speed should be significantly lower than in the type approval cycle.

1.2. Short driving cycles based on the type approval driving cycle

In Fig. 1 the European urban cycle together with the extra urban cycle is presented. The urban cycle has to be repeated four times before the extra urban part of the test cycle begins.

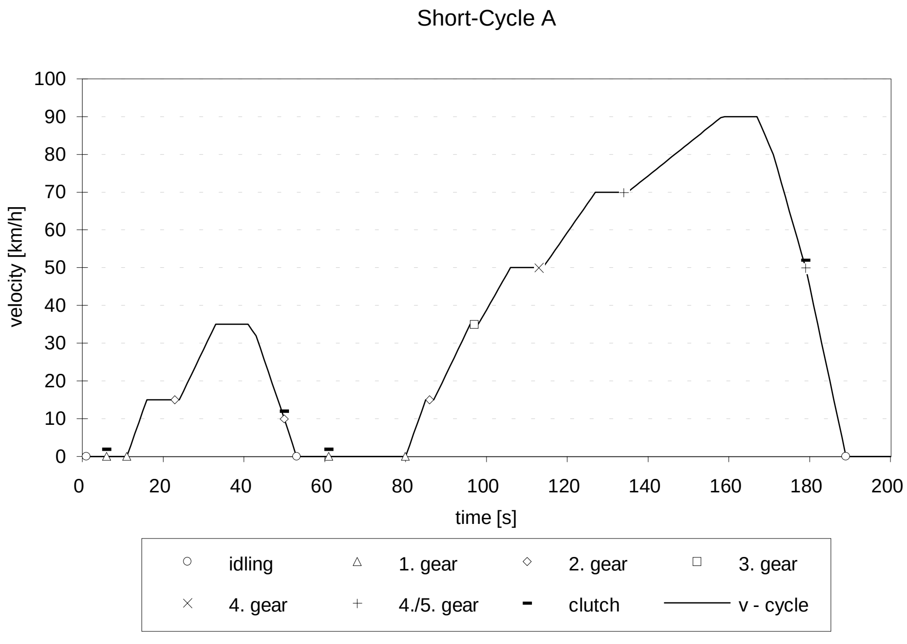
In the table beside the diagram the emission relevant parameters of the cycle are compiled. Besides the statistical parameters of speed and acceleration the percentage of idle and constant speed is given.



Parameters		NEDC
duration	[s]	1.180
distance	[m]	11013
maximum velocity	[km/h]	120
mean velocity	[km/h]	33,6
maximum acceler.	[m/s^2]	1,04
maximum v*a	[m^2/s^3]	9,3
minimum v*a	[m^2/s^3]	-22,7
mean v*a	[m^2/s^3]	0,096
idling	%	24
constant velocity	%	40
SD v	[km/h]	31,0
SD a	[m/s^2]	0,44
SD v*a	[m^2/s^3]	4,2

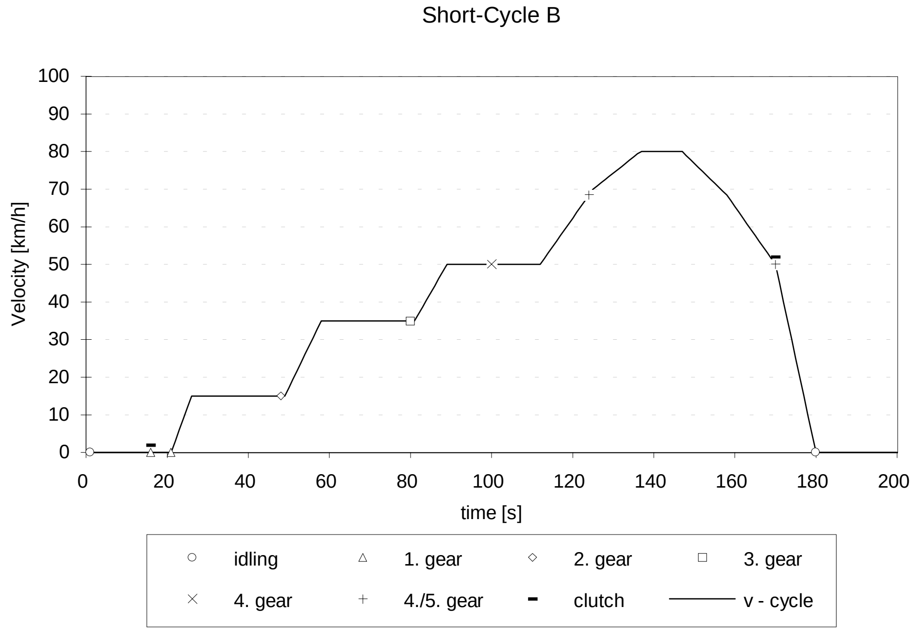
Figure 1: New European Driving Cycle (NEDC) and statistical parameters of the cycle

Fig. 2 to 4 show the speed curves of the three proposals for the short cycles. In the tables beside the diagrams the deviation to the NEDC parameters is shown.



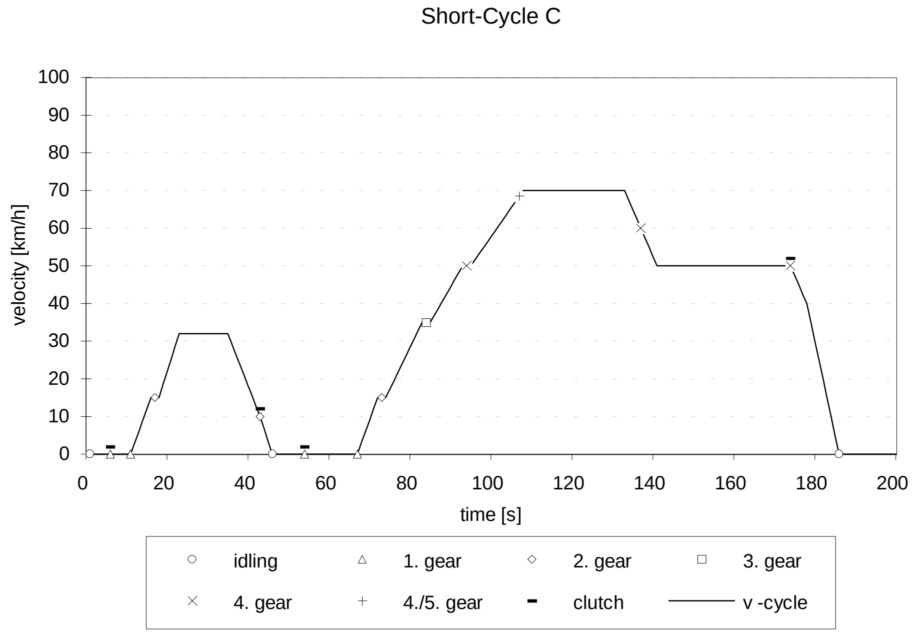
Deviation to NEDC [%]	
duration	-83
distance	-82
maximum velocity	-25
mean velocity	6
maximum acceler.	-20
maximum v*a	-10
minimum v*a	-3
mean v*a	50
idling	3
constant velocity	-44
SD v	1
SD a	23
SD v*a	41

Figure 2 **:** Short cycle A and the percentage of deviation of the statistical parameters between cycle A and NEDC



Deviation to NEDC [%]	
duration	-83
distance	-82
maximum velocity	-33
mean velocity	7
maximum acceler.	-20
maximum v*a	-10
minimum v*a	-23
mean v*a	-10
idling	-14
constant velocity	0
SD v	-12
SD a	-5
SD v*a	0

Figure 3 : Short cycle B and the percentage of deviation of the statistical parameters between cycle B and NEDC



Deviation to NEDC [%]	
duration	-83
distance	-83
maximum velocity	-42
mean velocity	-3
maximum acceler.	-9
maximum v*a	-9
minimum v*a	-40
mean v*a	24
idling	-3
constant velocity	-1
SD v	-18
SD a	12
SD v*a	-1

Figure 4 : Short cycle C and the percentage of deviation of the statistical parameters between cycle C and NEDC

All three proposals for a short cycle have a very small deviation to the mean speed of the NEDC. Cycle C has the lowest maximum speed and the percentage of idle and constant speed is similar to the NEDC.

The construction principles of the short cycles can be described as follows:

- Cycle A mainly reflects the different acceleration and decelerations of the NEDC with the consequence that the percentage of constant speed is too low.

- Cycle B reflects the constant speeds of the NEDC up to 80 km/h. A separation of urban and extra urban driving behaviour is not possible.
- Cycle C is a composition of original parts of the NEDC.

The selection of the cycle with the best correlation to the results of the NEDC will be conducted on the basis of a special test programme which will be described in the following section.

1.3. Test programme for TÜV short cycle selection

In order to take into account the influence of different engine size on the results the preliminary measurements were conducted with three vehicles representing the three classes of engine capacity (1,4 l, 1,4 l - 2,0 l and > 2,0 l). Table 1 contains a compilation of the technical parameters of the three test vehicles.

Table 1 : Technical parameters of the test vehicles for TÜV cycle selection

vehicle type	displacement [l]	power [kW]	weight [kg]	no. of gears	year of production	km-driven
VW Polo	1,27	40	785	4	1991	42242
Opel Vectra	1,80	66	1100	5	1993	22893
Audi 100	2,31	98	1370	5	1991	80870

At the beginning emission and fuel consumption in the NEDC were measured for the three test vehicles. The measurements for each vehicle were repeated four times. In a second step emissions and fuel consumption were measured in all proposed TÜV short test cycles. The measurements in the short cycles were repeated at least four times for each vehicle. In each short cycle measurement the cycle was repeated for one time.

The chassis dynamometer setting was in accordance to the type approval procedure. The measurements were performed at ambient temperatures of 22 to 24°C. The ambient pressure was within a range of 995 to 1025 mbar

For the three test vehicles Fig. 5 to 7 contain the average emissions and the average fuel consumption in connection with the standard deviation in each cycle. Because the type approval measurement begins with a cold start after a soak time of at least 12 h and as the measurement in a short cycle is conducted with warmed up engine, for comparative reasons a NEDC result with hot start was calculated on the basis of the forth urban cycle of the NEDC.

If one compares the results in the NEDC with the standards of the EU regulation 91/441/EEC it can be stated that the Polo and Vectra are below the standards whereas the Audi 100 exceeds the standard for the sum of HC and NO_X by about 50 %.

It can be seen that the emissions in the short test cycles are comparable to the emission of the hot NEDC. The standard deviations of the emissions are larger in the short tests than in the NEDC. The fuel consumption of short tests B and C are significantly lower than in short test A. The fuel consumption in short test A is very similar to that of the NEDC.

The main selection criteria for the short cycle is the correlation to the result in the NEDC. For the purpose of correlation the emission result of the second short test was set against the result in the NEDC.

In Fig. 8 the short test results for HC, CO NO_X and fuel consumption are correlated with the respective hot NEDC results. Taking into account only the square of the correlation coefficient the selection of one short test is very difficult. Since the fuel consumption of short test A is very similar to the consumption in the NEDC with warmed up engine, this cycle was selected.

In analogy to the previous figure Fig. 9 shows the correlation of the short test results with the cold NEDC results. Except of HC the correlation is also good. The gradient of the regression line differs especially for HC and CO and is smaller for NO_X and fuel consumption.

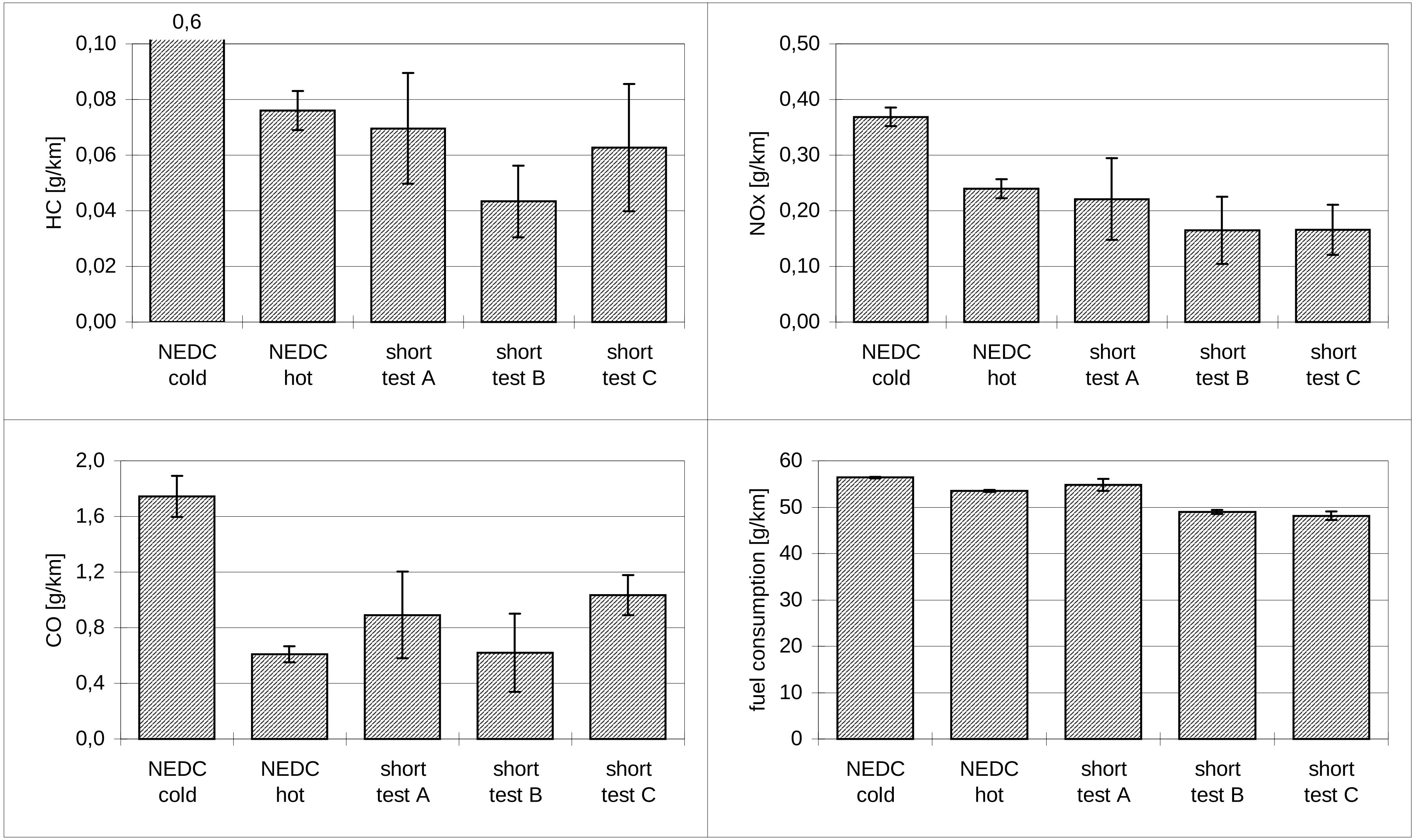


Figure 5 : Average emissions and average fuel consumption in different cycles for the vehicle VW Polo

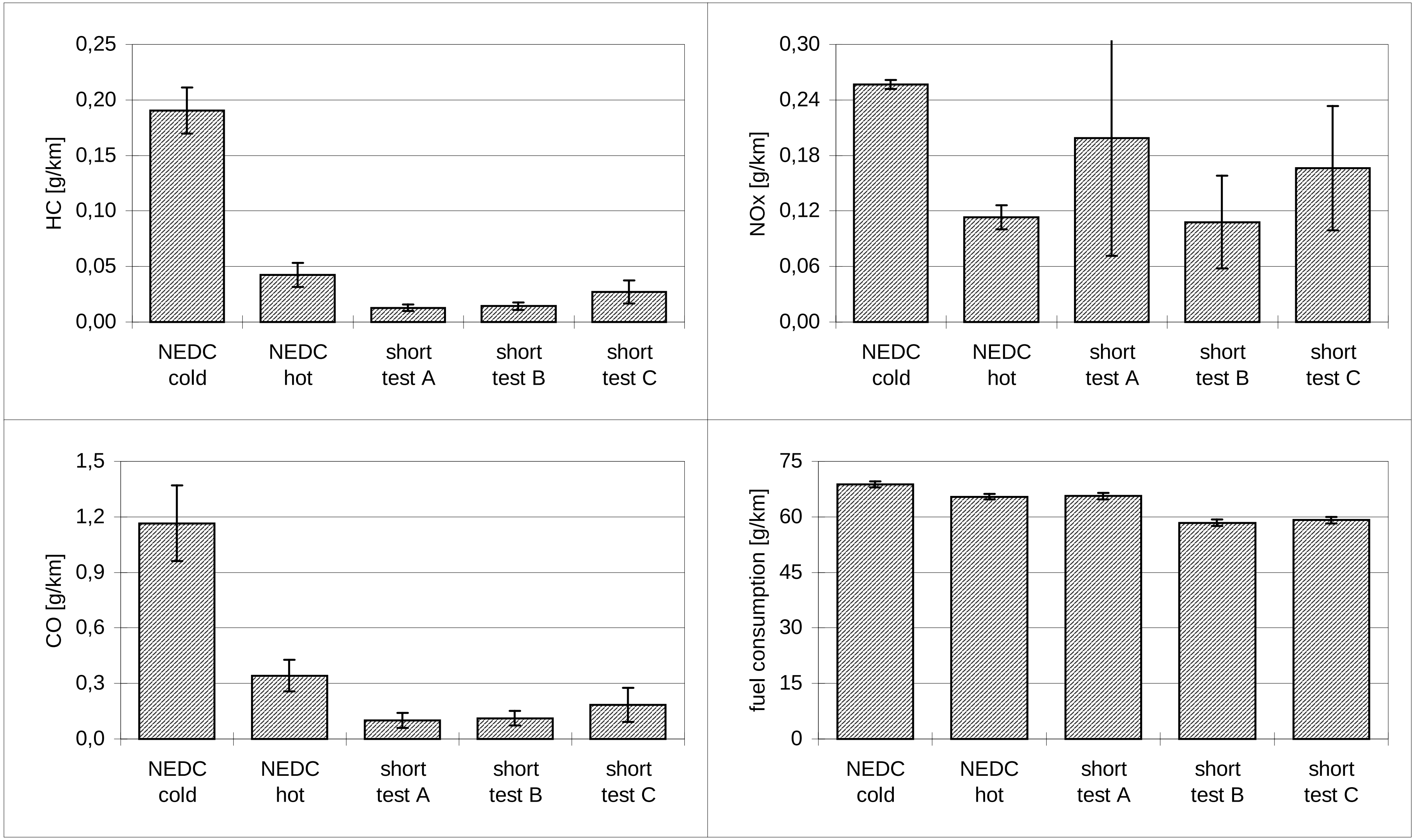


Figure 6 : Average emissions and average fuel consumption in different cycles for the vehicle Opel Vectra

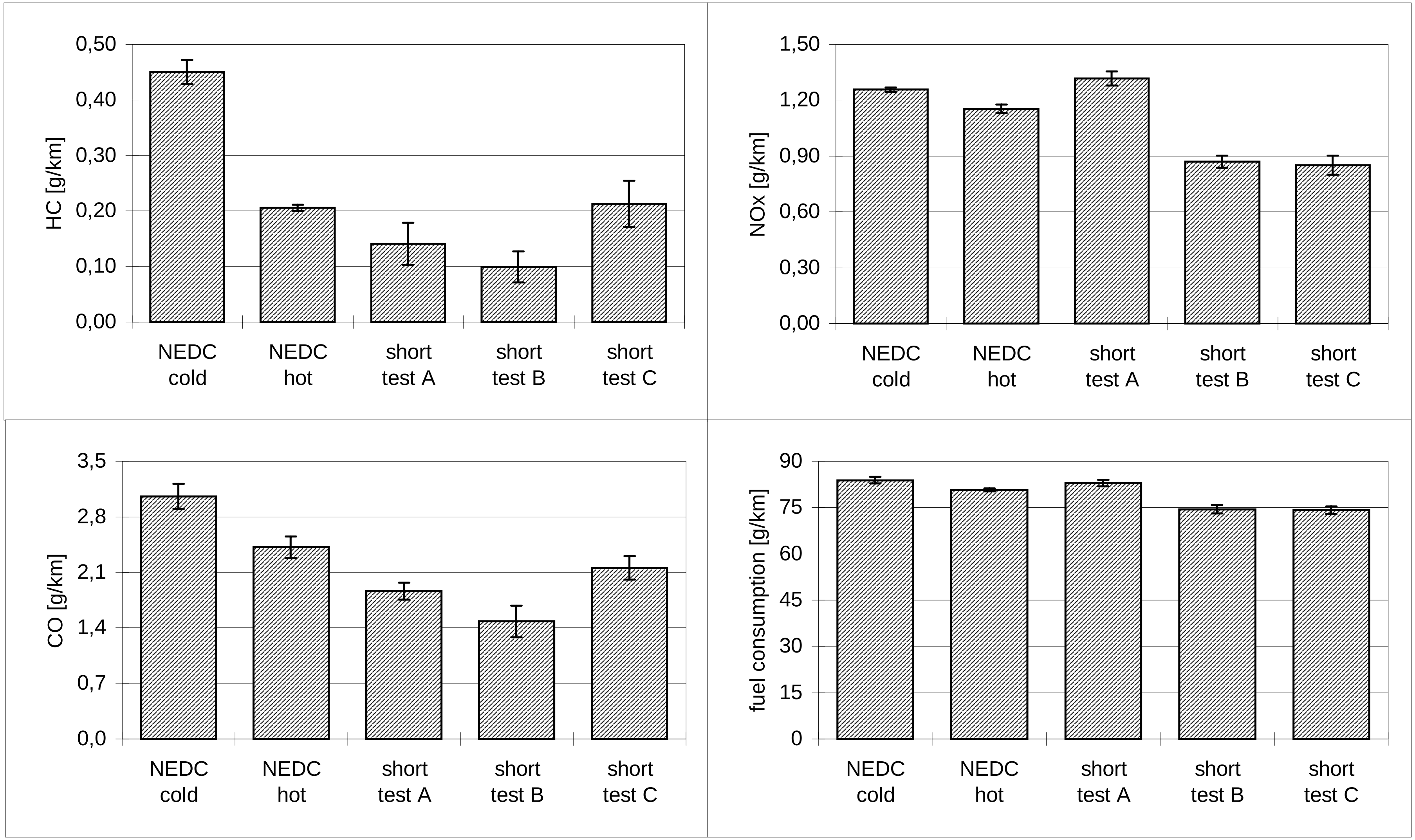


Figure 7 : Average emissions and average fuel consumption in different cycles for the vehicle Audi 100

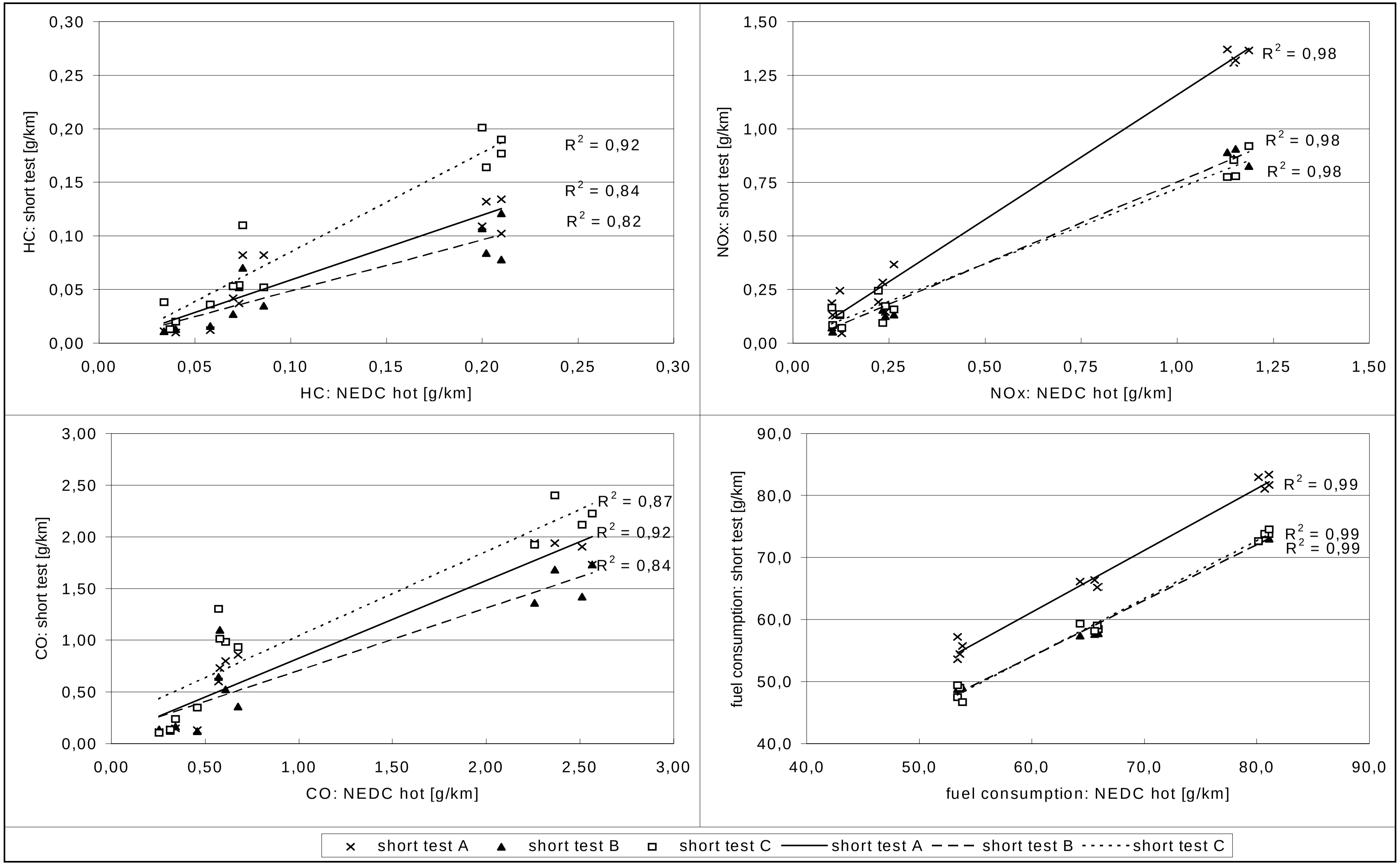


Figure 8 : Correlation between short test results and results in the hot NEDC for HC, CO, NO_X and fuel consumption

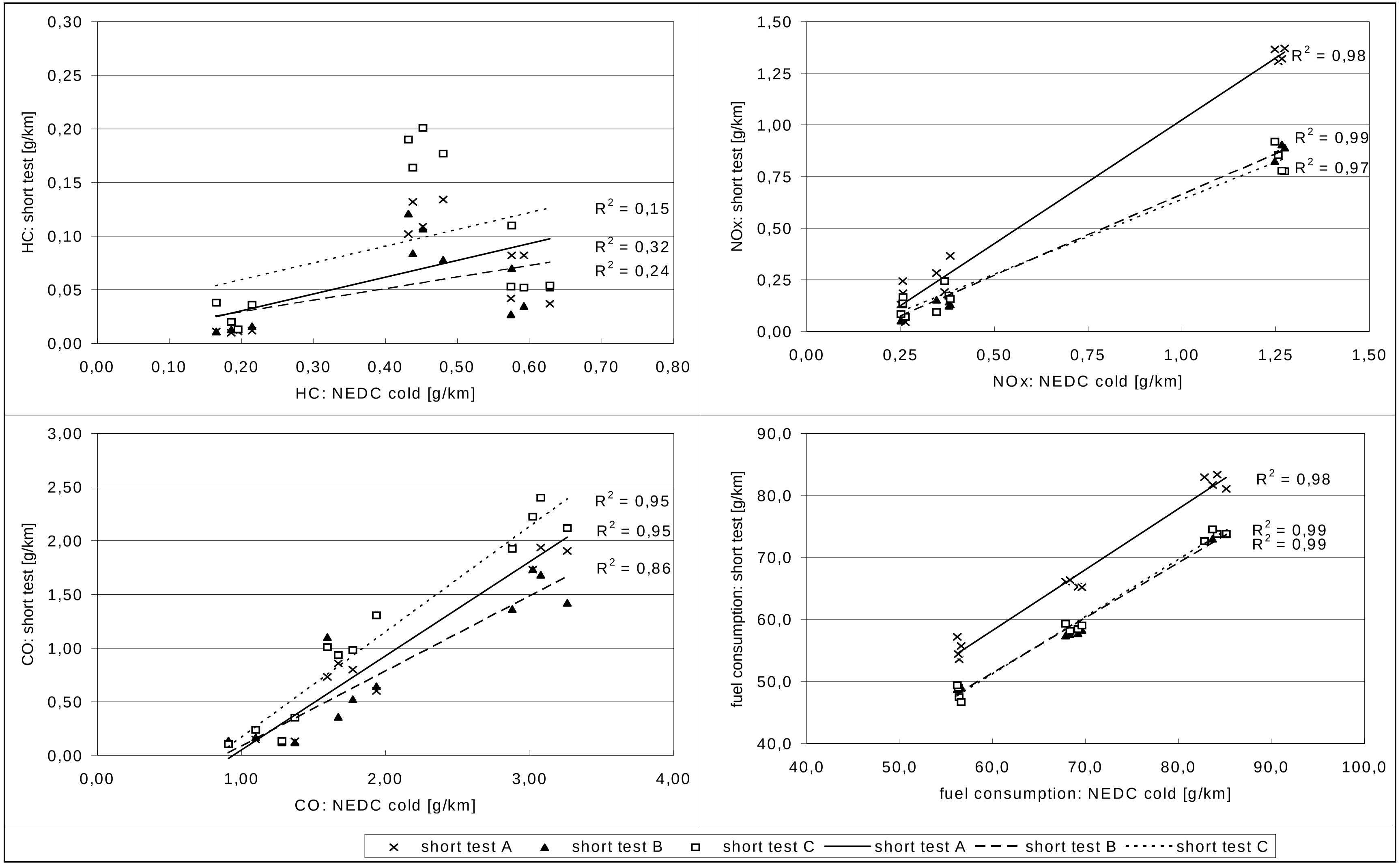


Fig. 9: Correlation between short test results and results in the cold NEDC for HC, CO, NO_X and fuel consumption

2. Short driving cycle based on the European real driving (*modem* short cycle)

2.1 -Introduction

With the aim of defining typical vehicle real-world operating conditions, a database on actual vehicle use has been built-up (EEC research programme, DRIVE[3] - *modem*[4] , see also [4] and [5]). An experimental study was carried out by INRETS in France, TÜV-Rheinland in Germany and TRRL in Great Britain, using 58 privately-owned vehicles, equipped with a data-acquisition system to record their operating conditions at one second time intervals. Measurements were performed using an on-board data recording system on 60 privately-owned vehicles, from 3 European countries, and driven for their normal uses by their owners.

As regards the definition of a inspection procedure to test the emissions of in-use passenger cars, it has been proposed to used this database in order to develop a short driving cycle based on real driving and should be as representative as possible.

Data collection and specific analyses required for this study are summed-up in appendices 1 and 2. The method and concepts developed and used within the DRIVE-modem research are described more in detail in [6].

From the analyses of distributions derived from in-actual-use data, the probable ranges of various parameters are defined: duration, length, number of kinematic sequences of each type, average speed, stop rate, and idling relative duration. Simulations are then processed according to the pre-defined criteria, allowing the construction of a short driving cycle, representative of the European traffic and derived from real driving data.

2.2 - Preliminary considerations for the construction of a short driving cycle

2.2.1 - Representativity

The main initial reason for the construction of a transient short driving cycle, based on real driving, was to use a representative driving cycle, in order to measure realistically the pollutant emissions during a trip.

It has been shown in other studies, that the ECE driving cycle poorly represents the actual driving conditions, and that was already demonstrated in 1978, through experimentation conducted by the European Car Manufacturers themselves (see [7]).

More recently, it was shown that the ECE (Urban or Urban + Extra-Urban) driving cycles, and the FTP75 Driving cycles are not representative of the typical European Urban Driving (see [8]):

---

[3] DRIVE: Dedicated Road Infrastructure for Vehicle Safety in Europe - EEC research programme- DG XIII

[4] modem : Modelling of Emissions and Fuel Consumption in Urban Areas - DRIVE Project V1053.- by TRRL (UK), TÜV-Rheinland (FRG), CEDIA (B), INRETS (F)

- as regards their average speed, the FTP75 and (ECE 15 + Extra-Urban) Driving Cycles roughly correspond to European free-urban traffic,

- the FTP75 Driving Cycle has a realistic rate of acceleration and number of speed variations, while both European Driving Cycles have very low rates of acceleration and very low number of speed variations, not representing the actual driving conditions,

- lastly, when examining the overall shapes of the Driving Cycles compared to real driving, both European Driving Cycles are obviously very far from the real driving.

For these reasons, it was decided that such a short driving cycle should be derived from real-world condition recording, and to develop short test cycles reflecting the real world driving behaviour, on the basis of the DRIVE-modem data collected.

2.2.2 - Main orientations

The following objectives were contemplated for the definition of the short cycle:

1 - to focus on "central", representative trips, in order to define the average characteristics that a short cycle must meet,

2 - to keep in mind that these average characteristics have to concern a relatively high number of real trips (and do not correspond to extreme or marginal cases).

2.2.3 - First criteria

The following elements were firstly into account :

- Cycle duration : the duration of the cycles will be chosen in accordance to the results of the investigation conducted by TÜV on the short cycles, and if possible, in accordance to the statistic observed within the DRIVE-modem data collection ; due also to the test constraints within a real frame of Inspection programme, it is clear that the cycle duration has to be as short as possible, that means, taken into account the existing Inspection programme (in the USA in particular), a duration approximately of 3 to 5 minutes.

- Cycle distance : the distance of the cycle will be determined by the observed statistic distributions.

- Traffic condition : Due to the above constraints of duration and distance, and taking into account the observed statistics, it seemed to be better to built a driving cycle representing mainly the urban conditions (urban trips), but as the cycle has to reflect the real-world traffic, extra-urban conditions not excluded, the cycle will be constructed, by trying to integrate both urban and extra-urban conditions.

A short cycle should be composed by a small number of kinematic sequences representing the various types of traffic conditions.

2.2.4 - Other aspects

The works conducted as part of the DRIVE-modem research have allowed the characterisation of traffic conditions through the analysis of the kinematic sequences, and the characterisation of the trips as regards their distance, duration, and composition in sequence types. It was proposed to use this database and statistics to determine the average characteristics for a short Driving Cycle, and to build-up it.

Many short test cycles should be proposed, so that a comparison and a selection will be possible. The speed curve will be probably smoothed to eliminate some peaks. It should be possible to limit the maximum accelerations, so that all the cars will be able to follow the cycle.

Gear ratio change: it will not be possible to use different gear ratio for each car tested. The algorithm developed within DRIVE-modem should be used to simulate the gear ratio change, according to the observed driving patterns. Taken into account the short duration of the test cycles, the tools should require some improvement, in order to select gear ratio representing the most used strategies. The algorithm should be used many times, in order to determine range, or interval, in which the gears will have to be changed. Other possibilities are to use gear ratios as they were recorded, and / or to define and adjust them through preliminary tests.

2.3 - Average parameters that a short driving cycle should meet

In order to meet the previous objectives, the following parameters have been considered to define a short driving cycle :

- the trip duration,

- the distance travelled,

- the average speed,

- the idle duration (relative to the total duration),

- the stop rate (relative to the travelled distance),

- the total number of kinematic sequences, including the eventual trip-end idle sequence,

- the numbers of each sequence type (congested and free-flow urban, road and motorway types).

The average parameters have been calculated over the whole groups of trips (see Table 2), as well as intervals to define probable ranges for each parameters, when we exclude the extreme trips in both sides of the distributions. Two possibilities were contemplated:

- the interval 25 - 75% of the distributions of the trips as regards one variable (i.e. we selected the central 50% portion, by excluding roughly 20 to 25% on both sides of the histogram, in order to get a central range of variation of the variable),

- the most probable range, defined by limits on both sides of the top portion of the histogram (i.e. the portion for which maximum probabilities were observed).

	urban trips	road trips	motorway trips	all together
Average duration (min)	9	13	57	12
interval 25 - 75% (min.)	2 - 12	6 - 16	30 - 75	4 - 14
probable range (min.)	0 - 8	4 - 12	20 - 40	0 - 10
Average length (km)	4.3	9.5	76	8.7
interval 25 - 75% (km)	0.8 - 4.5	3 - 11	30 - 100	1 - 7
probable range (km)	0 - 3	2 - 6	> 20	0 - 3
Average Speed (km/h)	29	44	80	43
interval 25 - 75% (km/h)	14 - 26	30 - 46	57 - 90	18 - 36
probable range (km)	12 - 27	27 - 39	> 60	15 - 33
Idle duration (in %)				
interval 25 - 75%	16 - 33	7 - 18	0 - 6	10 - 28
probable range (%)	15 - 30	3 - 18	0 - 10	6 - 18
Stop rate (stop / km)				
interval 25 - 75%	2 - 6	0.3 - 1	0 - 1	0 - 4
probable range	0 - 6	0 - 1.5	< 2	0 - 4
Average number of sequences per trip, and probable range for each sequence type				
- class 1 (congested urban)	2.5 [0-3]	0.8 [0-2]	1.6 [0-3]	2.0 [0-3]
- class 2 (free-flow urban)	3.3 [0-4]	1.9 [0-3]	2.0 [0-4]	2.7 [0-3]
- class 3 (road conditions)	0.5 [0-1]	2.0 [1-3]	1.6 [0-3]	1.0 [0-2]
- class 4 (motorway conditions)	0.0 [0-0]	0.0 [0-0]	1.2 [1-2]	0.1 [0-0]
- trip-end idle sequence	0.8	0.8	0.8	0.8
total	7.1 [1-6]	5.4 [1-6]	7.2 [2-10]	6.5 [2-6]

Table 2 : average characteristics and their probable ranges according to the 3 trip groups obtained by classification

These ranges are given Table 2. All trips being considered, we can see that the duration ranges are 4 to 14 minutes (central 50% portion of the trips ranges), or 0 to 10 minutes (most probable range).

We can so consider that a trip with a duration of 3 to 5 minutes is not the most "central" one, but has a good level of probability.

Rather than consider the distributions of each of the parameters, individually, and in order to focus on the most central trips (all parameters being considered simultaneously), the results of the factorial analysis have been used. In fact, the Factorial Analysis is based on the distances between the trips and the gravity centre of the sample, and integrating the various initial variables of the analysis . Using this distance, calculated for each trip, it is possible to consider the most central portion of the trips, by selecting trips for which the distance is below a certain limit. In this case, we have considered the 65% central portion of the trips, and then, we have established the average parameters and their probable ranges (interval 25-75%).

On the other hand, in order to focus on trips for which duration is in the order of 3 to 6 minutes, to know accurately what are their characteristics, the same exercise was done, when considering only these trips. The average parameters as well as their probable ranges are shown in Table 3.

	all together		65% central portion		3 to 6 min. trips only		Most probable characteristics
Average duration (min)	12		12		4.4		
probable range (min.)	0 - 10		2 - 9		3 - 6		[3 - 5]
Average length (km)	8.7		6.9		1.8		
probable range (km)	0 - 3		0 - 3		0 - 3		[1-3]
Average Speed (km/h)	43		34		25		
probable range (km/h)	15 - 33		18 - 32		18 - 30		[20-30]
Idle duration (in %)			21		21		
probable range	6 - 18		10 - 28		4 - 24		[10-30]
Stop rate (stop / km)			1.2		2.1		
probable range	0 - 4		0.5 - 2.5		0.5 - 2.5		[1-5]
Average number of sequences and probable range for each type per trip							
- class 1 (congested urban)	2.0	[0-3]	2.4	[0-3]	1.0	[0-2]	[1]
- class 2 (free-flow urban)	2.7	[0-3]	3.7	[1-5]	1.7	[0-3]	[2]
- class 3 (road conditions)	1.0	[0-2]	1.2	[0-2]	0.4	[0-1]	[1]
- class 4 (motorway conditions)	0.1	[0-0]	0.0	[0-0]	0.0	[0-0]	[0]
- trip-end idle sequence	0.8		0.9		0.8		[1]
total	6.5	[2-6]	8.2	[3-7]	3.9	[2-5]	[5]

Table 3 : average characteristics and probable ranges, established for

- all the trips

- the 65% central portion of the trips (all trip types being considered)

- the 3-6 min. duration trips (all trip types being considered)

Lastly, the intervals were improved as shown in the last column of Table 3, to define the parameters of the simulations, taking into account in particular the cross distribution between duration and number of each sequence type.

2.4 - Representativity of a short driving cycle

As described before, we can notice the following points concerning the representativity of the short cycle :

- this cycle is not an average or medium trip, but it corresponds to a relatively high number of trips,

- the cycle is composed of a low number of sequences (5 in all). For this reason, it does not represent the great variety of driving patterns,

- the cycle is composed of real sequences and so it looks like real driving,

- this cycle does not include any motorway kinematic sequence, but it includes a road sequence,

- as this road sequence has to be short (due to the total sequence number of the cycle), a particular attention concerns this sequence : in fact, short road sequences have often low speeds and are closed to urban sequences. Consequently, the final cycle will be chosen so that its road sequence has a sufficient level of average speed (at least 40 km/h). In this manner, it is possible to integrate extra-urban conditions within a short cycle.

- lastly, because of the very short duration of the cycle and of the previous considerations, it is not recommendable to share such a cycle in two parts (urban and extra-urban) and to consider that both parts are representative of their respective traffic conditions, or to extrapolate results using the respective mileage shares given above. Such a cycle can be considered realistic as it represents real driving and has a certain level of probability amongst the recorded trips.

2.5 - Simulation of a short Driving Cycle

Taken into account the previous results, the Driving Cycle simulation data was processed using the following criteria:

- trips were considered amongst the total group of 7600 trips, including urban and non-urban driving,

- the kinematic sequences of all the trips were considered ; their statistics and rules of successions were established for the whole group,

- the generation of the cycle resulted from the random selection of sequences satisfying the rules of successions and other statistic data,

- the cycle obtained had to satisfy simultaneously the previous criteria, so that its characteristics are very close to the average values obtained previously, in particular, it had to be composed by 1 congested urban sequence, 1 or 2 free-flow urban sequences, and one road sequence.

Simulation data was processed, giving 4 sets of 20, 11, 19 and 30 simulated trips, very close to the average characteristics contemplated. The average characteristics obtained with the set of simulated trips are given in Appendix 3. Typical trips are illustrated in Appendix 4, giving an idea of what such trips are really.

A representative driving cycle was selected within these simulations taking into account the following criteria :

- first of all, we tried to choose a cycle with an average speed in the order of 25 km/h, but for these trips the speed of the road sequence was relatively low, so the cycle was chosen with an average speed level of 30 km/h, allowing an average speed of 40 km/h for the road sequence,

- other variables were examined: acceleration rate (in the order of 0.8, not more because of the difficulty for small cars to reproduce to high level of acceleration), the maximum speed (70 km/h), the speed and acceleration histograms: these parameters were chosen to be close to the average values obtained on the whole sample of simulated trips, and not marginal,

- the idle rate (close to 20%) and stop rate (2 stops/km), duration (4.4 min.), and distance (1.8 km) were selected to be as close as possible to the average characteristics calculated for the trips ranging from 3 to 6 min. (see Table 3).

- lastly, the cycle satisfying these criteria were carefully displayed, in order to avoid those presenting portion that could be very difficult to reproduce on a chassis dynamometer.

The most satisfying cycle has the number 57 in the simulation called : S4.

As this cycle had a too high level of idle, the idle duration has been decreased by 15 seconds. As the congested urban sequence was to difficult to reproduce it was replaced by another equivalent, resulting from similar simulation. The final average characteristics are given Table 4, as well as the corresponding characteristics of Standard Driving Cycles, including the New-York City Cycle (NYCC). This driving cycle is illustrated in Appendix 5. The second by second form is given in Appendix 6.

Cycle	duration (min)	distance (km)	stop duration (min)	sequences number /km	average speed (km/h)	running speed (km/h)	acceleration rate (m/s2)	stop duration in %
modem short cycle	**4.25**	**2.230**	**0.95**	**2.2**	**31.4**	**40.3**	**0.80**	**22.2**
ECE R15 Urban DC	13.0	4.06	4.2	3.0	18.7	27.7	0.52	31
ECE 15 Urban + extra urban	19.7	11.01	4.7	1.3	33.6	44.1	0.42	24
FTP 75	31.4	17.69	6.3	1.2	33.9	40,0	0.69	20
NYCC	10.0	1.8		3.6	11.4			39

Table 4 : Average characteristics of the modem short driving Cycle (ref. 57.S4) derived from real-world driving conditions, and comparison with 4 European and American Standard Driving Cycles

2.6 - Other considerations

The software available to calculate the gear ratio automatically (cf. [6]) has not been used here. This tool is particularly well adapted when specific gear changes are required for each type of cars, depending on their characteristics (power, weight, etc.).

In this particular study, gear changes are required, which are not dependent on car specifications.

In a first approach, the recorded actual gear ratios are associated to the speed curve (see Appendix 5). It is proposed to adjust them so that they could be used with most of the cars.

In the same way, the speed curve could be slightly adapted (fitting, etc.) so that all the cars could follow it. Further analyses and tests on a chassis dynamometer should allow determining whether it is necessary or not to limit the level of the accelerations and decelerations, as it has been done for the FTP procedure for instance.

The Driving Cycle as well as the gear ratios could be provided on a second-time-interval basis in ASCII form.

3. Preliminary comparison between the short cycles

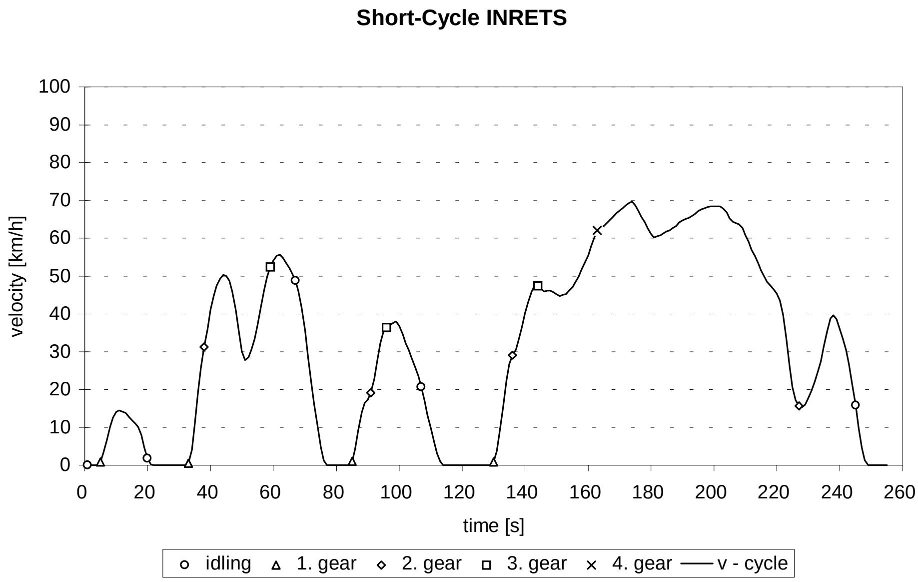
Preliminary comparison between the TÜV short cycle (based on the type approval test, cf. chapter 1) and the MODEM short cycle (which reflects real world conditions, cf. chapter 2) has been conducted through a test programme for the measurement of the pollutant emissions of a single vehicle described in Table 5.

Table 5: *Technical data of the test vehicle for the comparison of the short cycles*

vehicle type	displacement [l]	power [kW]	weight [kg]	no. of gears	year of production	km-driven
VW Golf	1,80	66	928	5	1987	62639

The test programme included the following cycles: NEDC, short cycle A and MODEM short cycle. The measurements in each cycle were repeated four times.

Fig. 10 contains the speed curve of the MODEM short cycle together with a table which shows the deviation of specific parameters to the comparable values of the NEDC.



Deviation to NEDC [%]	
duration	-78
distance	-80
maximum velocity	-42
mean velocity	-6
maximum acceler.	124
maximum v*a	90
minimum v*a	-26
mean v*a	175
idling	-31
constant velocity	-95
SD v	-22
SD a	66
SD v*a	42

Figure 10 : MODEM short cycle and the percentage of deviation of the statistical parameters between MODEM cycle and NEDC

The measurements for the MODEM short cycle were performed with one vehicle. Fig. 11 shows the average emissions and the average fuel consumption in connection with the standard deviation in each cycle. Compared to the results in short cycle A the CO- and NO_X emissions and the fuel consumption in the MODEM short cycle are significantly higher because of the more transient driving behaviour expressed by the very high mean v·a and the standard deviation of v·a. The mean NO_X emission is 75 % higher than in the NEDC with cold start.

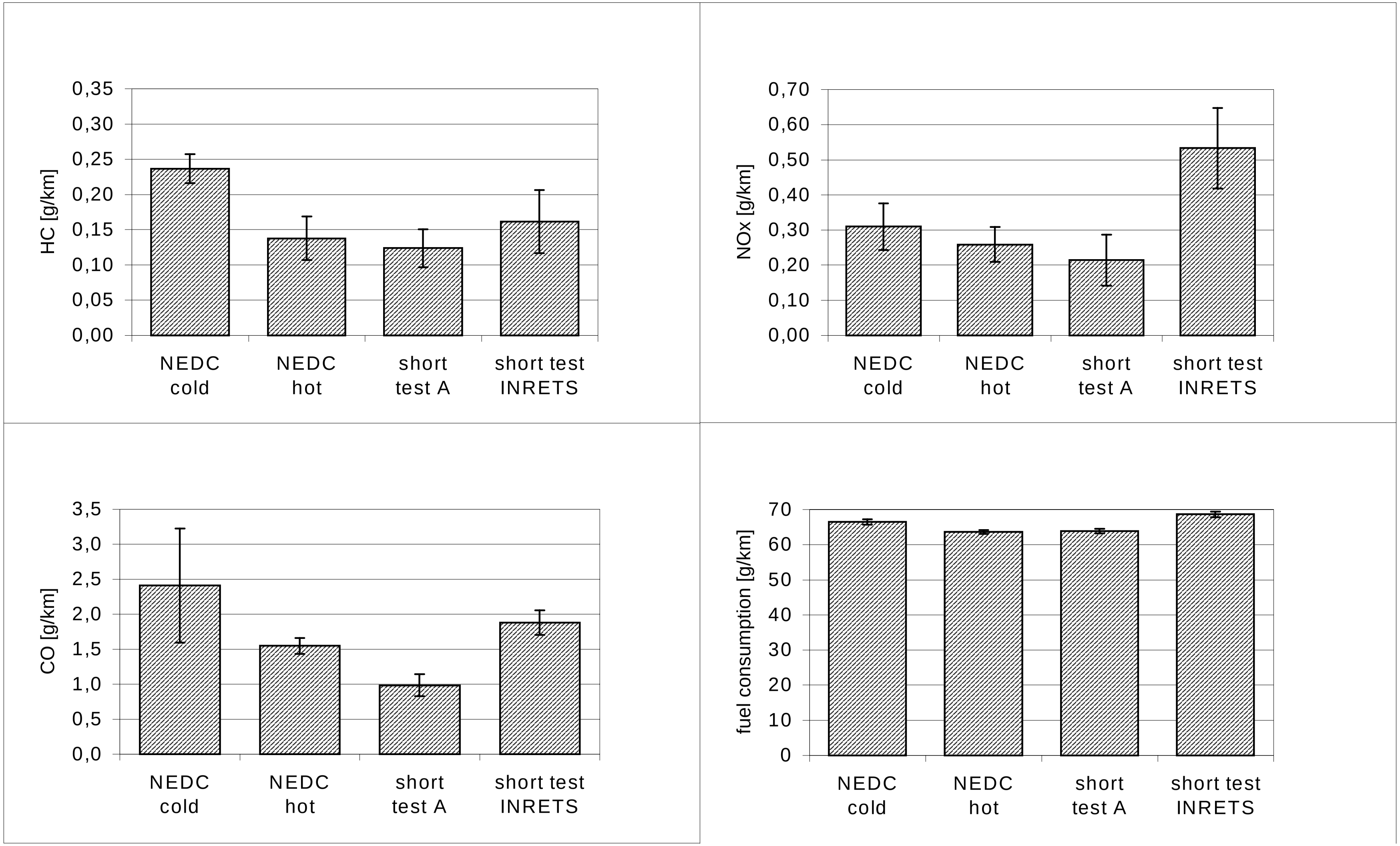


Figure 11 : Average emissions and average fuel consumption in different cycles for the vehicle VW Golf

4. Reference driving cycles based on the European real driving (*modem* cycles)

4.1 - Introduction

The objective of this task was to constitute a full set of driving cycles, representing urban and extra-urban European driving, in order to measure "the reference" of the actual exhaust emissions. It is based on the DRIVE-modem data and on the kinematic concepts developed within this project : characterisation of traffic conditions into 4 classes, classification of the trips (urban, road and motorway trips), as described in [6] and recapitulated in appendices 1 and 2. It was assumed that the total duration of test should not exceed 30 min.

Various assumptions have been contemplated:

- 3 cycles, representing urban, road and motorway conditions,
- 2 cycles, representing urban and extra-urban conditions,
- to re-use one of the 14 DRIVE-modem urban cycles
- to adapt and use a software for the automatic calculation of the gear ratio, depending on the car characteristics [6].

4.2 - Urban driving

The whole set of trips recorded and identified as urban through the characterisation of the driving condition, include congested traffic and free-flowing urban traffic. For this reason, the average characteristics are relatively "easy" (29 km/h on average with a probable range from 14 to 26 km/h, see appendix 9). An urban driving cycle built-up taken into account these average statistics won't meet the specific congested traffic conditions. In order to avoid that, it is proposed to find out a partition of the urban trips, that reflects both urban conditions : congested and non-congested. That means that 2 urban driving cycles will be required to describe the urban situation.

Clustering, as applied within the DRIVE-modem project, enabled the determination of three typical groups of trips (urban, road, motorway). The same tools allow at the next step to separate urban trips into 2 groups. Due to the method used (dynamic clustering), the two urban sub-groups do not exactly represent the initial urban group (some of the trips initially affected to the urban group, are not affected in one of the 2 urban sub-groups, and reciprocally), and that led to some minor modifications of the urban statistics. For this reason, the trips initially considered as urban and not belonging to an urban sub-group have not been considered (That distortion concerns 2 trips only).

The already built-up DRIVE-modem urban cycles have been analysed as regards their main kinematics parameters and compared to the statistics parameters obtained for the two groups of trips : congested and free-flow urban. As this comparison was not totally satisfying, it was decided to develop 2 specific cycles and to use none of the existing 14 urban cycles derived from DRIVE-modem.

4.3 - Extra-urban driving

The statistics calculated over road and motorway trips show that these 2 groups are to much different to be considered as a unique group and to develop only one cycle representing both groups (see appendix 7). Consequently, two driving cycles were required to describe separately road and motorway conditions.

4.4 - Method

The main steps of the method are briefly recapitulated hereafter :

- **classification of the trips into 4 classes** : taken into account the concepts from DRIVE-modem, and the initial clustering into three typical groups of trips (urban, road, motorway), the same tools has allowed to separate urban trips into 2 groups. Average characteristics of the resulting and probable range of the parameters of the 4 classes of trips are given in appendix 9.

- **selection within the 4 groups** : in order to avoid extreme trips, some selection were tested and applied for each trip group. For road and motorway trips, 5% of the extreme trips as regards their length and their average speed were eliminated (representing respectively 16% of the road trips number, and 30 of the road mileage, and 16% of the motorway trip number, and 27% of the motorway mileage). In the same way, the 5% longer of all the urban trips were eliminated. As the 2 urban sub-groups were not sufficiently differentiated as regards their average characteristics, a dysymetric selection was made as regards their speed : the 5-75% interval for the average speed distribution was considered for the congested urban trips, while the 25-95% interval was considered for the free-flowing trips. By this way, it was possible to differentiate sufficiently the two sub-groups.

In all, the above selection led to consider 68% of the recorded trips (59% of the mileage). Between 55 and 84% of the trips were considered for each of the four trips categories to assess the statistic parameters that should be met by the cycles (see appendix 7, A7.2).

- **statistics calculation** : over the 4 predetermined trip groups, some characteristics have been calculated in order to define the most pertinent characteristics of the corresponding driving cycles. These characteristics were : duration, distance, average speed, idle duration, stop rate and the probabilities of kinematic sequences of each type. These parameters were described by their average values over the whole group but also by their most probable range (when examining the distribution of the values) and by the interval 25-75% of the distributions.

- **simulation parameters** : from the previous calculations, the simulation parameters have been determined accurately for each type of driving cycle to be simulated : the exact number of sequences of each type was determined as well as a narrow range for the total cycle duration, length, average speed, stop rate and idle duration (see appendix 7, A7.2).

- **simulation** : with the previous parameters, and using the simulation tools developed for DRIVE-modem and adapted for this project, 10 to 20 driving cycles have been simulated for each of the different trips type. The final selection was conducted mainly from the kinematic parameters and from the displaying of the speed profiles. From that point of view, it was shown that, even with close parameters, the driving cycles could vary in their appearance. Unfortunately, we cannot know if the very arbitrary final choice has a determining influence on the pollutant emissions. This influence could be assessed using an instantaneous emissions model such as the "*modem*" software.

- **grouping of the free-flow urban driving cycle and the motorway one**: according to the pre-determined statistics, a typical motorway trip consists in some urban sequences followed by one or two motorway sequences. The motorway driving cycle was simulated according to this rule. But in order to minimise the total test duration, it was possible to substitute the first part of the motorway driving cycle by the free-flow urban driving cycle.

The 4 driving cycles are available in an ASCII form and are provided in appendix 8.

4.5 - Gear use software for automatic determination

Taken into account that this driving cycle will be used to establish the reference of the actual exhaust emissions, it seemed necessary to adapt gears for each car, depending on its technical characteristics in order to get the more realistic driving conditions.

That implied some adaptations of the software developed within DRIVE-modem, as it did not concern extra-urban conditions.

The following steps have been conducted:

- **calculation of the gear change statistics over the whole DRIVE-mode data collection**: previously, these statistics were established over the urban driving conditions. They have been processed over the whole quantity of data. These statistics were calculated separately for the 4 gears vehicles, and for the 5 gears vehicles, and consist in probabilities tables for each combination : initial gear - final gear. These tables concern the gear change duration (dimension 21), and the "engine speed - acceleration" matrix (dimension 20x21) at which the gear changes occur. These last variables were converted into non-dimensional form, as regards the vehicle characteristics. That represent roughly 30 matrix 20x21 for the 4-gears vehicles, and 36 matrix 20x21 for the 5-gears vehicles.

- **selection** : as the total duration of test (driving cycles) is very short as compared to the initial data collection, it was necessary to filter the statistics tables, in order to avoid rare situations. For that, all the situations that did not occur at least 20 times during the data collection were eliminated. As some mis-functionning were observed in some situations for which no statistics were found (function of the speed profile and of the vehicle characteristics), due to a too severe filtering of the initial statistics, this filtering level has been slightly decreased.

- **adaptation of the software** : the software required some modifications: to take into account the new driving cycles, to take into account the new statistics. Some other improvements have been done, such, as the language selection through files selection (that means that an other language can bee implemented without compilation), and the structure of the application, with data files, etc. And finally, the software was adapted and compiled for PC - MSDOS usage and made available to the partners that conduct emissions measurements.

4.6. Average characteristics of the real driving cycles and weighing

The main characteristics of the four reference actual driving cycles as well as the short actual driving cycle have been recapitulated in Table 6. The corresponding statistics for the different trips classes are provided in appendix 7.

The total mileage represented by each of the trip classes correspond normally to the weight of the respective driving cycles (see Table 7, 1st column). Due to the simplification in order to

decrease the total test duration, the motorway driving cycle is then limited to the motorway part of the motorway trips (i.e. the motorway sequences). We can see in Table 7 that the difference in weights between motorway trips and kinematic sequences is rather limited, and so, the weights of the trip classes are kept unchanged and used for corresponding driving cycles.

The only way to correct that limited discrepancy should be to consider the end-part of the free-flow urban driving cycle (i.e. from second 231 to 360) and to include resulting pollutant emissions in the motorway test results. Then, the resulting test cycle would be closer to the motorway trip class as regards its kinematic parameters (see table 6) and could be affected by the weight of the motorway trips class.

	duration (s)	distance km	average speed (km/h)	running speed (km/h)	stop duration (s)
IMODEM SHORT CYCLE	255	2,246	31,7	39,6	51
IMODEM CONGESTED URBAN	428	1,705	14,3	20,9	134
IMODEM FREE-FLOW URBAN	355	2,248	22,8	28,5	71
IMODEM ROAD	712	8,485	42,9	49,6	96
IMODEM MOTORWAY	452	12,683	101,0	103,5	11
FREE-FLOW URBAN + MOTORWAY	*807*	*14,930*	*66,6*	*74,1*	*82*
** FREE-FLOW URBAN + MOTORWAY (from 231 to end)*	*576*	*13,525*	*84,5*	*91,2*	*42*
	stop number	**stop duration (%)**	**stop /km**	**average acceleration (m/s2)**	**standard dev. acceleration (m/s2)**
IMODEM SHORT CYCLE	5	20,0	2,23	0,84	0,69
IMODEM CONGESTED URBAN	8	31,3	4,69	0,74	0,55
IMODEM FREE-FLOW URBAN	7	20,0	3,11	0,81	0,70
IMODEM ROAD	5	13,5	0,59	0,84	0,67
IMODEM MOTORWAY	2	2,4	0,16	0,72	0,46
FREE-FLOW URBAN + MOTORWAY	*8*	*10,2*	*0,54*	*0,77*	*0,58*
** FREE-FLOW URBAN + MOTORWAY (from 231 to end)*	*5*	*7,3*	*0,37*	*0,81*	*0,57*

Table 6 : Average characteristics of the Driving Cycle derived from real-world driving conditions

	weight of the trip classes and of the corresponding driving cycles in % of distance	*weight of the kinematic sequence classes in % of distance*
CONGESTED URBAN	**17,4**	*2,2*
FREE-FLOW URBAN	**12,4**	*15,7*
ROAD	**40,5**	*49,6*
MOTORWAY	**29,7**	*32,6*
	100,0	*100,0*

Table 7 : Weighing of the four reference Driving Cycles derived from real-world driving conditions

Conclusions

Short driving cycles have been built-up for the inspection of the in-use vehicles. One is based on the type approval test (TÜV short driving cycle), the aim being that pollutant emissions measured during such a procedure correlate well with the emissions values measured using the existing vehicle homologation procedure. Preliminary emissions measurement have allowed to validate on a certain extent this cycle.

The second cycle (*modem* short driving cycle), based on the actual European driving, is proposed to have a better measurement of the on-the-road pollutant emissions. This short driving cycle corresponds to a relatively high number of recorded trips. It is composed of 3 urban and one road real kinematic driving sequences plus an end-trip idle sequence. By this way, the cycle includes urban and extra-urban conditions but the motorway driving is not covered.

Using the same database and the same method, reference actual driving cycles have been developed to characterise the actual pollutant emissions corresponding to four typical driving situations : the congested and free-flowing urban driving, the road driving and the motorway driving. A simulation software allows to determine realistically the gears to be used during the tests as a function of the vehicles characteristics and the observed driving behaviour. The four driving cycles (*modem* driving cycles), associated with the simulation software constitute a very representative test basis, for the assessment and efficiency measurement of various inspection procedures, of which the transient tests using the previous short driving cycles.

References

[1] TÜV Rheinland: Das Abgas-Emissionsverhalten von Personenkraftwagen in der Bundesrepublik Deutschland im Bezugsjahr 1985. UBA-Forschungsbericht 104 05 143. UBA-Berichte 7/87, Erich Schmidt Verlag, Berlin

[2] P. Jost; D. Hassel; F.-J. Weber; K.-S. Sonnborn: Emission and Fuel Consumption Modelling Based on Continous Measurements. Deliverable No. 7 of the Drive Project V 1053 "Modelling of emissions and consumption in urban areas - MODEM", May, 1992

[3] TÜV Rheinland: Abgas-Emissionsfaktoren von Pkw in der Bundesrepublik Deutschland. Abschlußbericht des UBA-FE-Vorhabens 104 05 152. Dezember 1993. UBA-Berichte 8/94, Erich Schmidt Verlag, Berlin

[4] R. Joumard, A.J. Hickman, J. Nemerlin, D. Hassel. Modelling of emissions and consumption in urban areas - final report. DRIVE-modem project V1053. INRETS report LEN9213, Bron, France, 54p. 1992

[5] M. André, R. Joumard, A.J. Hickman, D. Hassel. Realistic Driving Cycles for passenger cars - Modelling of emissions and consumption in urban areas. DRIVE-*modem* project V1053. September 1991. INRETS report: LEN9105, 29 p., Bron, France.

[6] M. André, A.J. Hickman, D. Hassel, R. Joumard. Driving cycles for emissions measurements under European Conditions. SAE Technical Paper, SAE International Congress & Exposition, February 1995

[7] M. Kuhler, D. Karstens. Improved Driving Cycles for Testing Automotive Exhaust Emissions. Volkswagen AG, Germany. SAEP 780650, 1978.

[8] M. André. Statistical elements for the definition of a new European Evaporative Emissions Control Procedure; diurnal test conditions and Urban Driving Cycle. Study for the European Commission, DGXI, November 1994. INRETS report LEN9434, 49 p. Bron, France.

Appendices

Appendix 1 - The DRIVE-*modem* data base **39**

Appendix 2 - Characterisation of the European Driving - basic elements **41**

Appendix 3 - Kinematic parameters of simulated short driving cycles **45**

Appendix 4 - Typical simulated short trips **48**

Appendix 5 - Proposal for a short transient driving cycle, derived from real driving data (modem short cycle) **51**

Appendix 6 - Short transient driving cycle (*modem*) - second by second form **53**

Appendix 7 -Average characteristics of the different trip groups and simulation parameters **55**

Appendix 8 - Proposal for reference transient driving cycles, derived from real driving data (modem cycles) **57**

Appendix 9 - Reference driving cycles - second by second form **59**

Appendix 1 - The DRIVE-*modem* data base

The basic principle of this DRIVE-*modem* study was the observation of use and operating conditions of vehicles, driven for their normal purposes by their owners. With this aim in view, privately-owned vehicles were equipped with sensors and data-acquisition systems to record at each second the main parameters of vehicle operation. They were then returned to their owners who used them normally.

Vehicles were selected in 6 European cities, to describe a great variety of urban traffic conditions: London and Derby in the UK, Cologne and Krefeld in Germany, Marseilles and Grenoble in France. The vehicle models were selected to describe at best the vehicle fleets in operation in each country, according to their popularity, age, mileage, technology (engine capacity, power, type: petrol, diesel, injection, catalyst, etc.). The vehicles to be tested were finally selected by random sampling from an address list of owners of the selected models, in the relevant geographical areas, and then according to some criteria of representativity and variety: age, sex, driver's professional and marital status, and annual mileage.

The vehicles were then equipped with data acquisition systems (data logger placed in the rear boot and sensors under the bonnet). The main parameters of vehicle operation were recorded at one second time intervals: date and time, vehicle speed, engine speed, throttle position, fuel consumption, engine and ambient temperatures, use of auxiliary equipment such as wipers, brake, choke. The vehicles were used for their normal purposes by their owners for periods of about one month. A total of 58 vehicles were successfully tested. These measurements represent 1 580 days of vehicles monitoring. A total of 8 230 trips have been correctly recorded and represent 73 300 kilometres travelled, for a driving duration of 1 690 hours (Table A1.1). The DRIVE-modem database concerns only the passenger cars for private use (no commercial cars, no lorries).

	number of vehicles	monitoring duration (days)	trip number	driving duration (h)	distance (km)
Germany	19	556	3 124	642	33 020
France	21	638	3 243	670	24 680
Great-Britain	18	384	1 861	376	15 590
Total	58	1 580	8 228	1 690	73 280

*Table A1.1: Results of the different experimental studies (DRIVE-*modem* V1053 Research Project)*

Appendix 2 - Characterisation of the European Driving - basic elements

The main elements of the method are summed in Ref. 6, and are briefly recapitulated hereafter. The specific steps for the construction of a short driving cycles are given next.

The method used consisted in analysing the vehicle speed curve as a function of time and in highlighting the standard characteristics of this curve as a function of traffic conditions. Trip sections (or kinematic sequences) between two successive vehicle stops (beginning or end of the trip, intermediate stops, etc..) were considered. Such a distribution assumed that traffic conditions were relatively homogeneous within a prescribed sequence while they could be very heterogeneous during the whole trip due to the succession of varied sequences.

Four typical classes of kinematic sequences, corresponding to urban, congested urban, road and motorway traffic conditions, were identified using classification tools.

After the characterisation of the traffic conditions through the kinematic sequences, the trips were analysed taking into account their duration, length, and structure and composition in terms of kinematic sequences. In a similar way, factorial analyses and clustering enabled us to determine three typical groups of trips (urban, road and motorway trips).

Using the statistical description and the characterisations of the sequences and trips, it was possible to build-up Driving Cycles representative of the actual driving conditions, or specifically representative of urban or extra-urban traffic (see Fig. A2.1).

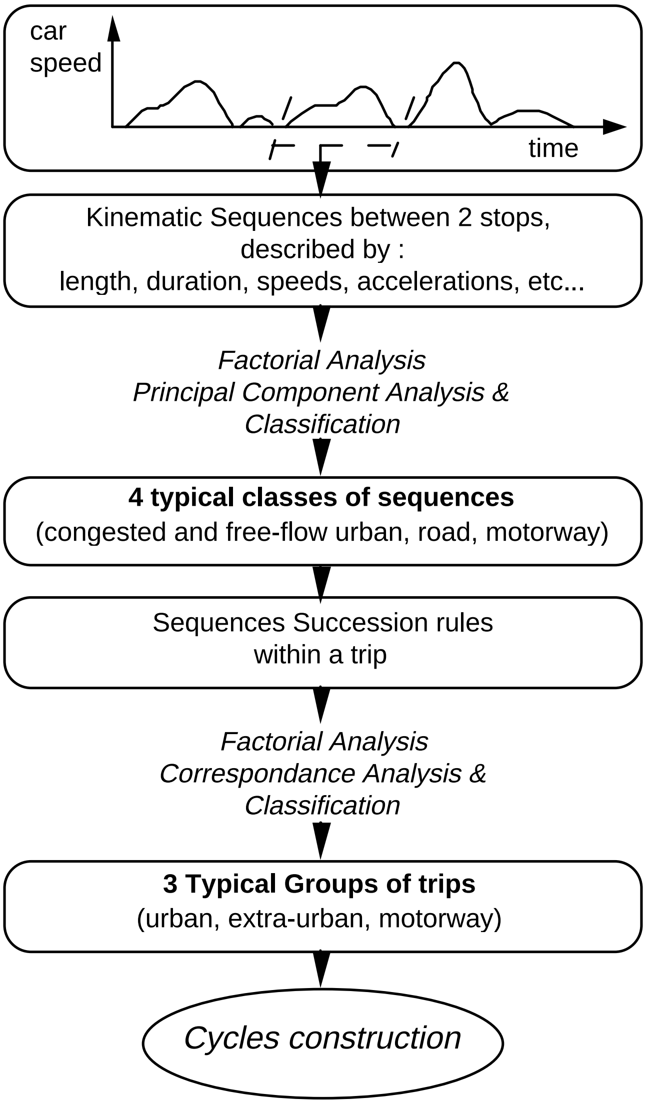
Table A2.1 recapitulates the average characteristics of the different classes of kinematic sequences, i.e. the traffic conditions. Table A2.2 illustrates the average characteristics of the three main groups of trips derived from these analyses.

A simulation tool was developed to draw-up the Driving Cycles, respecting the observed cross distribution of duration and distance and the sequences succession probabilities established for a given trip group, the observed distribution of the class factorial co-ordinates (i.e. roughly respecting the duration, distance, speed and acceleration distributions observed) of a given sequence class (see fig A2.2, for the particular case of urban driving cycles construction).

The resulting cycle consists in the succession of the selected recorded sequences, i.e. the actual speed versus time curves.

Apart from that, a software has been developed allowing the automatic determination of gearbox ratios taking into account the actual driving patterns, and adapted to each vehicle.

Figure A2.1: summary of the analysis



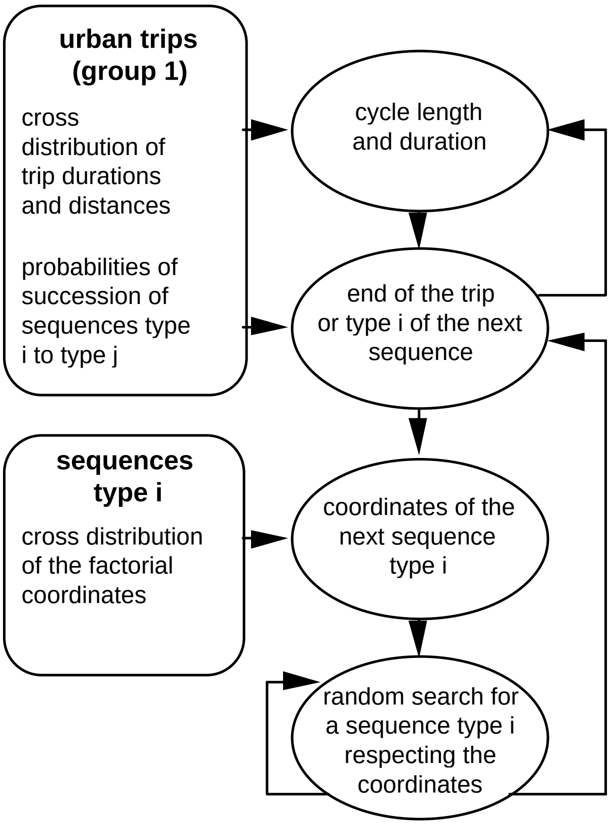
	1 - congested urban traffic	2- free-flow urban traffic	3 - road traffic	4 - motorway traffic	total
number of sequences (%)	35	46	18	1	43783 seq.
% of mileage	2.2	15.7	49.6	32.6	66463 km
% of consumption	7.3	24.0	42.6	26.1	
length (km)	0.09	0.5	4.2	57.7	1.5
duration (min)	0.8	1.4	5.0	37.4	2.1
average speed (km/h)	8	23	51	93	43
nb. of accelerations/km	24	3	0.8	0.2	1
consumption (l/100km)	25.1	12.0	7.1	6.4	7.7

Table A2.1 : Description of the 4 kinematic classes corresponding to traffic conditions

	group 1 urban trips	group 2 road trips	group 3 motorway trips	total
Number of trips	4714	2693	264	7672
Mileage (share in %)	30	40	30	66463 km
Average length (km)	4.4	9.6	75.8	8.7
Average duration (min)	9.0	13.1	56.7	12.1
Average Speed (km/h)	29.3	44.0	80.2	43.1
Average number of sequences of each type per trip				
- class 1 (congested urban)	2.6	0.9	1.7	2.0
- class 2 (free-flow urban)	3.2	1.8	2.0	2.7
- class 3 (road conditions)	0.5	1.9	1.5	1.0
- class 4 (motorway conditions)	0.01	0.003	1.2	0.05
total	7.1	5.4	7.1	6.5

Table A2.2 : comparison of trip groups obtained by classification

Figure A2.2 : flow chart of the driving cycles building up (Urban driving cycles)



Appendix 3 - Kinematic parameters of simulated short driving cycles

Two sets of 20 and 11 driving cycles

Kinematic parameters of 20 simulated short driving cycles (S1)							derived from the European Research Project DRIVE-modem V1053					
Cycle	duration (min)	distance (km)	stop duration (min)	Average speed (km/h)	Running speed (km/h)	Maxi speed (km/h)	Road Sequ. Speed (km/h)	Nber of sequ. per km	Stop rate stop/km	Speed variat per km	idle dur. %	acceleration rate m/s2
s1.001	4,82	2,321	0,65	28,9	33,4	75,1	39,7	2,2	1,7	15,9	13,5	0,87
s1.002	4,85	1,951	1,19	24,1	32,0	56,3	30,1	2,6	2,1	9,7	24,5	0,79
s1.003	5,68	2,575	1,50	27,2	37,0	65,3	44,2	1,9	1,2	12,8	26,4	0,78
s1.004	4,39	2,090	0,87	28,6	35,6	63,5	37,2	2,4	1,4	8,6	19,8	0,80
s1.005	5,79	2,267	1,08	23,5	28,9	64,5	28,7	2,2	1,8	15,9	18,7	0,83
s1.006	5,39	2,464	1,33	27,4	36,4	64,6	33,2	2,0	1,6	8,5	24,7	0,65
s1.007	5,07	2,380	0,88	28,2	34,1	61,7	39,2	2,1	1,7	8,4	17,4	0,85
s1.008	4,34	1,850	1,22	25,6	35,6	61,3	30,1	2,7	2,2	12,4	28,1	0,86
s1.009	4,91	2,012	0,90	24,6	30,1	53,8	27,7	2,5	2,0	9,4	18,3	0,81
s1.010	5,44	2,090	1,54	23,1	32,2	52,2	30,1	2,4	1,9	10,0	28,3	0,64
s1.011	4,38	1,858	1,07	25,5	33,7	59,7	37,3	2,7	2,2	8,6	24,4	0,77
s1.012	5,78	1,889	1,02	19,6	23,8	56,4	25,9	2,6	2,1	15,9	17,6	0,57
s1.013	5,86	2,790	0,92	28,6	33,9	66,3	40,4	1,8	1,4	13,3	15,7	0,63
s1.014	4,11	1,925	0,67	28,1	33,6	59,2	38,1	2,6	2,1	9,9	16,3	0,66
s1.015	5,55	2,412	1,23	26,1	33,5	58,6	33,6	2,1	1,7	14,9	22,2	0,78
s1.016	5,00	2,054	1,16	24,6	32,1	49,0	31,4	2,4	2,0	8,8	23,2	0,60
s1.017	5,59	2,046	1,01	22,0	26,8	67,9	29,9	2,4	1,5	15,2	18,1	0,82
s1.018	4,25	1,813	0,77	25,6	31,3	71,9	36,2	2,8	2,2	12,7	18,1	0,73
s1.019	5,06	2,435	1,22	28,9	38,0	66,2	41,0	2,1	1,6	9,0	24,1	0,58
s1.020	4,01	1,778	0,92	26,6	34,5	56,8	38,8	2,8	2,3	7,3	22,9	0,74
Kinematic parameters of 11 simulated short driving cycles (S3)							derived from the European Research Project DRIVE-modem V1053					
s3.031	3,04	1,387	0,50	27,4	32,8	56,3	33,0	3,6	2,9	11,5	16,4	0,92
s3.032	4,85	1,975	1,43	24,4	34,6	66,8	35,7	2,5	2,0	8,6	29,5	0,70
s3.033	3,38	1,431	0,52	25,4	30,0	59,3	31,8	3,5	2,8	13,3	15,4	0,85
s3.034	4,40	1,537	1,17	21,0	28,6	58,0	26,7	3,3	2,6	15,6	26,6	0,90
s3.035	4,66	1,681	1,07	21,6	28,1	53,6	38,8	3,0	2,4	13,7	23,0	0,84
s3.036	4,54	1,945	1,36	25,7	36,7	76,2	34,7	2,6	2,1	14,9	30,0	0,81
s3.037	4,22	1,926	1,11	27,4	37,2	64,2	34,5	2,6	2,1	9,3	26,3	0,85
s3.038	4,14	1,395	1,24	20,2	28,9	52,1	22,2	3,6	2,2	14,3	30,0	0,69
s3.039	4,21	1,713	0,61	24,4	28,6	64,6	26,3	2,9	2,3	18,1	14,5	1,22
s3.040	4,69	2,210	0,82	28,3	34,3	70,0	33,2	2,3	1,8	11,3	17,5	1,00
s3.041	4,91	2,334	0,50	28,5	31,8	69,4	32,8	2,1	1,7	15,9	10,2	1,02

A set of 19 driving cycles, of which the selected one was issued

Kinematic parameters of 19 simulated short driving cycles (S4) derived from the European Research Project DRIVE-modem V1053

Cycle	duration (mn)	distance (km)	stop duration (mn)	Average speed (km/h)	Running speed (km/h)	Maxi speed (km/h)	Road Sequ. Speed (km/h)	Nber of sequ. per km	Stop rate stop/km	Speed variat per km	idle dur. %	acceleration rate m/s2
s4.051	3,62	1,606	0,69	26,6	32,9	66,8	35,7	3,1	2,5	6,8	19,1	0,72
s4.052	4,62	1,849	0,98	24,0	30,5	51,7	32,7	2,7	2,2	9,7	21,2	0,74
s4.053	3,55	1,452	0,46	24,5	28,2	66,8	29,9	3,4	2,8	13,1	13,0	0,98
s4.054	4,81	2,183	0,64	27,2	31,4	62,0	33,9	2,3	1,8	12,8	13,3	0,84
s4.056	4,52	1,727	0,74	22,9	27,4	49,8	26,0	2,9	2,3	15,1	16,4	0,66
s4.057	4,41	2,200	1,17	29,9	40,7	69,1	41,9	2,3	1,8	5,9	26,5	0,80
s4.058	4,27	1,503	0,92	21,1	26,9	51,9	31,4	3,3	2,7	14,6	21,5	0,79
s4.059	3,56	1,679	0,70	28,3	35,2	62,9	40,1	3,0	2,4	8,9	19,7	0,91
s4.060	4,80	2,182	1,18	27,3	36,2	72,5	35,3	2,3	1,8	7,8	24,6	0,83
s4.061	3,92	1,685	1,01	25,8	34,7	61,7	32,8	3,0	1,8	11,3	25,8	0,87
s4.062	4,83	1,808	1,35	22,5	31,2	48,3	33,9	2,8	2,2	10,5	28,0	0,64
s4.063	4,27	1,911	0,81	26,9	33,1	62,2	35,0	2,6	2,1	17,3	19,0	0,84
s4.064	4,03	1,973	0,60	29,4	34,5	62,0	37,2	2,5	1,5	9,6	14,9	0,61
s4.065	3,88	1,484	1,01	22,9	31,0	51,7	32,7	3,4	2,7	10,8	26,0	0,79
s4.066	4,42	1,481	1,03	20,1	26,2	49,7	37,7	3,4	2,7	18,9	23,3	0,66
s4.067	4,38	1,807	1,19	24,8	34,0	65,1	33,8	2,8	2,2	15,5	27,2	0,67
s4.068	4,59	1,865	0,68	24,4	28,6	62,1	26,8	2,7	2,1	12,9	14,8	0,95
s4.069	4,63	2,135	1,00	27,7	35,3	70,7	44,5	2,3	1,9	9,4	21,6	0,82
s4.070	4,32	1,876	0,63	26,1	30,5	55,0	34,3	2,7	2,1	11,7	14,6	0,79

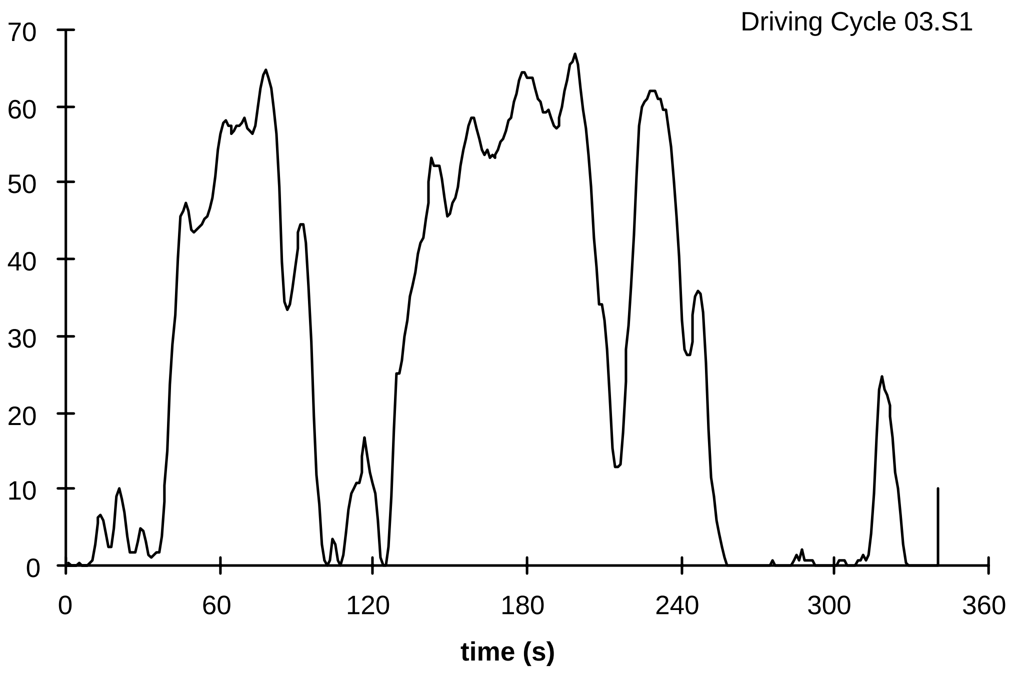
Kinematic parameters of the selected short driving cycle and its modifications

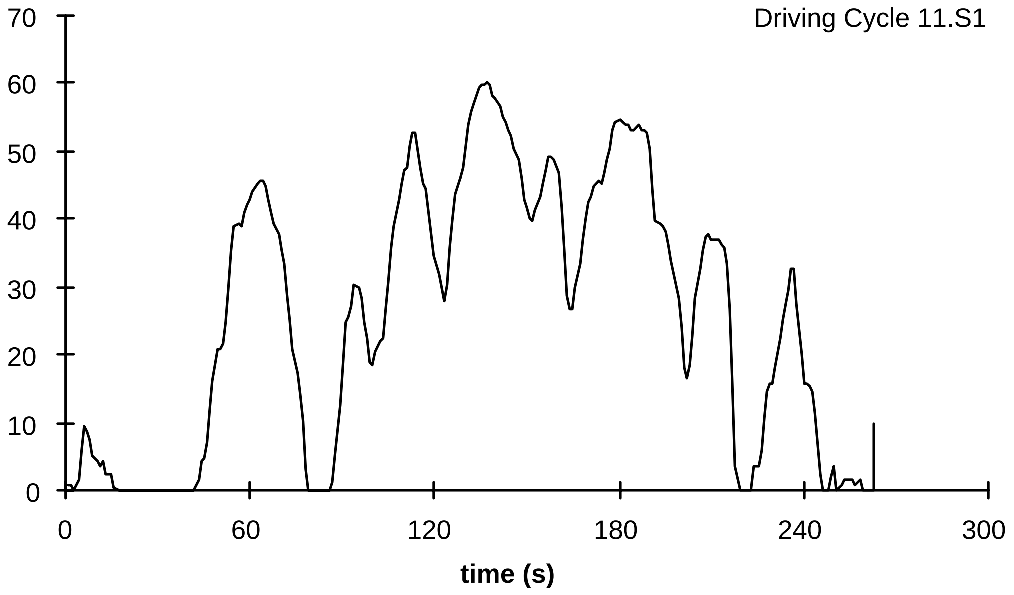
s4.057	**4,42**	**2,200**	**1,17**	**29,9**	**40,6**	**69,1**	**41,9**	**2,3**	**1,8**	**5,9**	**26,5**	**0,80**
s4.057b	**4,27**	**2,231**	**0,95**	**31,3**	**40,3**	**69,1**	**41,9**	**2,3**	**1,8**	**4,9**	**22,2**	**0,80**
s4.057c	**4,27**	**2,231**	**0,87**	**31,3**	**39,4**	**68,9**	**41,9**	**2,3**	**1,8**	**4,0**	**20,4**	**0,77**

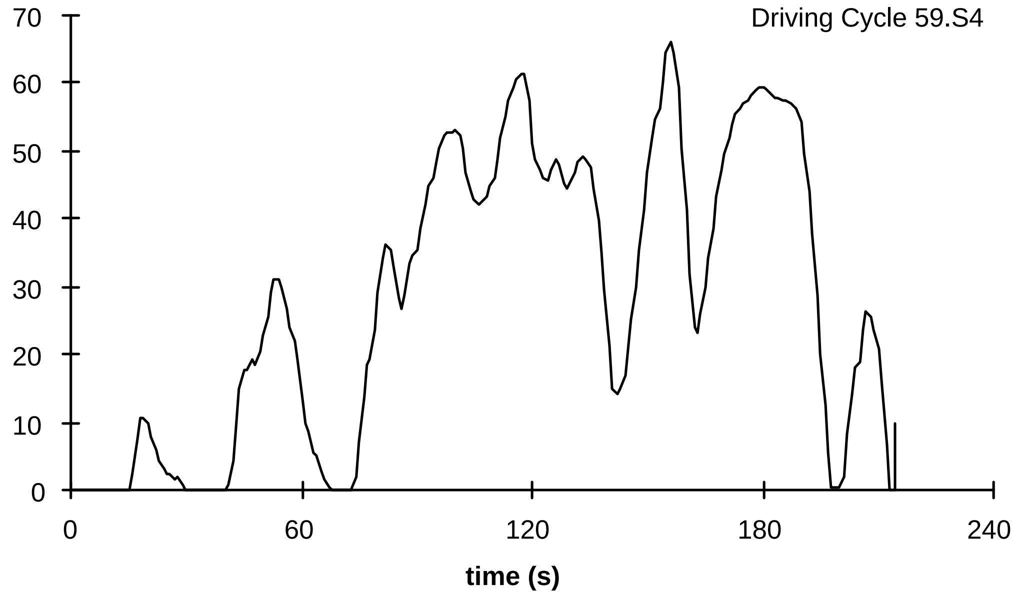
A set of 30 driving cycles

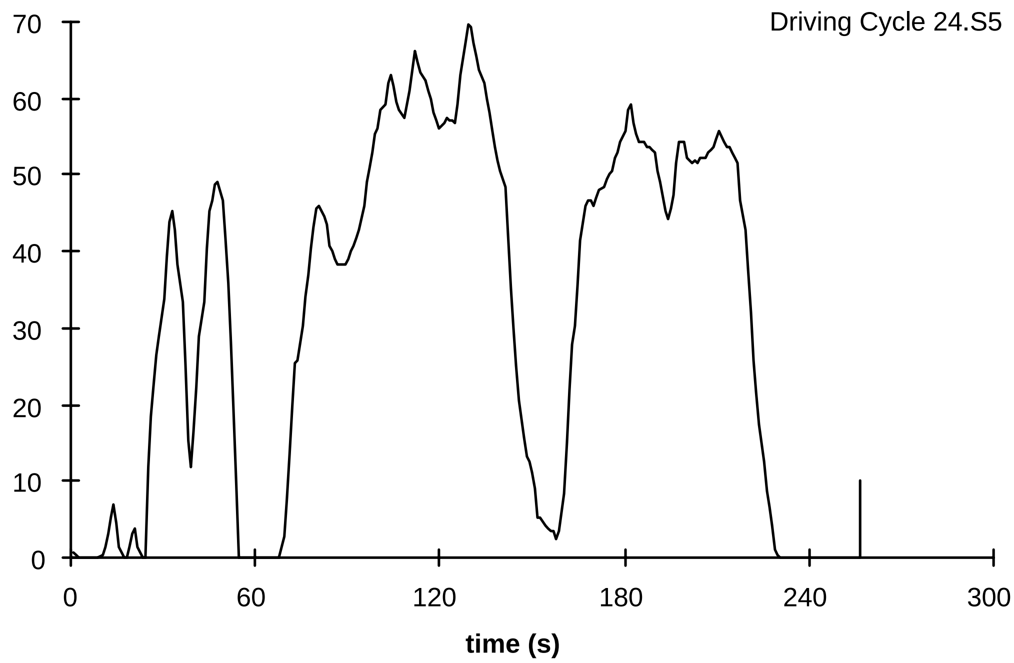
Kinematic parameters of 30 simulated short driving cycles (S5)							derived from the European Research Project DRIVE-modem V1053					
Cycle	duration (mn)	distance (km)	stop duration (mn)	Average speed (km/h)	Running speed (km/h)	Maxi speed (km/h)	Road Sequ. Speed (km/h)	Nber of sequ. per km	Stop rate stop/km	Speed variat per km	idle dur. %	acceleration rate m/s2
s5.001	4,95	1,971	1,05	23,9	30,3	61,9	19,7	2,5	2,0	15,2	21,2	0,68
s5.002	4,44	1,892	0,67	25,6	30,1	57,0	26,2	2,6	2,1	11,6	15,1	0,75
s5.003	4,88	2,044	0,86	25,1	30,5	53,8	34,1	2,0	1,5	14,2	17,6	0,59
s5.004	4,52	1,674	0,56	22,2	25,4	49,1	27,0	2,4	1,2	20,9	12,4	0,67
s5.005	4,02	2,198	0,94	32,8	42,8	80,4	42,6	1,8	1,4	8,2	23,4	0,91
s5.006	3,78	1,648	1,06	26,2	36,4	56,6	37,6	2,4	1,8	7,9	28,0	0,73
s5.007	4,35	1,731	0,57	23,9	27,5	52,0	28,4	2,3	1,7	12,7	13,1	0,89
s5.008	3,21	1,288	0,87	24,1	33,0	63,9	37,1	3,1	2,3	13,2	27,1	0,80
s5.009	3,50	1,761	0,66	30,2	37,2	53,5	37,7	2,3	1,7	11,4	18,9	0,70
s5.010	4,63	2,692	0,50	34,9	39,1	67,6	38,9	1,5	1,1	10,8	10,8	0,77
s5.011	4,91	2,231	0,76	27,3	32,3	80,8	34,0	1,8	1,3	17,5	15,5	0,98
s5.012	3,79	1,497	0,71	23,7	29,2	64,1	30,6	2,7	2,0	14,0	18,7	0,84
s5.013	4,26	2,412	1,26	34,0	48,2	92,7	47,5	1,7	1,2	7,0	29,6	1,07
s5.014	3,81	2,012	0,95	31,7	42,2	71,4	40,6	2,0	1,5	5,0	24,9	0,80
s5.015	5,00	2,866	1,17	34,4	44,9	61,3	50,1	1,4	1,1	6,6	23,4	0,52
s5.016	4,97	2,874	0,58	34,7	39,3	66,8	38,7	1,4	1,0	8,0	11,7	0,60
s5.017	3,67	1,867	0,56	30,5	36,0	53,6	38,8	2,1	1,6	7,5	15,3	0,67
s5.018	4,35	2,149	0,68	29,6	35,1	67,1	37,0	1,9	1,4	11,6	15,6	0,81
s5.019	4,47	1,526	0,57	20,5	23,5	38,7	25,3	2,6	2,0	13,8	12,8	0,46
s5.020	3,67	2,011	0,42	32,9	37,1	60,9	41,4	2,0	1,5	16,4	11,4	0,73
s5.021	3,37	1,237	0,76	22,0	28,4	59,1	30,5	3,2	2,4	23,4	22,6	0,96
s5.022	3,55	2,256	0,54	38,1	45,0	73,5	45,1	1,8	1,3	4,0	15,2	0,82
s5.023	4,94	1,838	1,24	22,3	29,8	63,7	36,4	2,7	2,2	15,2	25,1	0,79
s5.024	4,28	2,216	0,92	31,1	39,6	67,7	40,2	1,8	0,9	7,7	21,5	0,85
s5.025	4,78	2,105	0,98	26,4	33,2	67,9	37,5	1,9	1,4	15,7	20,5	0,62
s5.026	4,71	2,247	1,13	28,6	37,7	62,0	36,5	1,8	1,3	9,3	24,0	0,65
s5.027	3,17	1,481	0,39	28,0	32,0	56,6	34,9	2,7	2,0	12,1	12,3	0,93
s5.028	3,94	1,620	1,04	24,7	33,5	58,4	30,9	3,1	2,5	4,9	26,4	0,62
s5.029	4,62	2,038	0,95	26,5	33,3	62,9	39,2	2,0	1,5	14,2	20,6	0,73
s5.030	4,66	2,132	1,38	27,5	39,0	69,3	37,7	1,9	1,4	7,5	29,6	0,81

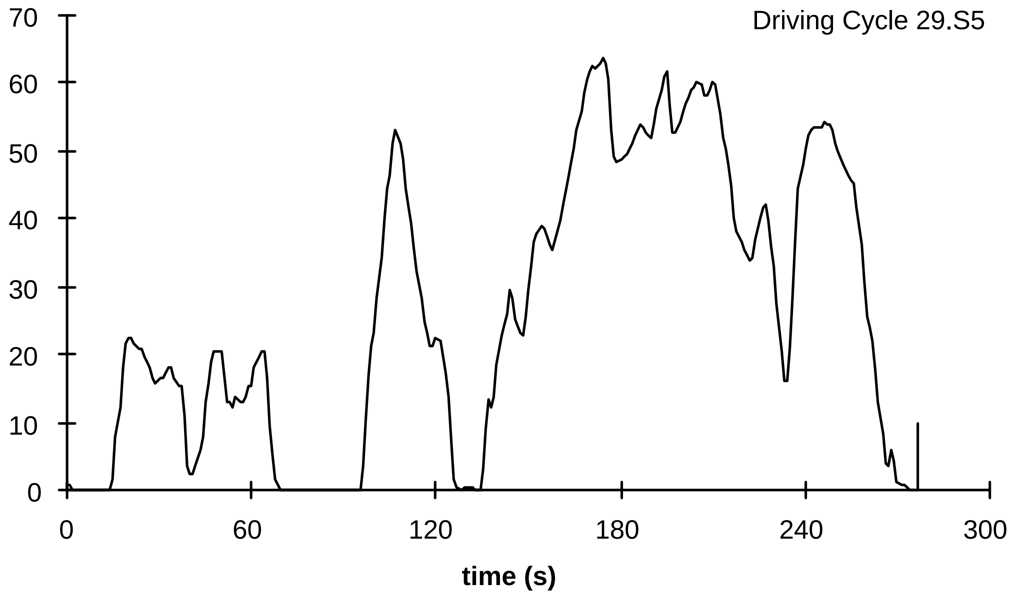
Appendix 4 - Typical simulated short trips






Driving Cycle 59.S4
70
60
50
40
30
20
10
0
0
60
120
180
240
time (s)

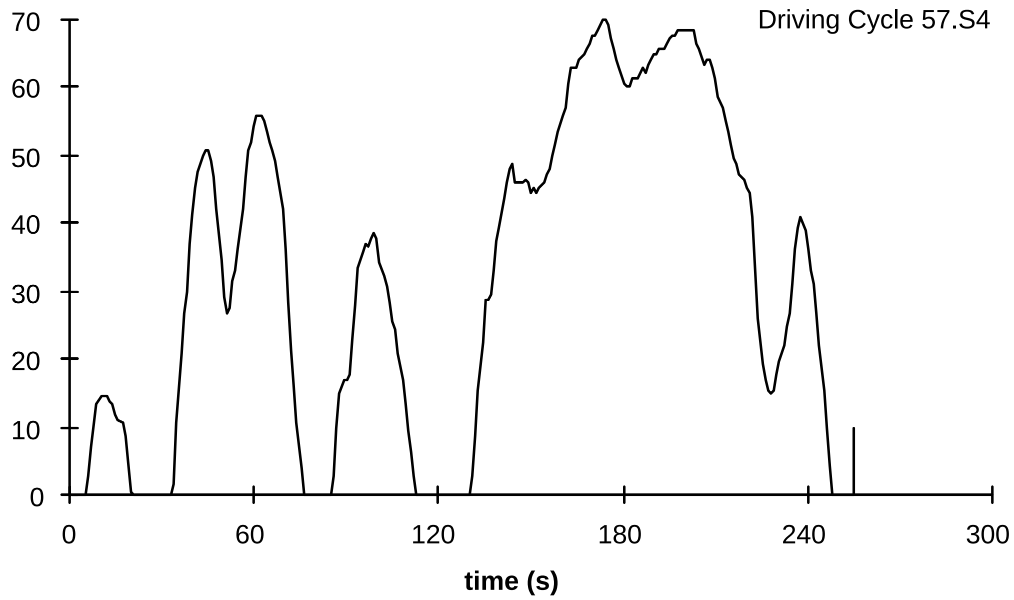

Driving Cycle 24.S5
70
60
50
40
30
20
10
0
0
60
120
180
240
300
time (s)



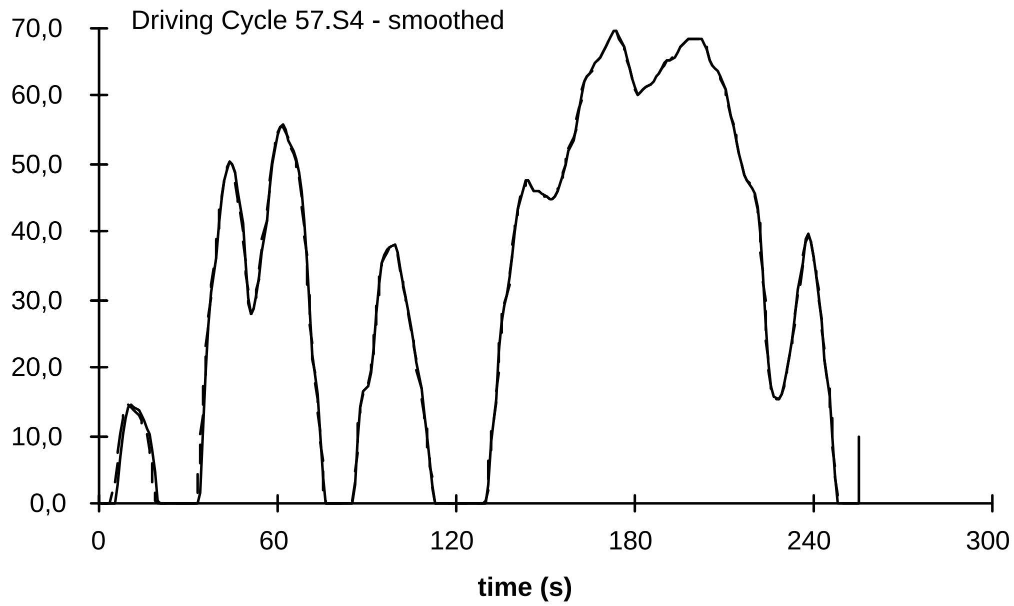
Driving Cycle 29.S5
70
60
50
40
30
20
10
0
0
60
120
180
240
300
time (s)

Appendix 5 - Proposal for a short transient driving cycle, derived from real driving data (modem short cycle)

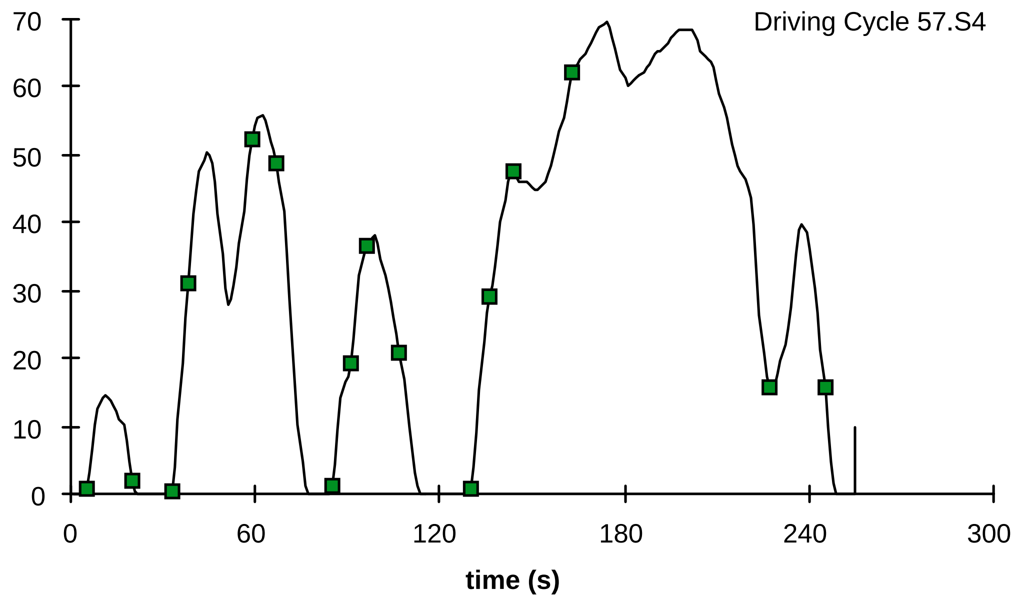
A.5.1 - Raw data



A.5.2 - Smoothed curve



A.5.3 - Position of the gearbox ratios changes



Appendix 6 - Short transient driving cycle (*modem*) - second by second form

time (sec.)	speed (km/h)	gear ratio
1	0.0	0
2	0.0	0
3	0.0	0
4	0.0	0
5	0.0	1
6	2.6	1
7	6.6	1
8	10.1	1
9	12.6	1
10	14.1	1
11	14.5	1
12	14.2	1
13	13.8	1
14	12.9	1
15	12.0	1
16	11.1	1
17	10.1	0
18	8.0	0
19	4.7	0
20	0.5	0
21	0.0	0
22	0.0	0
23	0.0	0
24	0.0	0
25	0.0	0
26	0.0	0
27	0.0	0
28	0.0	0
29	0.0	0
30	0.0	1
31	1.5	1
32	6.5	1
33	11.8	1
34	17.7	1
35	23.3	1
36	27.8	1
37	32.0	2
38	34.5	2
39	38.2	2
40	41.1	2
41	44.4	2
42	47.5	2
43	49.3	2
44	50.3	2
45	50.1	2
46	48.8	2
47	45.9	2
48	41.1	2
49	35.2	2
50	30.1	2
51	27.8	2
52	28.6	2
53	30.6	2
54	33.4	2
55	37.0	2
56	41.6	2
57	46.5	2
58	49.8	2
59	52.4	3
60	54.1	3
61	55.4	3
62	55.7	3
63	54.9	3
64	53.6	3
65	52.1	3
66	50.6	3
67	48.8	0
68	45.9	0
69	41.6	0
70	35.5	0
71	28.6	0
72	21.9	0
73	16.1	0
74	10.2	0
75	3.8	0
76	0.0	0
77	0.0	0
78	0.0	0
79	0.0	0
80	0.0	0
81	0.0	0
82	0.0	0
83	0.0	0
84	0.0	0
85	0.0	1
86	2.9	1
87	9.3	1
88	14.0	1
89	16.4	1
90	17.3	2
91	19.2	2
92	22.8	2
93	28.0	2
94	32.3	2
95	35.4	3
96	36.4	3
97	37.1	3
98	37.6	3
99	38.0	3
100	36.8	3
101	34.7	3
102	32.3	3
103	30.4	3
104	28.3	3
105	26.1	3
106	23.5	3
107	20.7	0
108	17.1	0
109	13.3	0
110	9.7	0
111	6.2	0
112	2.9	0
113	0.0	0
114	0.0	0
115	0.0	0
116	0.0	0
117	0.0	0
118	0.0	0
119	0.0	0
120	0.0	0
121	0.0	0
122	0.0	0
123	0.0	0
124	0.0	0
125	0.0	0
126	0.0	0
127	0.0	0
128	0.0	0
129	0.0	0
130	0.0	1
131	2.8	1
132	8.9	1
133	15.5	1
134	22.3	1
135	26.8	1
136	29.1	2
137	30.6	2
138	33.4	2
139	36.7	2
140	40.2	2
141	43.1	2
142	45.9	2
143	47.5	3
144	47.5	3
145	46.8	3
146	45.9	3
147	46.1	3
148	46.1	3
149	45.7	3
150	45.2	3
151	44.7	3
152	45.0	3
153	45.2	3
154	46.1	3
155	47.1	3
156	48.5	3
157	49.9	3
158	51.7	3
159	53.6	3
160	55.5	3
161	57.9	3
162	60.2	3
163	62.1	4
164	62.8	4
165	63.3	4
166	64.0	4
167	64.9	4
168	65.6	4
169	66.6	4
170	67.3	4
171	68.0	4
172	68.7	4
173	69.4	4
174	69.7	4
175	68.7	4
176	67.3	4
177	65.6	4
178	64.2	4
179	62.6	4
180	61.2	4
181	60.2	4
182	60.5	4
183	60.9	4
184	61.4	4
185	61.9	4
186	62.1	4
187	62.8	4
188	63.3	4
189	64.2	4
190	64.7	4
191	65.1	4
192	65.4	4
193	65.9	4
194	66.4	4
195	67.1	4
196	67.6	4
197	68.0	4
198	68.3	4
199	68.5	4
200	68.5	4
201	68.5	4
202	68.5	4
203	67.8	4
204	66.8	4
205	65.2	4
206	64.4	4
207	64.0	4
208	63.7	4
209	62.8	4
210	60.9	4
211	59.1	4
212	57.0	4
213	55.3	4
214	53.4	4
215	51.5	4
216	49.9	4
217	48.5	4
218	47.5	4
219	46.4	4
220	45.4	4
221	43.5	4
222	39.8	4
223	33.6	2
224	26.4	2
225	20.7	2
226	17.2	2
227	15.7	2
228	15.3	2
229	16.0	2
230	17.6	2
231	19.8	2
232	22.1	2
233	24.5	2
234	27.5	2
235	31.3	2
236	35.5	2
237	38.8	2
238	39.7	2
239	38.6	2
240	36.0	2
241	33.4	2
242	30.4	2
243	26.6	2
244	21.4	2
245	15.8	0
246	9.9	0
247	4.2	0
248	0.0	0
249	0.0	0
250	0.0	0
251	0.0	0
252	0.0	0
253	0.0	0
254	0.0	0
255	0.0	0

Appendix 7 -Average characteristics of the different trip groups and simulation parameters

A7.1 : Average characteristics and their probable ranges according to the 3 trip groups obtained by classification, and partition of the urban trips into 2 sub-groups (without selection)

	urban trips	road trips	motorway trips	all together	free-flow urban trips	congested urban trips
Number of trips	4602	2815	260	7677	2470	2130
Mileage	19885	26878	19701	66460	8188	11559
Average duration (min)	9	13	57	12	7.3	10.9
interval 25 - 75% (min.)	2.5 - 12	6 - 16	30 - 75	4 - 14	2 - 9	2 - 13
probable range (min.)	0 - 8	4 - 12	25 - 40	0 - 10	0 - 8	0 - 6
Average length (km)	4.3	9.5	76	8.7	3.3	5.4
interval 25 - 75% (km)	0.8 - 4.5	3.5 - 11	30 - 100	1 - 7.5	0,8 - 4	0.4 - 5.5
probable range (km)	0 - 3	2 - 6	20 - 70	0 - 3	0 - 3	0 - 3
Average Speed (km/h)	29	44 (39)	80 (73)	43	27.4 (22,8)	29,8 (18,5)
interval 25 - 75% (km/h)	14 - 26	30 - 46	57 - 90	18 - 36	18 - 26	9 - 24
probable range (km)	12 - 27	27 - 39	63 - 78	15 - 33	15 - 27	12-21/ (3-24)
Idle duration (in %)		12,7 (13)	4,3 (5)		24,6 (24)	25,3 (29)
interval 25 - 75%	16 - 33	7 - 16	0 - 6	10 - 28	14 - 31	18 - 37
probable range (%)	15 - 30	3 - 18	0 - 9	6 - 18	15 - 30	15 - 27
Stop rate (stop / km)		0,6 (0,7)	0,1 (0,1)		2,0 (2,8)	3,6 (8,9)
interval 25 - 75%	2 - 6	0.3 - 1	0 - 0.5	0 - 4	1.4 - 3.0	1,7 - 7
probable range	0 - 6	0 - 1.5	0 - 0.5	0 - 4	1 - 3	1 - 2,5 (3)

Average number of sequences per trip, and probable range for each sequence type	urban trips		road trips		motorway trips		all together		free-flow urban trips		congested urban trips	
- class 1 (congested urban)	2.5	[1-3]	0.8	[0-1/0-2]	1.6	[1-2/0-3]	2.0	[1-2]	0,9	[0-1/0-2]	4.2	[2-4/1-4]
- class 2 (free-flow urban)	3.3	[1-4]	1.9	[1-2/0-3]	2.0	[1-3/0-4]	2.7	[1-3]	3,8	[1-4/2-5]	2.7	[1-3/0-3]
- class 3 (road conditions)	0.5	[0-1]	2.0	[1-2/1-3]	1.6	[1-2/0-3]	1.0	[0-1]	0.3	[0/0-1]	0.7	[0-1/0-1]
- class 4 (motorway conditions)	0.0	[0]	0.0	[0]	1.2	[1/1-2]	0.1	[0]	0.0	[0]	0.0	[0]
- trip-end idle sequence	0.8		0.8		0.8		0.8					
total	7.1	[3-8]	5.4	[3-6/2-6]	7.2	[4-9/3-7]	6.5	[3-7]	5,8	[3-7/2-6]	8,5	[3-9/2-6]

A7.2 : Average characteristics of the trip groups after selection and simulation parameters for the cycles building-up :

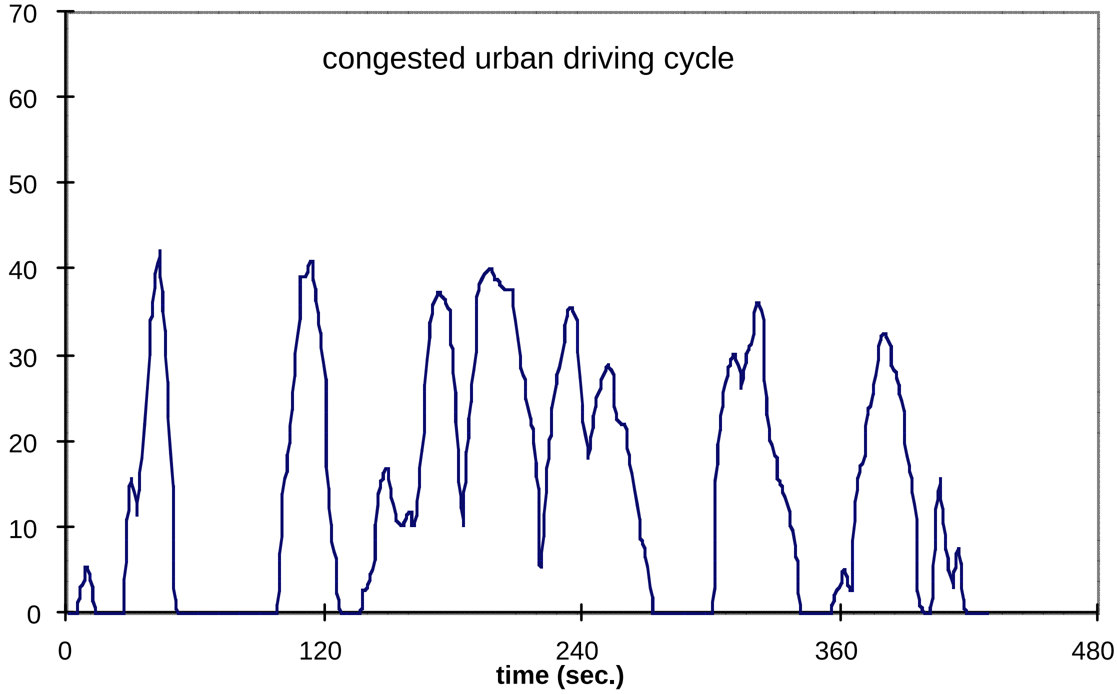
- *road and motorway trips : 5% of the extreme trips as regards their length and their average speed are eliminated*
- *urban trips : the 5% longer of all the urban trips were eliminated.*
    - *congested urban trips : the 5-75% interval of the average speed distribution is considered*
    - *free-flowing trips : the 25-95% interval of the average speed distribution is considered*

The global selection led to consider 5225 trips (68%) and 39327 km (59%) out of the total database

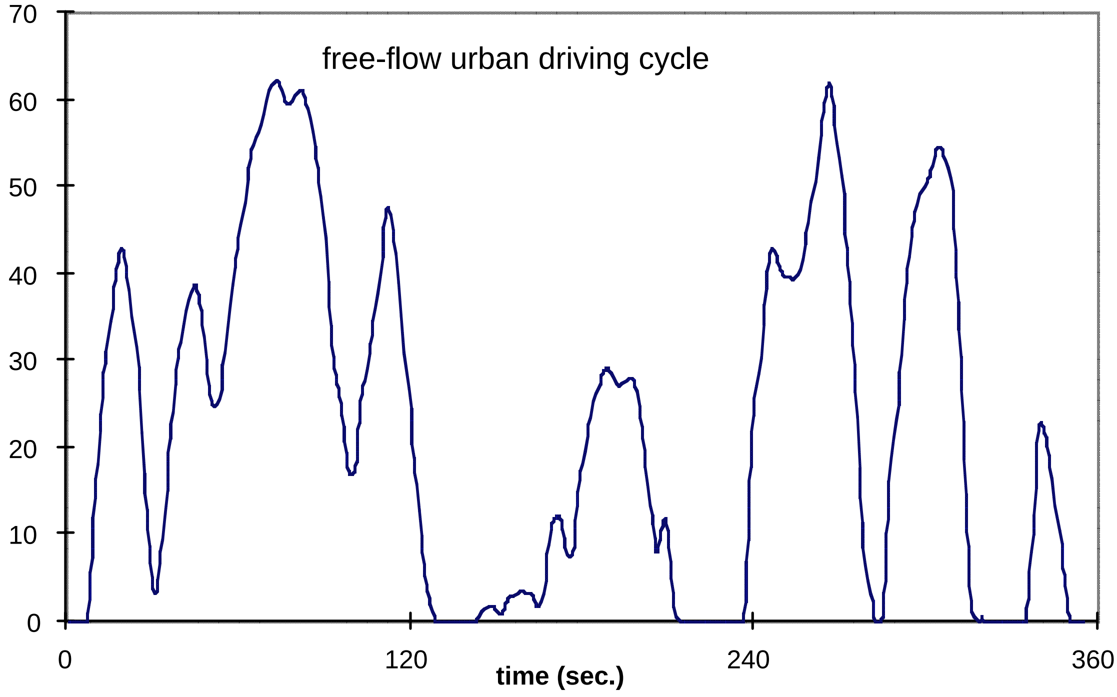
	road trips 5% D, 5%V	*simulation parameters*	motorway trips 5% D, 5%V	*simulation parameters*	free-flow urban trips 5%D, 25-95%V	*simulation parameters*	congested urban trips 5%D, 5-75%V	*simulation parameters*
Number of trips	2353 (84%)		218 (84%)		1479 (60%)		1174 (55%)	
Mileage %	70%		73%		3655 (45%)		2483 (21%)	
Average duration (min)	12.0	*10 - 13*	53.0	*17 - 25*	6.5	*5 - 8*	8.1	*7 - 9*
interval 25 - 75% (min.)	6.6 - 15.4		31.6 - 67.5		2.8 - 8		2.7 - 10.3	
probable range (min.)	4 - 12		30 - 35		0 - 8		0 - 6	
Average length (km)	8.0	*6.5 - 9*	66.1	*20 - 30*	2.5	*1.8 - 2.5*	2.1	*1.7 - 2.5*
interval 25 - 75% (km)	3.8 - 10.6		32.2 - 90		1 - 3.6		0.5 - 2.9	
probable range (km)	2 - 6		20 - 30		0.5 - 3		0.5 - 3	
Average Speed (km/h)	40.0	*38 - 45*	74.8	*73 - 80*	22.8	*21 - 27*	15.6	*13 - 17*
interval 25 - 75% (km/h)	30.8 - 45		67 - 87		20 - 26.4		10.5 - 18.6	
probable range (km)	27 - 39		63 - 78		21 - 24		12 - 18	
Idle duration (in %)	13.0	*11 - 14*	4.7	*0 - 10*	25.1	*17 - 25*	33.6	*30 - 35*
interval 25 - 75%	7 - 17.2		2 - 6.6		13.7 - 28.6		21 - 39	
probable range (%)	6 - 12				15 - 30		24 - 36	
Stop rate (stop / km)	0.58	*0.3 - 0.5*	0.1	*0 - 0.5*	1.97	*1.7 - 2.3*	3.55	*3 - 4.5*
interval 25 - 75%	0.3 - 1		0.1 - 0.4		1.44 - 2.46		2.7 - 6.1	
probable range	0.5 - 1				1 - 2.5		2 - 6	
Average number of sequences per trip, and probable range for each sequence type								
- class 1 (congested urban)	0.8 0-1/0-1	*0 - 1*	1.6 1-2/0-2	*0 - 2*	0.9 0-1/0-1	*1 - 1*	4.3 2-4/1-3/2	*4 - 4*
- class 2 (free-flow urban)	1.9 1-2/0-3	*1 - 2*	2.1 1-3/0-3	*1 - 2*	3.8 2-4/1-4	*4 - 4*	2.8 1-3/0-2/1	*2 - 3*
- class 3 (road conditions)	1.9 1-2/1-2	*1 - 2*	1.6 1-2/0-1	*0 - 1*	0.2 0/0-1	*0 - 0*	0.3 0/0-1/0	*0 - 1*
- class 4 (motorway conditions)	0	*0 - 0*	1.2 1/1	*1 - 2*	0	*0 - 0*	0	*0 - 0*
- trip-end idle sequence		*0 - 1*		*0 - 1*		*1 - 1*		*0 - 1*
total	5.4 3-6/2-5	*4 - 5*	7.4 5-9/3-10	*5 - 6*	5.6 2-7/2-5	*6 - 6*	8.3 3-9/2-5	*7 - 8*

Appendix 8 - Proposal for reference transient driving cycles, derived from real driving data (modem cycles)

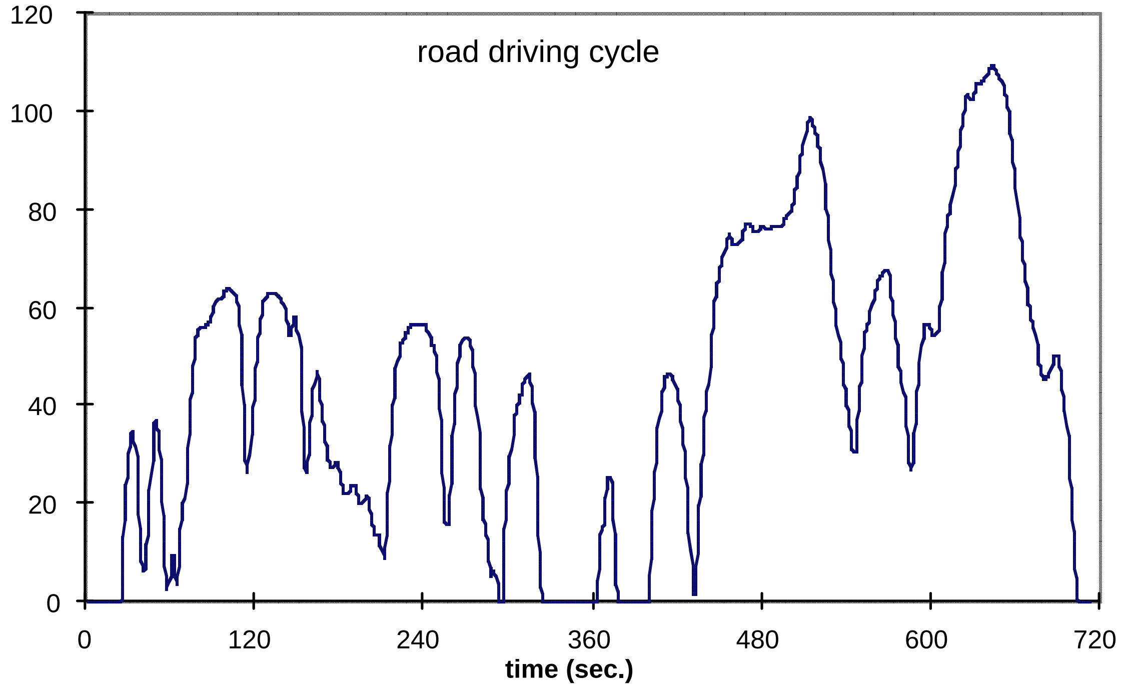
A.8.1 - A congested urban driving cycle



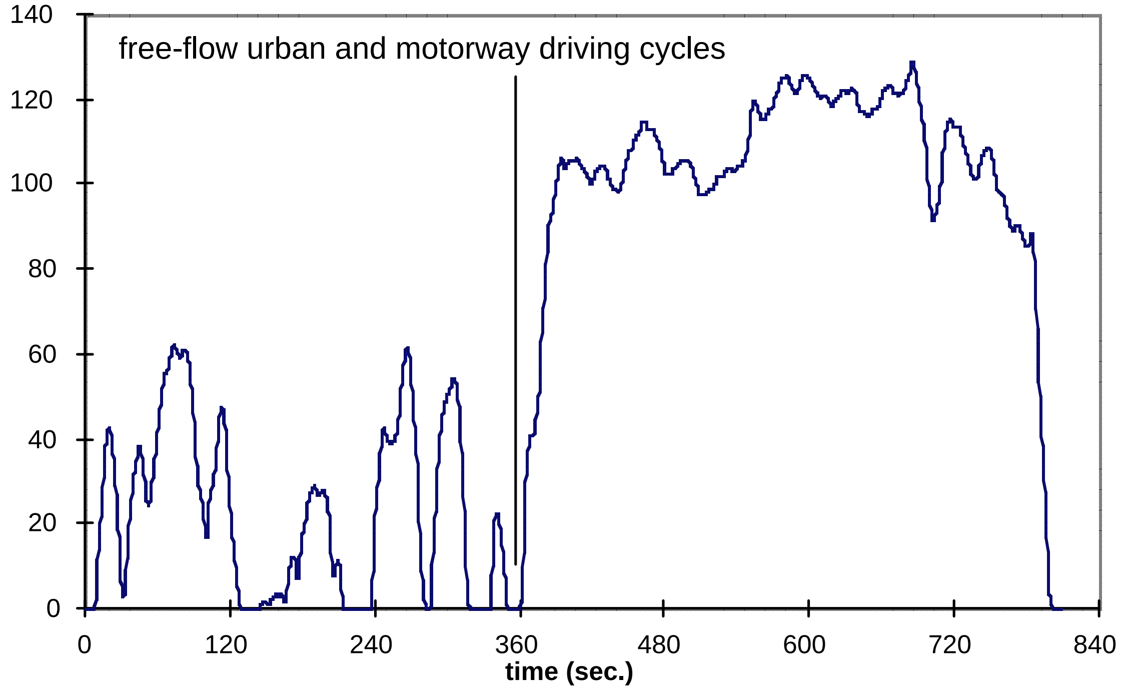
A.8.2 - A free-flowing urban driving cycle



A.8.3 - A road driving cycle



A.8.4 - A motorway driving cycle (including a free-flowing urban part)



Appendix 9 - Reference driving cycles - second by second form

A.9.1 - A congested urban driving cycle

time (sec.)	speed (km/h)
1	0.0
2	0.0
3	0.0
4	0.0
5	0.0
6	2.3
7	3.3
8	4.6
9	5.4
10	5.4
11	4.4
12	3.1
13	0.0
14	0.0
15	0.0
16	0.0
17	0.0
18	0.0
19	0.0
20	0.0
21	0.0
22	0.0
23	0.0
24	0.0
25	0.0
26	0.0
27	0.7
28	7.8
29	13.2
30	15.7
31	14.2
32	12.0
33	11.5
34	14.4
35	18.1
36	22.0
37	26.2
38	30.3
39	33.5
40	34.7
41	37.9
42	40.6
43	42.3
44	40.3
45	37.4
46	33.0
47	26.9
48	18.8
49	10.8
50	4.9
51	1.5
52	0.0
53	0.0
54	0.0
55	0.0
56	0.0
57	0.0
58	0.0
59	0.0
60	0.0
61	0.0
62	0.0
63	0.0
64	0.0
65	0.0
66	0.0
67	0.0
68	0.0
69	0.0
70	0.0
71	0.0
72	0.0
73	0.0
74	0.0
75	0.0
76	0.0
77	0.0
78	0.0
79	0.0
80	0.0
81	0.0
82	0.0
83	0.0
84	0.0
85	0.0
86	0.0
87	0.0
88	0.0
89	0.0
90	0.0
91	0.0
92	0.0
93	0.0
94	0.0
95	0.0
96	0.0
97	0.0
98	0.0
99	2.8
100	11.1
101	15.8
102	17.2
103	17.6
104	20.0
105	23.7
106	27.9
107	32.3
108	36.2
109	38.8
110	39.2
111	39.2
112	39.7
113	40.9
114	40.9
115	39.7
116	37.6
117	35.0
118	32.5
119	29.2
120	25.1
121	20.0
122	14.6
123	10.4
124	7.2
125	5.4
126	3.5
127	1.4
128	0.0
129	0.0
130	0.0
131	0.0
132	0.0
133	0.0
134	0.0
135	0.0
136	0.0
137	1.4
138	2.3
139	2.8
140	3.1
141	3.8
142	5.0
143	7.4
144	10.2
145	12.8
146	14.7
147	15.8
148	16.8
149	16.5
150	15.8
151	14.4
152	12.8
153	11.4
154	10.7
155	10.4
156	10.2
157	10.4
158	11.1
159	11.9
160	11.6
161	10.7
162	10.4
163	11.6
164	14.7
165	18.9
166	23.2
167	26.7
168	29.6
169	32.4
170	35.0
171	36.4
172	37.4
173	37.4
174	37.4
175	36.7
176	36.4
177	35.5
178	34.6
179	32.4
180	30.1
181	25.6
182	18.9
183	12.5
184	10.2
185	12.1
186	16.6
187	20.6
188	24.6
189	28.4
190	32.2
191	35.5
192	37.6
193	38.8
194	39.6
195	39.8
196	40.0
197	40.0
198	40.0
199	39.3
200	38.8
201	38.3
202	38.3
203	38.1
204	37.8
205	37.8
206	37.8
207	37.4
208	36.0
209	34.1
210	32.0
211	29.8
212	27.9
213	26.5
214	25.1
215	23.9
216	22.7
217	21.3
218	17.5
219	11.4
220	6.4
221	5.5
222	9.2
223	14.2
224	19.2
225	22.0
226	23.9
227	25.3
228	27.0
229	28.6
230	30.1
231	31.7
232	33.6
233	34.8
234	35.5
235	35.5
236	34.8
237	33.1
238	30.5
239	27.4
240	24.1
241	20.8
242	18.5
243	18.0
244	19.4
245	21.8
246	24.1
247	25.6
248	26.8
249	27.0
250	27.7
251	28.4
252	28.9
253	28.4
254	26.8
255	25.1
256	23.2
257	22.2
258	22.0
259	22.0
260	21.5
261	20.1
262	18.5
263	16.3
264	14.4
265	12.6
266	10.9
267	9.5
268	8.5
269	7.6
270	5.4
271	3.1
272	0.7
273	0.0
274	0.0
275	0.0
276	0.0
277	0.0
278	0.0
279	0.0
280	0.0
281	0.0
282	0.0
283	0.0
284	0.0
285	0.0
286	0.0
287	0.0
288	0.0
289	0.0
290	0.0
291	0.0
292	0.0
293	0.0
294	0.0
295	0.0
296	0.0
297	0.0
298	0.0
299	0.0
300	0.0
301	6.6
302	12.9
303	17.6
304	21.5
305	24.0
306	26.9
307	28.4
308	28.6
309	28.9
310	29.8
311	30.1
312	29.1
313	27.1
314	26.4
315	27.4
316	29.3
317	30.8
318	31.3
319	32.5
320	34.2
321	36.0
322	36.2
323	35.2
324	32.7
325	29.3
326	24.9
327	21.5
328	19.6
329	18.4
330	17.4
331	16.1
332	15.4
333	14.7
334	13.7
335	12.7
336	11.7
337	10.7
338	9.8
339	7.8
340	5.1
341	0.0
342	0.0
343	0.0
344	0.0
345	0.0
346	0.0
347	0.0
348	0.0
349	0.0
350	0.0
351	0.0
352	0.0
353	0.0
354	0.0
355	0.0
356	0.0
357	2.1
358	2.6
359	3.0
360	3.7
361	4.4
362	5.1
363	4.2
364	2.8
365	3.0
366	6.3
367	10.9
368	14.4
369	16.5
370	17.6
371	19.7
372	21.8
373	23.2
374	24.2
375	25.6
376	27.9
377	29.7
378	31.1
379	32.0
380	32.7
381	32.7
382	31.8
383	30.1
384	29.0
385	28.5
386	28.1
387	26.7
388	24.6
389	22.1
390	20.0
391	18.3
392	17.2
393	15.8
394	12.8
395	8.6
396	4.1
397	1.5
398	0.5
399	0.0
400	0.0
401	0.0
402	0.0
403	1.9
404	9.3
405	14.1
406	15.7
407	14.6
408	12.0
409	9.0
410	6.2
411	4.3
412	3.0
413	3.7
414	6.1
415	7.5
416	5.7
417	0.7
418	0.0
419	0.0
420	0.0
421	0.0
422	0.0
423	0.0
424	0.0
425	0.0
426	0.0
427	0.0
428	0.0

Appendix 9 (cont.) - Reference driving cycles - second by second form

A.9.2 - A free-flowing urban driving cycle

time (sec.)	speed (km/h)								
		70	59.9	142	0.0	214	0.0	286	6.7
		71	61.2	143	0.0	215	0.0	287	13.5
		72	62.1	144	0.7	216	0.0	288	18.8
1	0.0	73	62.3	145	1.1	217	0.0	289	23.2
2	0.0	74	61.9	146	1.5	218	0.0	290	26.5
3	0.0	75	61.2	147	1.7	219	0.0	291	30.6
4	0.0	76	60.3	148	1.7	220	0.0	292	35.0
5	0.0	77	59.7	149	1.8	221	0.0	293	39.0
6	0.0	78	59.6	150	1.3	222	0.0	294	42.0
7	0.0	79	60.0	151	1.0	223	0.0	295	44.4
8	2.6	80	60.6	152	1.0	224	0.0	296	46.2
9	8.9	81	61.0	153	1.6	225	0.0	297	48.0
10	14.3	82	60.9	154	2.4	226	0.0	298	49.2
11	18.2	83	60.3	155	2.9	227	0.0	299	49.9
12	21.9	84	59.1	156	3.1	228	0.0	300	50.6
13	25.9	85	57.8	157	3.3	229	0.0	301	51.3
14	30.9	86	56.2	158	3.5	230	0.0	302	52.4
15	34.6	87	54.5	159	3.6	231	0.0	303	53.6
16	37.3	88	52.0	160	3.4	232	0.0	304	54.5
17	39.3	89	48.8	161	3.2	233	0.0	305	54.5
18	41.4	90	44.1	162	3.4	234	0.0	306	54.1
19	43.0	91	39.0	163	3.1	235	0.0	307	52.9
20	42.5	92	33.9	164	2.1	236	0.0	308	51.0
21	40.8	93	30.4	165	1.9	237	2.4	309	47.6
22	38.0	94	28.3	166	3.3	238	11.9	310	42.7
23	35.2	95	26.7	167	6.2	239	19.4	311	36.7
24	31.6	96	24.9	168	8.8	240	23.9	312	30.4
25	26.8	97	22.4	169	10.6	241	27.2	313	23.0
26	21.6	98	19.4	170	11.5	242	30.3	314	14.6
27	16.9	99	17.0	171	12.0	243	34.3	315	7.0
28	12.7	100	17.2	172	12.1	244	38.4	316	2.3
29	8.7	101	20.1	173	11.5	245	41.4	317	0.5
30	5.2	102	23.9	174	9.5	246	42.9	318	0.0
31	3.2	103	26.2	175	7.7	247	42.6	319	0.5
32	3.6	104	27.8	176	7.6	248	41.9	320	0.0
33	7.0	105	29.1	177	10.2	249	40.8	321	0.0
34	12.5	106	30.9	178	13.5	250	40.2	322	0.0
35	17.5	107	33.2	179	16.4	251	39.6	323	0.0
36	21.1	108	36.1	180	18.2	252	39.6	324	0.0
37	24.0	109	39.9	181	19.8	253	39.2	325	0.0
38	27.4	110	43.7	182	21.5	254	39.5	326	0.0
39	30.3	111	46.6	183	23.6	255	39.8	327	0.0
40	32.2	112	47.8	184	25.4	256	40.6	328	0.0
41	33.9	113	46.9	185	26.8	257	41.8	329	0.0
42	35.8	114	45.0	186	27.8	258	43.5	330	0.0
43	37.9	115	42.2	187	28.6	259	45.9	331	0.0
44	38.7	116	39.0	188	29.0	260	48.2	332	0.0
45	38.7	117	35.1	189	29.1	261	50.7	333	0.0
46	37.6	118	31.0	190	28.6	262	53.3	334	0.0
47	35.7	119	26.7	191	28.0	263	56.0	335	0.0
48	32.9	120	22.4	192	27.3	264	58.6	336	3.8
49	30.0	121	18.8	193	27.1	265	60.5	337	12.3
50	27.2	122	15.7	194	27.3	266	62.0	338	18.6
51	25.3	123	12.9	195	27.7	267	61.3	339	22.1
52	24.6	124	9.9	196	28.0	268	59.2	340	22.9
53	25.6	125	6.7	197	28.0	269	55.2	341	22.4
54	28.0	126	4.2	198	27.6	270	51.1	342	21.1
55	30.9	127	2.6	199	26.4	271	46.9	343	19.2
56	33.8	128	0.0	200	24.6	272	42.9	344	16.5
57	36.4	129	0.0	201	22.3	273	38.9	345	13.5
58	38.7	130	0.0	202	19.6	274	34.3	346	10.3
59	40.8	131	0.0	203	15.8	275	29.5	347	7.5
60	42.9	132	0.0	204	11.3	276	23.5	348	5.3
61	45.6	133	0.0	205	8.3	277	17.6	349	2.8
62	48.3	134	0.0	206	8.0	278	11.4	350	0.1
63	51.0	135	0.0	207	9.5	279	6.7	351	0.0
64	53.3	136	0.0	208	11.1	280	3.4	352	0.0
65	54.9	137	0.0	209	11.8	281	1.4	353	0.0
66	55.6	138	0.0	210	10.3	282	0.0	354	0.0
67	56.2	139	0.0	211	7.0	283	0.0	355	0.0
68	57.1	140	0.0	212	3.3	284	0.0		
69	58.5	141	0.0	213	0.5	285	0.7		

Appendix 9 (cont.) - Reference driving cycles - second by second form

A.9.3 - A road driving cycle

time (sec.)	speed (km/h)												
		70	21.2	142	58.0	214	19.4	286	10.0	358	0.0	430	4.9
		71	24.2	143	56.4	215	24.6	287	7.0	359	0.0	431	1.8
		72	28.6	144	54.9	216	29.2	288	5.4	360	0.0	432	1.7
1	0.0	73	34.3	145	54.4	217	34.5	289	6.6	361	0.0	433	4.5
2	0.0	74	38.9	146	55.4	218	38.6	290	6.4	362	0.0	434	10.0
3	0.0	75	42.7	147	56.7	219	42.0	291	5.1	363	1.4	435	16.8
4	0.0	76	46.0	148	58.0	220	45.2	292	2.0	364	6.9	436	21.8
5	0.0	77	49.9	149	58.0	221	48.9	293	0.0	365	11.5	437	25.8
6	0.0	78	52.9	150	56.8	222	51.2	294	0.0	366	14.6	438	30.1
7	0.0	79	54.5	151	54.2	223	52.4	295	0.0	367	15.1	439	35.3
8	0.0	80	55.4	152	49.3	224	52.7	296	0.0	368	16.0	440	39.1
9	0.0	81	55.9	153	42.9	225	53.0	297	11.5	369	19.1	441	41.7
10	0.0	82	56.2	154	35.3	226	53.7	298	16.7	370	23.1	442	44.4
11	0.0	83	56.0	155	29.4	227	54.4	299	20.8	371	25.5	443	48.0
12	0.0	84	56.0	156	26.4	228	55.0	300	24.3	372	25.3	444	52.1
13	0.0	85	56.4	157	26.8	229	55.5	301	27.6	373	23.4	445	55.8
14	0.0	86	56.7	158	29.9	230	56.0	302	31.3	374	19.7	446	59.6
15	0.0	87	56.9	159	34.2	231	56.5	303	34.4	375	13.8	447	62.6
16	0.0	88	57.0	160	38.1	232	56.5	304	36.8	376	7.2	448	64.4
17	0.0	89	57.8	161	41.5	233	56.5	305	38.4	377	1.0	449	65.7
18	0.0	90	59.1	162	44.5	234	56.5	306	39.8	378	0.0	450	67.0
19	0.0	91	60.4	163	46.8	235	56.7	307	40.8	379	0.0	451	68.8
20	0.0	92	61.3	164	47.0	236	56.7	308	41.6	380	0.0	452	70.3
21	0.0	93	61.6	165	45.3	237	56.5	309	42.4	381	0.0	453	71.6
22	0.0	94	61.6	166	42.9	238	56.4	310	43.5	382	0.0	454	72.6
23	0.0	95	61.8	167	40.4	239	56.5	311	44.7	383	0.0	455	73.6
24	0.0	96	62.1	168	38.1	240	56.5	312	45.5	384	0.0	456	74.6
25	1.5	97	62.6	169	35.8	241	56.4	313	46.2	385	0.0	457	74.9
26	9.7	98	63.3	170	33.8	242	55.5	314	46.4	386	0.0	458	74.2
27	17.1	99	63.6	171	31.9	243	54.9	315	45.7	387	0.0	459	73.2
28	22.0	100	63.9	172	30.1	244	53.9	316	44.1	388	0.0	460	72.7
29	25.3	101	63.8	173	28.4	245	53.0	317	42.1	389	0.0	461	72.9
30	28.2	102	63.8	174	27.6	246	52.2	318	38.8	390	0.0	462	73.1
31	31.7	103	63.6	175	27.6	247	51.6	319	33.3	391	0.0	463	73.2
32	34.0	104	63.3	176	28.1	248	50.1	320	25.4	392	0.0	464	73.7
33	34.7	105	62.9	177	28.6	249	48.1	321	17.4	393	0.0	465	74.2
34	33.8	106	62.4	178	28.8	250	45.5	322	10.0	394	0.0	466	75.1
35	31.5	107	61.6	179	28.1	251	42.1	323	5.0	395	0.0	467	75.9
36	27.3	108	60.1	180	26.6	252	36.8	324	1.5	396	0.0	468	76.6
37	21.4	109	58.0	181	25.0	253	29.9	325	0.0	397	0.0	469	77.1
38	15.0	110	54.6	182	23.7	254	23.5	326	0.0	398	0.0	470	77.2
39	10.0	111	48.6	183	22.7	255	18.2	327	0.0	399	0.0	471	77.2
40	7.2	112	40.3	184	22.2	256	15.6	328	0.0	400	2.0	472	76.9
41	6.2	113	32.0	185	22.0	257	15.8	329	0.0	401	9.1	473	76.4
42	6.9	114	26.8	186	22.4	258	19.0	330	0.0	402	16.1	474	75.9
43	9.5	115	26.4	187	22.7	259	24.5	331	0.0	403	21.1	475	75.6
44	14.0	116	29.9	188	23.2	260	30.7	332	0.0	404	25.0	476	75.4
45	19.7	117	34.3	189	23.7	261	36.3	333	0.0	405	28.4	477	75.7
46	25.8	118	38.3	190	23.8	262	40.6	334	0.0	406	33.5	478	76.2
47	31.9	119	41.4	191	23.7	263	43.9	335	0.0	407	37.6	479	76.7
48	35.7	120	45.2	192	22.9	264	47.2	336	0.0	408	40.2	480	76.7
49	37.0	121	49.1	193	21.9	265	50.1	337	0.0	409	41.9	481	76.6
50	36.2	122	52.4	194	20.7	266	52.2	338	0.0	410	43.7	482	76.2
51	34.8	123	54.9	195	20.2	267	53.2	339	0.0	411	45.3	483	76.1
52	32.7	124	56.7	196	19.9	268	53.7	340	0.0	412	46.1	484	75.9
53	29.2	125	58.8	197	20.5	269	53.9	341	0.0	413	46.3	485	75.9
54	24.0	126	60.6	198	21.2	270	54.0	342	0.0	414	46.3	486	76.1
55	17.4	127	62.1	199	21.7	271	54.0	343	0.0	415	46.3	487	76.2
56	10.3	128	62.8	200	20.9	272	53.5	344	0.0	416	46.0	488	76.4
57	5.3	129	63.1	201	19.4	273	52.7	345	0.0	417	45.5	489	76.6
58	2.8	130	62.9	202	17.9	274	51.1	346	0.0	418	44.5	490	76.6
59	4.0	131	62.9	203	16.6	275	49.1	347	0.0	419	43.5	491	76.7
60	6.9	132	62.8	204	15.5	276	46.3	348	0.0	420	41.9	492	76.6
61	9.4	133	62.9	205	14.3	277	42.7	349	0.0	421	40.1	493	76.9
62	9.5	134	62.8	206	13.8	278	37.3	350	0.0	422	37.8	494	76.9
63	6.9	135	62.8	207	13.5	279	31.2	351	0.0	423	35.6	495	77.4
64	4.1	136	62.6	208	13.5	280	25.3	352	0.0	424	33.5	496	77.7
65	3.9	137	62.4	209	12.6	281	21.2	353	0.0	425	30.9	497	78.4
66	7.6	138	62.1	210	10.8	282	17.9	354	0.0	426	27.4	498	78.8
67	12.8	139	61.4	211	9.0	283	15.8	355	0.0	427	23.0	499	79.3
68	16.9	140	60.6	212	9.5	284	14.1	356	0.0	428	17.2	500	79.8
69	19.2	141	59.5	213	14.0	285	12.6	357	0.0	429	10.6	501	80.5

502	81.6	579	45.0	656	97.2
503	83.1	580	42.9	657	94.3
504	84.8	581	40.7	658	91.2
505	86.4	582	37.6	659	88.1
506	88.0	583	33.8	660	84.8
507	89.9	584	30.1	661	81.5
508	91.5	585	27.6	662	78.4
509	93.3	586	26.9	663	75.7
510	94.8	587	28.4	664	73.3
511	96.3	588	32.2	665	71.0
512	97.4	589	36.6	666	68.7
513	98.3	590	40.8	667	66.4
514	98.6	591	44.4	668	64.2
515	98.3	592	48.5	669	62.1
516	97.8	593	52.4	670	60.3
517	96.9	594	55.0	671	58.5
518	95.9	595	56.2	672	57.0
519	94.9	596	56.5	673	55.9
520	93.8	597	56.5	674	54.4
521	92.6	598	56.4	675	52.4
522	90.7	599	56.2	676	49.9
523	88.2	600	55.7	677	48.1
524	85.3	601	54.9	678	47.0
525	82.0	602	54.2	679	46.1
526	78.9	603	54.2	680	45.8
527	75.4	604	54.9	681	45.6
528	72.1	605	56.3	682	45.8
529	68.5	606	58.6	683	46.0
530	65.4	607	61.9	684	46.6
531	62.4	608	65.5	685	47.6
532	59.6	609	69.3	686	48.8
533	56.8	610	73.3	687	49.5
534	54.4	611	76.4	688	50.1
535	52.6	612	78.3	689	50.3
536	50.6	613	79.3	690	50.1
537	48.5	614	80.8	691	49.0
538	45.8	615	82.8	692	47.1
539	43.5	616	85.1	693	44.5
540	41.2	617	87.1	694	41.9
541	38.9	618	89.0	695	39.1
542	36.8	619	91.0	696	35.8
543	34.8	620	93.0	697	31.7
544	32.4	621	95.1	698	27.3
545	30.4	622	97.1	699	23.2
546	30.9	623	98.9	700	19.2
547	34.5	624	100.7	701	14.5
548	38.9	625	102.5	702	9.5
549	42.2	626	103.7	703	4.9
550	44.9	627	103.5	704	1.5
551	48.0	628	102.7	705	0.0
552	51.6	629	102.5	706	0.0
553	54.2	630	103.3	707	0.0
554	55.5	631	104.3	708	0.0
555	56.2	632	105.0	709	0.0
556	57.3	633	105.5	710	0.0
557	59.0	634	105.8	711	0.0
558	60.6	635	105.8	712	0.0
559	61.9	636	106.0		
560	62.9	637	106.1		
561	63.8	638	106.6		
562	64.9	639	107.1		
563	66.0	640	107.7		
564	66.8	641	108.4		
565	66.8	642	108.9		
566	66.8	643	109.2		
567	67.5	644	109.2		
568	67.8	645	108.9		
569	67.5	646	108.4		
570	65.7	647	107.9		
571	63.7	648	107.4		
572	61.4	649	106.8		
573	59.6	650	106.1		
574	57.3	651	105.3		
575	55.0	652	104.3		
576	52.1	653	103.2		
577	49.6	654	101.7		
578	47.1	655	99.9		

Appendix 9 (cont.) - Reference driving cycles - second by second form

A.9.4 - A motorway driving cycle (motorway part only)

time (sec.)	speed (km/h)												
		70	104.0	142	106.0	214	118.9	286	118.1	358	113.1	430	86.5
		71	104.1	143	105.9	215	119.8	287	117.5	359	114.5	431	82.0
		72	104.5	144	105.6	216	120.8	288	117.2	360	115.2	432	74.9
1	0.0	73	104.8	145	105.0	217	121.9	289	117.1	361	115.3	433	66.2
2	0.0	74	104.6	146	104.4	218	122.5	290	117.0	362	115.0	434	57.5
3	0.0	75	104.0	147	103.7	219	123.2	291	116.9	363	114.3	435	50.0
4	0.0	76	103.1	148	102.8	220	123.8	292	116.7	364	113.9	436	44.0
5	2.0	77	102.2	149	101.6	221	124.7	293	116.4	365	113.7	437	38.7
6	6.7	78	101.4	150	100.4	222	125.4	294	116.5	366	113.9	438	33.7
7	13.4	79	100.8	151	99.4	223	125.6	295	116.7	367	113.9	439	27.8
8	21.1	80	100.2	152	98.6	224	125.6	296	117.2	368	113.5	440	21.0
9	27.5	81	99.5	153	98.0	225	125.6	297	117.7	369	112.8	441	13.4
10	32.0	82	99.0	154	97.7	226	125.7	298	118.1	370	112.0	442	7.4
11	35.9	83	98.8	155	97.6	227	125.3	299	118.2	371	111.0	443	4.2
12	38.8	84	98.8	156	97.7	228	124.6	300	118.2	372	110.0	444	3.2
13	40.7	85	98.7	157	97.8	229	123.7	301	118.3	373	109.0	445	2.7
14	41.0	86	98.7	158	98.0	230	123.1	302	118.8	374	107.9	446	0.0
15	40.7	87	98.9	159	98.3	231	122.4	303	119.7	375	106.7	447	0.0
16	41.4	88	99.7	160	98.7	232	121.7	304	120.7	376	105.7	448	0.0
17	43.5	89	101.0	161	98.9	233	121.4	305	121.5	377	104.5	449	0.0
18	46.6	90	102.4	162	99.0	234	121.7	306	122.2	378	103.2	450	0.0
19	48.9	91	103.8	163	99.1	235	122.7	307	122.6	379	102.1	451	0.0
20	51.2	92	105.1	164	99.2	236	123.8	308	122.9	380	101.5	452	0.0
21	54.7	93	106.3	165	99.6	237	124.8	309	123.1	381	101.3		
22	60.1	94	107.3	166	100.1	238	125.6	310	123.5	382	101.4		
23	65.3	95	108.0	167	100.8	239	126.1	311	123.6	383	101.9		
24	69.3	96	108.3	168	101.4	240	126.2	312	123.4	384	102.8		
25	73.2	97	108.5	169	101.8	241	126.1	313	123.0	385	104.0		
26	78.2	98	109.1	170	102.0	242	125.9	314	122.4	386	105.3		
27	84.1	99	109.9	171	102.1	243	125.5	315	121.9	387	106.3		
28	89.0	100	110.8	172	102.2	244	125.1	316	121.6	388	107.0		
29	91.5	101	111.4	173	102.4	245	124.7	317	121.4	389	107.5		
30	92.7	102	111.9	174	102.7	246	124.2	318	121.3	390	108.0		
31	93.7	103	112.6	175	103.1	247	123.6	319	121.4	391	108.6		
32	95.6	104	113.4	176	103.5	248	123.0	320	121.6	392	109.0		
33	97.8	105	114.3	177	103.8	249	122.2	321	121.9	393	108.9		
34	99.7	106	114.9	178	104.1	250	121.6	322	122.2	394	108.3		
35	101.4	107	115.1	179	104.1	251	121.2	323	122.9	395	107.0		
36	102.8	108	114.8	180	103.8	252	121.0	324	123.8	396	105.5		
37	104.1	109	114.2	181	103.5	253	120.8	325	124.5	397	103.9		
38	105.4	110	113.5	182	103.4	254	120.7	326	124.9	398	102.4		
39	106.2	111	113.2	183	103.5	255	120.9	327	125.4	399	101.0		
40	105.8	112	113.2	184	103.9	256	121.1	328	126.6	400	99.7		
41	104.8	113	113.2	185	104.3	257	121.2	329	128.1	401	98.7		
42	104.0	114	113.2	186	104.5	258	121.0	330	128.7	402	98.2		
43	104.3	115	112.9	187	104.6	259	120.6	331	128.3	403	98.0		
44	105.0	116	112.3	188	104.5	260	120.0	332	126.7	404	97.6		
45	105.5	117	111.4	189	104.9	261	119.4	333	124.9	405	96.9		
46	105.7	118	110.7	190	105.5	262	118.9	334	122.8	406	95.8		
47	105.6	119	109.9	191	106.6	263	118.9	335	120.8	407	94.5		
48	105.5	120	109.2	192	108.0	264	119.3	336	118.7	408	93.3		
49	105.7	121	108.0	193	109.9	265	119.8	337	116.6	409	92.0		
50	106.0	122	107.3	194	112.0	266	120.3	338	114.3	410	90.9		
51	106.2	123	106.0	195	114.2	267	120.5	339	111.7	411	90.0		
52	106.1	124	104.9	196	116.4	268	120.6	340	108.9	412	89.5		
53	105.8	125	103.6	197	118.2	269	120.8	341	106.0	413	89.3		
54	105.4	126	102.9	198	119.5	270	121.3	342	103.0	414	89.5		
55	104.8	127	102.6	199	119.7	271	121.7	343	99.9	415	90.0		
56	104.2	128	102.5	200	119.4	272	122.0	344	96.8	416	90.4		
57	103.7	129	102.6	201	118.5	273	122.1	345	93.9	417	90.5		
58	103.2	130	103.0	202	117.5	274	122.0	346	91.8	418	90.2		
59	102.8	131	103.4	203	116.5	275	121.8	347	91.4	419	89.6		
60	102.2	132	103.9	204	115.8	276	121.7	348	92.1	420	88.7		
61	101.4	133	104.2	205	115.4	277	122.1	349	93.3	421	87.9		
62	100.7	134	104.6	206	115.3	278	122.5	350	94.5	422	87.0		
63	100.4	135	104.9	207	115.5	279	122.7	351	96.1	423	86.0		
64	100.8	136	105.1	208	115.9	280	122.5	352	98.4	424	85.3		
65	101.4	137	105.3	209	116.5	281	122.0	353	100.9	425	85.4		
66	102.2	138	105.5	210	117.1	282	121.4	354	103.5	426	86.3		
67	103.0	139	105.7	211	117.5	283	120.6	355	106.2	427	87.7		
68	103.6	140	105.8	212	117.9	284	119.7	356	108.8	428	88.7		
69	103.8	141	105.9	213	118.2	285	118.9	357	111.2	429	88.6		