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2nd CITA Research Study Programme on Emissions

Study 2: Motorcycle Exhaust Emissions and Noise

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Study 2: Motorcycle Exhaust Emissions and Noise

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Summary

INTRODUCTION

On the 29th of December 1999, the DG VII (as it then was) of the EU Commission approved CITA's application for a grant for a second programme of studies on emission testing at periodic and other inspections. This research programme consisted of 5 studies, one of which was **Motorcycle exhaust emissions and noise**. The study was included because motorcycles are not within the scope of the road-worthiness directive 96/96/EC and the Commission is under increasing pressure to re-examine the possibility of periodic inspection for this class of vehicles.

In order to execute this study, CITA put together a consortium of experts, namely TNO Automotive (project leader), VdTÜV (represented by TÜV NORD and DEKRA), MTC/Bilprovningen and the European Garage Equipment Association (EGEA).

The aim of the study was ***to give insight into the parameters that should be controlled on motorcycles and to develop test procedures, and if necessary equipment, for measuring exhaust emissions and noise during periodic inspection.***

In addition to harmonised procedures and standards, the study proposed a method to look whether there was evidence that the introduction of periodic inspection of motorcycles would be cost-beneficial.

TASKS AND METHODOLOGY

In order to answer the questions raised, the study involved the following tasks:

- Investigation and definition of the topics involved
- Definition of a basic measurement procedure to be used for future road-worthiness testing, based on available information on how to test exhaust gas emissions and noise on vehicles.
- Validation of the proposed procedure starting with the definition and execution of a validation programme of testing motorcycles to measure the exhaust and noise emissions of vehicles in use and to evaluate the correlation between stationary idle tests and loaded Type Approval tests of exhaust gas emissions and noise.
- Evaluation of the results and findings and the production of a proposal for an amendment to the road-worthiness directive 96/96/EC involving motorcycles.
- Proposing a method to estimate the cost-effectiveness of the proposed procedure.

Investigation and definition of the topics involved and definition of a basic measurement procedure

The starting point of the study was the acknowledgement that emission-wise, motorcycles as currently sold, are in fact at the technological level of passenger cars about 15 years ago. As legislation concerning emissions is tightened, clean technology will be developed and introduced in the near future. This acknowledgement led to the conclusion that the current European set-up for passenger car road-worthiness testing, as prescribed in directive 96/96/EC, was probably a good starting point for motorcycles, since this procedure was also developed some 15 years ago. For noise testing such a

parallel with directive 96/96/EC was not present, since noise testing is not part of the road-worthiness (RW) testing of passenger cars.

Based on the parallels with passenger car development, it was decided to take idle testing as a starting point for a draft road-worthiness test procedure, as is currently used for passenger cars. However, in addition to the similarities mentioned above, there are major differences between passenger cars and motorcycles. Having to cope with both 2- and 4-stroke engines, high and widely spread power to weight ratios, wide range of swept volume, typical exhaust configurations, both water and air cooled systems and, most importantly, the greater likelihood of tampering, makes motorcycle testing completely different to and more difficult than passenger car testing.

The proposed draft road-worthiness emission test procedure on exhaust gas was set up. This procedure was based on idle testing (at low and two elevated engine speeds) for gaseous emissions (CO and HC), using standard workshop test equipment for current RW testing of passenger cars. However, for defining a procedure for testing noise, it was decided to use the stationary test method (high idle engine speed) as is described in directive 97/24/EC Chapter 9. This test procedure is already used for in-use enforcement in some Member States. A draft version of a similar procedure was also available from an initiative in Germany for motorcycle RW testing. This basic procedure was used as a starting point for the development of the procedure used in the validation programme.

Validation of the proposed procedure

The proposed procedure was validated by testing 105 motorcycles (spread over all vehicle classes currently on sale in Europe). The validation procedure consisted of many vehicle tests, basically looking at the correlation between the (loaded) type approval test and the proposed road-worthiness test procedure, whilst taking into account the effect of several critical points in the procedure (e.g. preconditioning and connecting equipment). In addition, experience was gained on using standard exhaust gas measurement equipment, which was specially designed for 4-stroke engines, for testing 2-stroke motorcycles.

Evaluation of the results and findings

In order to identify a motorcycle as a 'high emitter' on exhaust gas emission and noise, two different definitions can be applicable. The first option, which is common practice during in-use compliance, is to identify each motorcycle that emits exhaust gas or noise over the applicable Type Approval limit. The second option, as generally used in inspection and maintenance programmes, is to identify only extreme high emitters.

The test work found that significant numbers of vehicles were 'high emitters' on gaseous emissions (using the definition of exceeding the applicable Type Approval limit (on all types of test (Type I, Type II and in-motion noise)). In figures: 74% of the tested 2-stroke motorcycles and 20% of the tested 4-stroke motorcycles exceeded the Type Approval limit for the Type I test (loaded driving cycle on a chassis dynamometer) whereas only 11% of all tested vehicles exceeded the limit of the Type II test (low idle test). Only 5% of the motorcycles tested exceeded the applicable limit on both the Type I and Type II test and two vehicles exceeded the Type I limit for NO_x. Most high emitters for exhaust gas were found for vehicles type approved under the latest (most stringent) legislation (directive 97/24/EC Chapter 5, stage 1).

However, it must be noted that the above mentioned numbers most probably do not represent the actual situation on the European road; the actual situation most probably is even worse then found in this study. The cause of this probable mismatch is the fact that the vehicles tested in the underlying investigation were, to a large extend, rather new and well maintained. In addition, the often tampered in-use small class vehicles (<125 cm^3) were largely under represented (caused by the withdrawal of the Spanish partner).

On noise, 80% and 75% respectively of the motorcycles that comply with directive 97/24/EC Chapter 9 and 78/1015/EEC exceeded the applicable Type Approval limit on the in-motion test. As the noise emission results of the stationary tests are compared with the noise emission measured at time of Type Approval, 56% of the motorcycles had higher noise emissions during the tests executed in the validation programme and 40% of those exceeded the value at time of Type Approval by more than 5 dB(A).

Detailed evaluation of the exhaust gas and noise emission data showed no significant direct correlations between the results of the (loaded Type I) type approval test and the (idle) proposed RW test, either for gaseous emissions or for noise. To meet the objective of road-worthiness testing on emissions (locate 'high emitters'), a different approach to data analysis was followed. Figure 1 shows the basic concept of optimising the "errors of omission and commission".

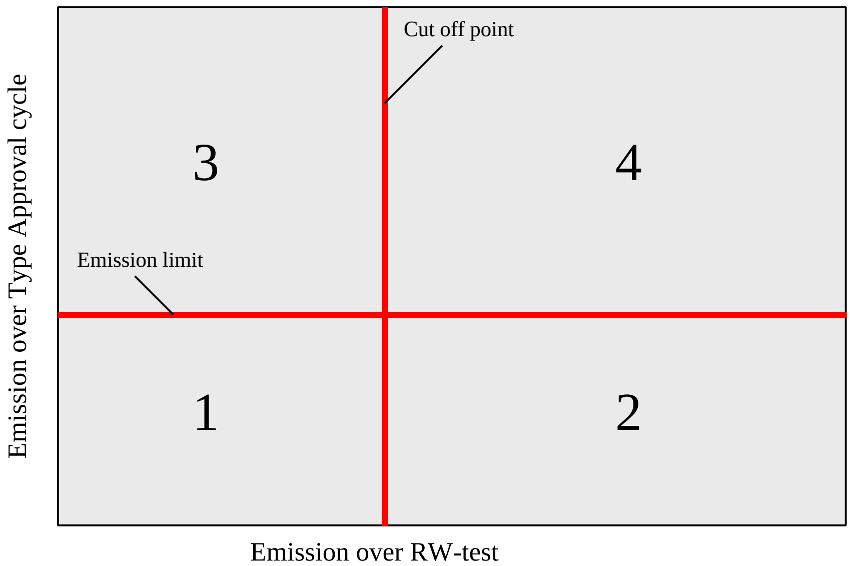

Figure 1: Basic approach

This approach, optimising the relative amount of errors of omission and commission based on the Type I test, was found suitable for finding high emitters on gaseous components CO and HC. Following this approach, cut off points for each of the three defined idle speeds, for CO and HC were determined for most of the vehicle technology classes distinguished. The accuracy of the measurement method and the equipment used was found sufficient for the purpose, taking into account some precautions (like proper pre-conditioning, cooling and connections to the vehicles exhaust system).

For motorcycles introduced on the market under future (more stringent) legislation, the procedure could not be validated. It is the opinion of the researchers that the emission levels of future technology may well cause problems in terms of measurement accuracy, because the drop in emission levels will most probably be greater than one order of magnitude.

For noise emissions, however, the accuracy of the measurement method (and circumstances) and the accuracy of the measurement equipment already poses problems under current legislation. Although this is partly caused by this measurement inaccuracy, a more important factor is the lack of a defined relationship between noise emissions at stationary (high idle) and in-motion (loaded) operating conditions. In order to avoid a large number of errors of commission, these problems led to a proposal for a noise threshold for stationary measurement of 10 dB (A) higher than the stationary noise level at time of Type Approval. Using this procedure only extremely high noise emitting vehicles will be detected (6% of the vehicles exceeded the excess noise limit of 10 dB(A)).

Estimation of the cost-effectiveness
The cost effectiveness of any proposed procedure, as well as its technological feasibility, must be assessed. In this study a procedure for calculating the cost effectiveness of a proposed RW test protocol was described. This procedure has already been used for the evaluation of the passenger car RW testing. An actual calculation of the cost effectiveness of the proposed procedures has not been executed within the framework of this study. On the one hand, an optimal procedure has not been established yet, whilst on the other hand, too many parameters in the calculation are country specific to enable an actual cost effectiveness estimation.

OVERALL CONCLUSIONS AND RECOMMENDATIONS

The investigation described in this report provided good insight into the possibilities of road-worthiness testing of motorcycles. Based on the evaluation of the data from the extensive validation programme, the protocol for road-worthiness testing initially proposed has proved to be more or less adequate for establishing a motorcycle's emission performance test (gaseous and noise) in relation to its type approval set-up.

Using the applicable Type Approval limit, the test work showed that 25% respectively 80% of the vehicles tested were not compliant on gaseous (Type I test) and noise (in-motion) emissions. However, for noise, the reservation is made that the tests were *not* performed on a test track as specified in Chapter 9 of the 97/24/EC directive.

It also became clear that very few of the tested motorcycles had been tampered with (2% on emissions and 4% on noise/exhaust). As indicated by the report of IMMA [1:Motorcycle noise: The curious silence: a report by the motorcycle industry] this is an underestimation of the real world situation, probably caused because 72% of vehicles were supplied by importers and official dealers on behalf of the motorcycle industry. However, without the help of the industry, it would not have been possible to obtain sufficient vehicles for extensive testing within the timeframe of the study.

The above mentioned high percentage of vehicles qualified as 'high emitters' seems to justify the necessity of road-worthiness testing, even more when taking into account the non-real world representative vehicle sample.

The recommended test procedure based on the results of this study, is an idle test procedure executed at low and high idle speeds using standard workshop equipment already in use for road-worthiness testing for gaseous components of passenger cars. A standard noise measurement device should, however, be added. Taking into account some additional precautions while testing, the accuracy and reproducibility of the gaseous emission measurements can be good for most of the current vehicle fleet. For noise measurements however, the reproducibility of the procedure poses practical problems.

The test results for gaseous emissions established using the proposed procedure could not be compared directly with the Type Approval limit values. In order to establish whether a vehicle is “in compliance” with the applicable TA limits, a set of threshold values (cut off points) has been calculated, based on the rule that the vehicle sample may not contain more than 5% errors of commission. These threshold values and optimal idling speeds are different for each vehicle technology class, but the range is between 3.5 and 8 Vol.-% for CO and 4000 and 8000 ppm for HC.

In order to simplify the final procedure it is recommended to investigate the possibility to establish *one* common threshold value (at one or more certain idling speeds) for each component (CO and/or HC) for all current vehicle technology classes, without increasing the errors of commission to an undesirable level. This would involve recalculating errors of omission and commission for all vehicle classes for several “common” threshold values. This recalculation could even prove that measuring only one gaseous component might be sufficient.

Noise emissions during the stationary idle test proved not to correlate with in-motion noise, posing a problem for the procedure. In addition, measured noise emissions are not as reproducible as gaseous emissions, which together means that only extremely high emitters can be established using the stationary noise test. Improving the procedure (by executing an in-motion noise test with high quality sound measurement equipment at special pavement) would significantly increase the complexity and cost of the road-worthiness test rendering its unsuitable for use during RW inspection.

For future vehicles the study was not as conclusive as it proved to be for the current vehicle fleet. Few of the latest 4-stroke engines with catalyst (under 97/24/EC Chapter 5) were included and only one 2-stroke vehicle with catalytic converter was available. Since these two vehicle classes will predominate in future due to new steps in emission legislation, additional research should be executed in order to determine the suitability of the proposed idle road-worthiness test procedure for assessing these vehicle categories. Whether or not it is suitable will largely depend, firstly on the behaviour of new technology under idle conditions (compared to loaded conditions) and secondly on whether the actual emissions, which will be about an order of magnitude lower than the emissions under the current legislation, cause problems with the accuracy of current measurement equipment.

In order to assess the cost effectiveness of the proposed procedure, a basic calculation method has been presented in this report. In order to give an example of the method, a 'back of the envelope' calculation has been executed for the Dutch situation that contains a lot of assumptions. Because of the large differences in the way road-worthiness testing is organised across Europe and the fact that no actual threshold levels have been established, it was not possible to calculate the actual cost effectiveness of the proposed procedure within the scope of the project.

Despite of the questions still to be answered, a first draft amendment text to directive 96/96/EC was set-up leaving open the actual threshold values and idling speeds for testing. Because this draft set-up is very much in line with parts of exhaust gas testing at Type Approval, using a 4.5 Vol.-% threshold for CO at low idle speed could be applied for the time being. Following the same approach for noise justifies an excess noise limit value of 10 dB(A) at the stationary test. The effectiveness of this approach however still has to be determined.

Disclaimer

Important note:

Although this study was organised in the name of CITA, the conclusions and recommendations contained in this report are a reflection of the views of the six organisations that undertook the work. Neither the report nor its conclusions and recommendations have been formally adopted by the CITA Bureau Permanent or by vote of the rest of the CITA membership and so they do not necessarily represent the views of CITA as a whole or of individual CITA members.

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L Repeatability of exhaust gas emission measurements

Acronyms and abbreviations

cm^3	cubic centimetre
CO	Carbon monoxyde
CO_2	Carbon dioxyde
COP	Conformity of Production
CVS	Constant Volume Sampling
DG VII	Directorate General VII (Transport) of the EU Commission
EC	European Commission
ECE	Economic Commission for Europe
EEC	European Economic Community
EUDC	Extra Urban Driving Cycle
FC	Fuel Consumption
FHB	Fachhochschule Biel, Switzerland
HC	Hydrocarbons
I/M	Inspection and Maintenance
IUC	In-use compliance
NO_x	Oxydes of nitrogen
OBD	On-board Diagnostics
OBM	On-board Measurement
ppm	parts per million
RESS	Replacement Exhaust Silencing System
RW	road-worthiness
TA	Type Approval
UBA	UmweltbundesAmt
UDC	Urban Driving Cycle
US-FTP	United States Federal Test Procedure
yr	year

Conversion factors

ton	1000 kilograms

1 General Introduction

On 29th December 1999, the DG VII (as it then was) of the EU Commission approved CITA's application for a grant for a second programme of studies on emission testing at periodic and other inspections.

This research programme consists of 5 studies. These are:

(1) 'Best practice' procedure for petrol vehicles;
(2) Motorcycle exhaust emissions and noise;
(3) Use of OBD during periodic inspection;
(4) Influence of catalyst temperature on emission measurements at periodic inspection;
(5) Feasibility study of a large-scale data gathering exercise.

The programme is being steered by the CITA Working Group on Emissions.

This report describes the findings from study (2) on motorcycle exhaust emissions and noise.

In order to execute the study, under leadership of CITA a consortium of experts has been set up, including TNO Automotive (project leader), VdTÜV (represented by TÜV NORD and DEKRA), MTC/Bilprovningen and the European Garage Equipment Association (EGEA). This consortium consists of experts on road-worthiness (RW) testing in general (and in particular for motorcycles), experts on Type Approval testing (especially motorcycles) and periodical inspection and in-use compliance, experts on measurement equipment and experts on automotive environmental legislation. In the initial stages of the project, another partner, AECA-ITV, the Spanish association of periodic inspection bodies, said that they would participate. Unfortunately, due to budgetary reasons they had to withdraw at an early stage. Two of the other partners, TNO Automotive and TÜV NORD/DEKRA took on additional test work to ensure that the total amount of test work remains as planned.

The execution of the study has been closely linked to another EC project: Artemis. This 5th framework project deals among other things with determining the real-world exhaust emissions from 2-wheeled vehicles and includes a large amount of vehicle tests in the TNO Automotive and TÜV NORD laboratories. Combining the test work of Artemis and the current study was found to be a very cost-efficient way of dealing with the work, although some delay in the Artemis project caused the current study to be delayed as well.

2 Introduction on motorcycle emissions and noise testing

Motorcycles are not within the scope of the road-worthiness directive 96/96/EC. The European Commission's technical adaptation committee has discussed a proposal to extend the scope to include them on a number of occasions. It was opposed by a majority of Member States, particularly those that had only just introduced, or were still in the process of introducing, periodic inspection of cars and light goods vehicles. However with increasing concern about the achievement of demanding air quality standards, attention is now being focused on all sources of exhaust emissions and how they might be controlled. In addition, concern is growing in a number of Member States about noise from motorcycles. While the noise levels of new machines can be controlled via Type Approval, control on vehicles in-use is difficult without effective periodic inspection. The Commission is under increasing pressure to re-raise the possibility of periodic inspection for this class of vehicle.

If periodic inspection of motorcycles is to be introduced, even if it is only for limited items, it is better that it is done on the basis of properly considered and developed harmonised test procedures and equipment standards. CITA therefore proposed to the European Commission a study to produce the required procedures and standards.

The aim of the investigation described in this report was to give insight in to the parameters that should be controlled on motorcycles and to develop test procedures, and if necessary equipment, for measuring exhaust emissions and noise during periodic inspection.

In addition to harmonised procedures and standards, there needs to be clear evidence that the introduction of periodic inspection of motorcycles would be cost-beneficial. Good estimates of the cost of testing, including any associated equipment and reliable estimates of the likely benefits are required before such calculations can be undertaken. The experimental work in this study provides data from which estimates can be made. The estimates of cost-effectiveness are made by an independent research institute to ensure that they are reliable and impartial.

Critical components on motorcycles are required to be fitted with anti-tampering devices to stop unauthorised adjustments and alterations that would affect the level of exhaust emissions. There is currently little data on whether these measures are effective or not. During the checks on the motorcycles in this study, the state of the anti-tampering devices has been checked and the effectiveness of the current control assessed.

TASKS AND METHODOLOGY

In order to answer the questions raised, the study involved the following tasks:

I. Investigation and definition of the topics involved, dealing with:
   - The critical motorcycle parameters (including anti-tampering devices) that have to be examined and controlled during periodic inspection of motorcycles.
   - The critical inspection parameters that must be controlled during testing to ensure the quality, reliability and repeatability of the measurements.

  - Problems with current measuring instruments in relation to testing exhaust emissions and noise from motorcycles with both 2- and 4-stroke engines.
  - Evaluation of (alternative) measuring instruments for exhaust emissions and noise adapted for use with motorcycle with both 2- and 4-stroke engines.

II. Definition of a basic measurement procedure to be used for future road-worthiness testing, based on available information on how to test exhaust gas emissions and noise on vehicles.

III. Validation of the proposed procedure. Starting with the definition and execution of a programme of testing of motorcycles to measure the exhaust emissions and noise of vehicles in use and to evaluate the correlation between static idle tests and Type Approval tests of exhaust gas emissions and noise. The programme was conducted in three different countries to ensure a proper identification of any geographical factors. It included measurements of 105 types (both 2- and 4-stroke engines) spread over the 3 countries. The motorcycles chosen for testing were a representative sample of vehicles in-use in Europe. They were tested both ‘as received’ and in some cases after maintenance.

IV. Evaluation of the results and findings and the production of a proposal for an amendment to the road-worthiness directive 96/96/EC.

V. Proposing a procedure to estimate the cost-effectiveness of the proposed procedure.

The main elements of the study were carried out by the four main participating organisations and laboratories working jointly on the initial evaluations and definition stages and in parallel for the testing and measurement phase. The European Garage Equipment Association (EGEA) has assisted with advice and the development and supply of suitably modified measuring equipment.

The study has been conducted under the general supervision of the CITA Working Group on Emissions.

3 Definition of the measurement procedure

Background

Currently not much is known about the actual exhaust gas and noise emissions of motorcycles in the field, although seven of the fifteen EU Member States have road-worthiness tests in place for motorcycles. These programmes are currently mainly focusing on safety issues. The reason for this situation is the fact that environmental legislation has not been widely applied to motorcycles until recently. There has been an ECE Type Approval procedure (and limit values for the driving cycle and idle-CO test) for two- and three-wheeled vehicles since September 1979, but very few countries have actually adopted this. An EU Type Approval (TA) procedure only came into force in 1999 (EU Directive 97/24/EC), and therefore exhaust emission levels are not assessed by current in-service road-worthiness test procedures.

This time frame of exhaust gas legislation for motorcycles plays an important role in the set up of road-worthiness testing. Since actual Type Approval legislation only come into force rather recently, it was necessary to decide which (legislative) categories of vehicles should be dealt with when developing possible test procedures. That is: whether the procedure should be applied to *all* motorcycles on the road, or only to the vehicles subject to some kind of Type Approval (in practice: later than June 1999) or only to vehicles sold after the proposed road-worthiness test procedure was introduced. An important consideration here is the fact that the way the limit values for Type Approval are set up has a basic influence on the approach to setting limit values for road-worthiness testing. Older motorcycle legislation used vehicle weight dependent TA limits; current legislation is based on fixed absolute limit values, but segregated into different technology classes (2-stroke, 4-stroke); future legislation will be based on engine capacity and maximum vehicle speed.

When setting up a road-worthiness test procedure for motorcycles for exhaust emissions and noise, significant lessons can be drawn from the procedures that have been used for passenger cars (prescribed in directive 96/96/EC) for some years. The similarities between passenger cars and motorcycles on the topics under investigation are obvious, mainly in the field of combustion principle, technical components used, fuel type and power transmission to the wheel(s). In the period from mid 1994 to end 1997, an extensive project on road-worthiness testing for cars was carried out by a consortium of research institutes on behalf of the Commission: DGs VII (Transport), XI (Environment) and XVII (energy). Relevant conclusions from this study were:

- That the current test procedure according to Directive 92/55/EEC was both sufficiently selective and the most cost effective for non-catalyst cars, if used in combination with suitable (preferably type specific) cut-off points.
- That this procedure was insufficiently selective for catalyst equipped cars, whereas for these cars a dynamic test method (short driving cycle) was much more selective, and additionally very cost effective if it could be carried out only in dedicated testing stations.

This suggests that for the present situation (where most motorcycles are still non-catalyst vehicles) the set-up as currently used for passenger car periodical inspection, that is some kind of idle test (e.g. low idle and high idle), enabling the static and unloaded measurement of exhaust gas composition (typical components) and noise, could be a good starting point for the motorcycle procedure. This would have the added advantage that such a test is less dependent on the actual TA procedure. But when testing motorcycles, some additional items have to be taken into account. These are:

– *2-stroke and non-catalyst engines versus 4-stroke 3-way catalyst technology*.
  One of the main differences between recent car and motorcycle technology is the limited use of catalyst technology and the use of 2-stroke engines (still used for significant numbers of motorcycles), compared to 4-stroke 3-way catalyst technology. This wide spread in technology causes the emission concentrations of motorcycles to spread over about 5 decades (10 ppm up to 10 Vol.-% for CO and HC). On the one hand, this makes it almost impossible to take reliable measurements on all vehicles using one instrument only. On the other hand, contamination of the sampling equipment after measuring a high emitter will probably cause problems during subsequent measurements on rather “clean” engines.

– *Typical vehicle classes*
  Where for passenger cars the classification of what is a “passenger car” is rather clear, this is not the case for motorcycles. For cars, due to European regulations on European Type Approval, clear definitions have been adopted Europe wide. At the moment there are still different definitions throughout Europe, especially differing on the point of moped/motorcycle. For these types of vehicles the exhaust emission procedure (driving cycle) and applicable limits are different. Within the noise directive 97/24/EC Chapter 9 different noise limits are applicable for engine capacity less 80 cm^3, between 80 and 175 cm^3 and over 175 cm^3.

– *Typical exhaust systems*
  The exhaust systems of motorcycles have, 3 (or 4) main purposes: keeping exhaust gas away from the driver, lowering/changing the sound level and looking good. The fourth possibility is cleaning the exhaust gas by using an inserted catalyst converter. "Looking good" and "changing the sound level" are different issues for motorcycles than they are for most passenger cars. This causes the layout of the system to be completely different from that of a passenger car, introducing problems with the insertion of sample probes and problems with the stationary noise measurement, since the (not encapsulated) engine itself may be an important additional noise source after the exhaust noise. Additionally the noise production at elevated engine speeds may cause problems during measurements in the workshop, as is already the case for diesel engined cars tested in the so-called free acceleration test.

– *Typical engine cooling systems*
  Water-cooling is a standard way of engine cooling for passenger cars. Motorcycles can be either direct air-cooled or water-cooled (with or without a cooling fan). This possible difference in cooling systems can influence the emission behaviour of a vehicle when tested at zero vehicle speed (idling). Air-cooled systems are likely to be more sensitive in this respect.

– *High power to weight ratio and high revving engines*
  When considering typical idle test conditions, the speed at which the engine is tested, is a critical part of the procedure. For passenger cars the speed ranges are very similar for all cars (especially when looking at one fuel type at a time), while for motorcycles the maximum engine speed (and even the low idle speed) may differ

by a factor of 3 between different types of motorcycles (mopeds, scooters, motorcycles, 2 or 4 stroke, etc.). This means special attention has to be paid to the selection of the actual value for the idle test engine speed.
The same sensitivity as mentioned for engine speed ranges, is relevant for power to weight ratios. For passenger cars they may differ from 35 kW/ton up to 200 kW/ton, but motorcycles may spread from 40 kW/ton up to more than 400 kW/ton. This may mean that especially for the ultra high power to weight ratios, the significance of an idle test maybe rather limited (the engine not being under any load during inspection).

– *Tampering*
  Apart from a transportation mode, motorcycles have always been a way to express one's individualism. The rather simple and cheap technological set-up of motorcycles (especially in the past) has lead to owners tampering with their vehicles in order to achieve more power, more sound and better looks. This tampering can have significant negative influences, however, on the exhaust gas composition and the sound level of the vehicles. Although in an increasing number of countries it is officially not allowed to fit non original parts to the engine of a motorcycle, tampering is still an issue to be aware of. Although tampering of the latest motorcycles is becoming less likely, because of the complexity of the technology that is now used, and because most vehicles are already overpowered even for sporty use. Changing the exhaust system in order to change the sound is, however, still an important topic for the noise production.

3.1 Current exhaust gas emission and noise directives in Europe

Exhaust gas emissions

The first exhaust gas emission legislation for motorcycles in Europe, was the Regulation 40 of the ECE. It became effective in September 1979. It contained legal limits for CO and HC produced during a driving cycle (Type I test) and for CO in an idle test (Type II test). The limit values for the Type I test were different for 2-stroke technology and for 4-stroke technology, and depended on the weight of the vehicle. The limit value for the Type II test (idle engine speed) was 4.5 Vol.-% CO. In 1988 the limits values for the Type I test were reduced (ECE Reg. 40-01). The reduction amounted to 20 % overall for 2-strokes and 30-40 % (CO and HC respectively) for 4-strokes. The limit value for the Type II test remained unchanged. Even so very few countries actually adopted this Regulation in their national legislation since the permitted emissions were judged too high to have any real effect. Switzerland and Austria were two European countries that adopted the ECE R 40 procedure, but with more stringent limit values. Some countries in the Far East did apply ECE R 40 though.

In June 1999, EU Directive 97/24/EC became effective. This legislation was adopted from the ECE procedure, but combined it with much more stringent limit values. These limit values are still different for 2-stroke and 4-stroke, but are no longer dependent on any other vehicle or engine characteristic. The TA limit values for both ECE R40-01 and 97/24/EC Chapter 5 are given in Table 1, Table 2 and Table 3. The limit values for the Type I test (driving cycle) are summarised in Table 1 for ECE Regulation 40-01 and in Table 2 for directive 97/24/EC Chapter 5. In Table 3 the TA limit for the Type II test (idle test) is given.

Table 1: TA Type I test emission limits ECE Regulation 40-01

Reference weight m in [kg]	CO [g/km] 2-stroke	HC [g/km] 2-stroke	CO [g/km] 4-stroke	HC [g/km] 4-stroke
<100	12.8	8	17.5	4.2
100 = m = 300	12.8 + 19.2 * (m-100)/200	8 + 4 * (m-100)/200	17.5 + 17.5 * (m-100)/200	4.2 + 1.8 * (m-100)/200
> 300	32	12	35	6

Note: 'reference weight' of the motorcycle is calculated by: curb mass + full fuel tank + 75 kg driver weight

Table 2: TA Type I test emission limits for directive 97/24/EC Chapter 5

	2-stroke [g/km]	4-stroke [g/km]
CO	8	13
HC	4	3
NO_x	0.1	0.3

Table 3: TA Type II test emission limits for ECE R 40-01 and 97/24/EC Chapter 5

CO	4.5 Vol.-%

For 2003 and 2006 two new stages are foreseen. The first of these only changes the limits (and without any further differentiation between engine technologies). The second comes with two sets of limits for two different engine capacities (but no differentiation between engine technologies), in combination with a further change in procedure, which is also different for the two engine capacity classes.

The test cycle for ECE R 40 and R 40-01 was the urban driving cycle (UDC), as used for cars. The test was started from cold (20 – 30°C), but sampling started after two subcycles, so the test was effectively a warm test. The same procedure was adopted for 97/24/EC Chapter 5, stages 1 (1999) and 2 (2003). Starting with stage 3 (2006) either the same cycle will be used, but with sampling from the cold start (for low engine capacity), or this same cycle, also sampled from cold, but extended with the extra-urban driving cycle (EUDC) as used for cars (for higher engine capacity). As an alternative, the new world-cycle currently under development may be used, provided that it is ready by that time; but the limit values applicable to this last option will have to be determined.

Within the proposed amendment to directive 97/24/EC Chapter 5 section 2.2.1.2 (as current available as document 2000/0136 (COD), C5-0136/02, PE-CONS 3615/02) measures are already taken to introduce future road-worthiness testing. In that it is prescribed that the motorcycle manufacturer must provide the emission values of CO at idle speed and CO at an elevated engine speed together with both engine speeds and the engine oil temperature at the time the TA test is executed. This data should also be available for all technical inspection organisations in each Member State at the time a technical inspection procedure comes into force.

Noise emissions

Noise emission legislation for motorcycles has been developed by both the EU (starting with directive 78/1015/EEC) and the ECE (ECE Regulation 41). Regarding noise both have the same requirements. Current legislation is contained in 97/24/EC Chapter 9 that uses the same test procedure as the earlier directive but specifies lower limit values.

Currently, all Member States have adopted directive 97/24/EC for type approving new models. In the TA procedure two different types of noise tests are specified, one being a stationary test and the other being a noise test measuring the motorcycle in-motion. A summary of the prescription of both tests is supplied in Appendix J. For all directives mentioned above, a TA limit value is only given for the motorcycle in-motion test. The limit value is dependent on the engine capacity of the motorcycle (see Table 4).

Table 4: Noise emission limits for motorcycle in-motion test of directives 78/1015/EEC and 97/24/EC Chapter 9

Motorcycle category by cubic capacity (in cm^3)	Sound level limits in dB(A) and dates of entry into force for national Type Approval of motorcycle			
	First stage limits in dB(A)	Dates of entry into force for national approval	Second stage limits in dB(A)	Dates of entry into force for national approval
1. = 80	77	1 October 1988	**75**	1 October 1993
2. > 80 = 175	79	1 October 1989	**77**	31 December 1994
3. > 175	82	1 October 1988	**80**	1 October 1993

Note: The noise emission limits for 97/24/EC Chapter 9 are the same as the limits for the second stage

Before 97/24/EC Chapter 9 came into force, some countries already used the procedure for testing motorcycles for noise emissions written down in the EEC directive and ECE Regulation. In the Table in Appendix A of this report, an overview is given of the state (situation at November 1995) of enforcement and legislation on noise emissions for mopeds and motorcycles [1].

Noise legislation for in-use compliance purposes is not yet supported in all European countries. The countries involved in this study (Germany, the Netherlands, Spain and Sweden) have already adopted the stationary test procedure as prescribed in 78/1015/EEC and ECE Regulation 41 for in-use compliance testing and in some cases for annual inspections. The main differences between the procedure applied in Sweden on one hand and Germany, the Netherlands and Spain on the other hand is the engine speed during idle measurement definition. Germany, the Netherlands and Spain adopted the engine speed definition of 78/1015/ EEC or ECE R41. The Swedish authorities however, chose a more scientific definition of the engine speed by testing all motorcycles at the same engine piston speed. Therefore a table of actual engine speed against the engine cylinder stroke was included in the Swedish legislation (see Appendix B).

Germany and Spain have already introduced periodic inspection on noise every 2 or 4 years respectively. In both countries the stationary noise test procedure is mandatory with the difference that the stationary noise test is executed on every motorcycle in

Spain. In Germany the inspector can decide whether the stationary noise test has to be executed or not dependent on the noise emission level he or she hears.
Whilst only a few countries undertake noise measurements during official annual inspections, many European countries use the Police to undertake in-use compliance noise measurements (in order to enforce legislation). In some countries (Germany, Italy, the Netherlands and Spain) the noise emission of the motorcycle may not exceed the reference value with an extra tolerance of +5 dB (A). The reference value in this case being the noise emission measured during Type Approval, as indicated on the identification plate of the motorcycle which also specifies the engine speed at which the motorcycle has to be tested is also indicated.

The measurement procedure for the in-motion noise tests on vehicles as specified in the EU-Directive and ECE-Regulation is based on the international standard ISO 362 (third edition; 1998). The stationary test procedure is based on ISO 5130 (1982). Both standards are currently under revision by working group ISO TC 43/SC 1/WG 42, which is a joint working group under ISO TC 43 'Acoustics' and ISO TC 22 'Road Vehicles'.

The aim of the revision of ISO 362 is to introduce essential changes in the test procedures for the different vehicle categories in order to improve the representativeness of the test conditions with respect to normal driving conditions. Up to now the Type Approval test results for passenger cars and motorcycles do not correlate to a satisfactory degree with the noise emission values under normal operation in urban traffic. The revision of the test procedure for motorcycles is primarily the responsibility of ISO TC 22/SC 22/WG 16. This group will advise WG 42, the group that is in charge of the revision of the complete standard ISO 362. The revised standard will include the revised motorcycle test procedure once WG42 has aligned it to the procedures used for other vehicles.

The revision of ISO 5130 will probably not be very fundamental. Instruction on how to deal with changes in vehicles exhaust positions that have come into use in recent years will be introduced, but the measurement principle will remain largely unchanged.

Although greater accuracy and a better correlation with noise emissions in normal traffic are needed, these needs are considered to be not compatible with requirements of ease of operation and suitability of road side test locations. The revised standards may possibly be published in 2004.

3.2 Road-Worthiness (RW) measurement procedure definition

Based on the information described before, a draft procedure for executing periodic inspection of motorcycles had to be set up. The basic idea was to set up a technically sound procedure, which should also be cost-effective in operation. The aim for a cost-effective procedure largely dictated the options that were taken into account. This approach limited the options basically to those that had been applied for passenger cars already, because of the availability of infrastructure and equipment for executing the work. This means that the draft motorcycle procedure in principle would be based on actual workshop tests looking at idle emissions of noise and exhaust gas. This approach makes even more sense, taking into account that today’s motorcycle technology is more or less at the point that passenger car technology was at the time when the road-worthiness tests (for exhaust emissions) for passenger cars were originally introduced.

Other options for road-worthiness testing of vehicles will become available in due time, because of current developments in vehicle technology (OBD, OBM, remote sensing etc.). These possible options for future road-worthiness testing will not be part of this study but could be dealt with in the proposed EC project on the cost and benefits of future options for road-worthiness testing.

As it turned out, a similar initiative to develop a road-worthiness test procedure for motorcycles had already been initiated by the UBA in Germany, closely involving TÜV Nord in the process. This initiative lead to a draft test protocol being available at the start of this study.
This German protocol was taken as a starting point, but was first evaluated thoroughly, taking into account the additional information gathered in the context of the project.
In order to set up an adequate procedure for motorcycle road-worthiness testing on noise and exhaust gas emissions, several points were taken into account:

- Vehicle categorisation (age and technical layout)
- Critical components to be checked (engine speeds for idle testing of noise and exhaust emissions)
- Test equipment to be used
- Test sequence

3.2.1 *Draft road-worthiness test set-up*

Taking into account the items mentioned above, a draft road-worthiness test procedure for motorcycles was defined. It was decided within the project team to focus on developing and validating *one* single basic procedure for *all* motorcycles, based on the passenger car procedure (directive 96/96/EC) as was also done in the German proposal. Because of the noise issue with motorcycles, a noise measurement was added. Possible additional differentiation that may be needed in the procedure in order to take care of differences between passenger cars and motorcycles and different types of motorcycles should become clear during a validation of the basic procedure. This validation was the main experimental part of this current study (see paragraph 3.2.2 and Chapter 4).

The basic procedure proposed consists of:

- general check of the vehicle status
- vehicle preconditioning (up to standard operation conditions)
- installation of test equipment (basic passenger car set up with special adapters)
- low idle test for gaseous emissions (components still to be determined)
- high idle test for gaseous emissions (engine speed and emission components still to be determined)
- high idle stationary noise test

Next some additional considerations concerning the basic protocol are discussed.

– *General check up of the vehicle status*
  This part of the procedure should in fact be part of regular service, but in the case of motorcycles it is meant to assess possible modification/tampering with the engine (carburettors) and exhaust system. The information is relevant on one hand to

explain possible increased emission levels of exhaust gas and noise, but on the other hand it is needed for selection of the measurement equipment/range.

- *Vehicle preconditioning*
  As emissions are largely dependent on the operating temperature of the engine and exhaust (catalyst), appropriate preconditioning of the vehicle will be important for obtaining correct and reproducible test results. The actual effects of certain types of preconditioning are not yet known and assessment of this topic therefore will be part of validation work.

- *Installation of test equipment*
  The basic idea of the protocol for motorcycles is to use (as much as possible) the test set-up used for passenger cars, only adding a noise test (and equipment). Basically this should not cause problems, but there are two issues to be aware about:
  1. The basic configuration of the exhaust system of motorcycles is different from passenger cars. Mostly it is not possible to insert a sample probe into the exhaust pipe deep enough in order to avoid dilution with ambient air. This problem is further increased by large pulsations at the end of the exhaust system, due to the combination of high engine speeds, small number of cylinders and limited length of the total exhaust system. In order to deal with this problem, special adapters can be used and should be validated.
  2. The emissions of 2-stroke engines and/or tampered engines can rise to levels, which the standard passenger car equipment is not designed for. Although the actual (extremely high) value is not interesting for assessing the performance of the vehicle (extreme level = non-compliant), the measurement equipment could be temporarily or even permanently damaged. Therefore some means of protection of the instruments, without influencing the measurement accuracy should be developed and validated.

- *Idle and high idle test on gaseous emissions*
  Starting point for the road-worthiness test has been the measurements of emissions at some kind of idle test (without engine load). This type of test can be executed relatively easily without the use of a chassis dynamometer and therefore gives good possibilities in being easy to execute and cheap.

  For testing exhaust emissions, using only a low idle test would, most probably, not be a good option because of the fact that most current (carburettor) vehicles use different fuelling strategies for low idling and elevated engine speeds. Therefore the basic test will not be limited to a low idle test only but will include a test at elevated engine speed. During the definition phase of the project however it was not clear how to define the elevated idle speed because the engine speed ranges of motorcycles are very different from vehicle type to vehicle type. Therefore the maximum engine speed of a vehicle should, in principle, be taken into account while testing.

  During the initial discussions of the study, it was not possible to decide on the high idle engine speed definition. The main questions that were unanswered concerned the choice between a fixed high idle engine test speed for all vehicles (which would be easy to implement in the test centres) and a vehicle specific engine speed (better reflecting the actual engine speed range of the actual vehicle tested). Because the possible benefits of vehicle specific high idle testing could not be quantified at the start of the project, it was decided to evaluate the pro's and con's of high idle testing within the project. Therefore the project group choose to use both one fixed high idle speed for all vehicles and a vehicle specific high idle engine speed. The vehicle specific high idle speed was set at 50% maximum engine speed (in analogy with 3000 rpm for passenger cars with an average range up to 6000 rpm).

In the end the evaluation of the road-worthiness test for emissions was conducted on the motorcycles on three different engine speeds being:

- Idle: idle engine speed (as in the Type II test of directive 97/24/EC Chapter 5)
- Medium idle: fixed engine speed of 3000 rpm (easy to prescribe, but not flexible)
- High idle: engine speed being 50% of the maximum permitted engine speed (to be calculated for each vehicle separately, but more flexible)

– *High idle stationary noise test*
At present, noise measurements are not part of the test protocol for passenger cars; therefore a new protocol had to be defined. It was decided to use the stationary noise test procedure according to directive 97/24/EC Chapter 9. This is a rather straightforward procedure, which can also be applied in a workshop. The problem with the noise limit values (in contrary to exhaust emissions) is that they are related to the performance at Type Approval and therefore are different for each type of motorcycle. This could seriously complicate a procedure but on the other hand, for all motorcycles, which have been type approved, the limit value can directly be found on the identification plate of the motorcycle, as is the engine speed to be used for testing. For older motorcycles the engine speed can be derived using the procedure (as indicated in directives 78/1085/EC, ECE R41 and 97/24/EC Chapter 9):

If the engine speed at maximum power (rated power) of the motorcycle is lower than 5000 rpm the engine speed to test noise is prescribed as ***3S/4****, in which S is the engine speed at rated power. In all other cases the engine speed to test noise is* ***S/2****.*

The only significant open question at this point was, whether such an idle test would be realistic for finding loud vehicles, since it is known that some tampered vehicles get loud only under non-idle circumstances. Therefore within the framework of the validation of the procedure, a non-idle (motorcycle in-motion) test was executed as well.

Compiling the items discussed above the following basic procedure was adopted:

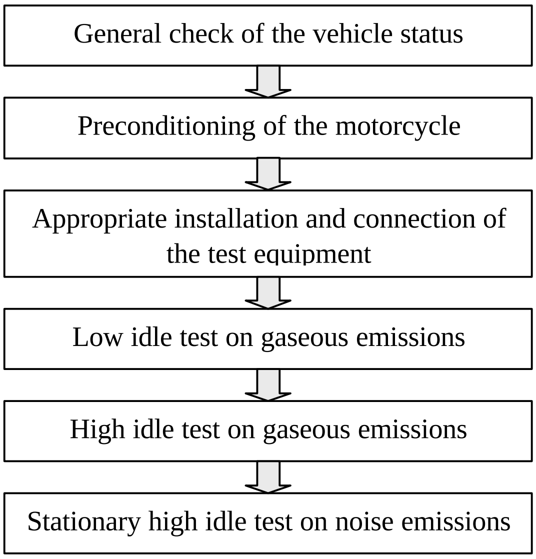

Figure 2: Proposed procedure for road-worthiness testing

In order to address the effect of the open topics mentioned above and set up a final proposal for a test procedure, a large-scale validation was set up, as described in the next Chapter.

3.3 Definition of the validation measurement programme

In order to validate the effectiveness and functionality of the proposed road-worthiness test procedure, a large-scale test programme was executed. The following points had to be examined:

- Is the proposed procedure capable of distinguishing between vehicles that just do or just do not meet their Type Approval exhaust and sound emission performance;
- Is the procedure appropriate for finding badly maintained vehicles;
- What are the (additional) specifications of the test equipment to be used;
- What is the repeatability (sensitivity) of the test procedure;
- What practical problems will occur while testing in the field;
- Which threshold values should be used in order to be cost-effective in the end;
- What role does tampering play and can it be detected.

In order to answer the questions mentioned above, a dedicated validation programme was executed. This programme consisted of testing 105 motorcycles spread over 3 different laboratories using all of the components of the proposed draft test procedure. In addition to executing the actual draft test components, some additional tests were executed in order to assess the relevance of the procedure compared to Type Approval (TA) and real-world emission behaviour.

Next the basic considerations while setting up the validation protocol are discussed.

3.3.1 Driving cycle selection

The first point to be decided on is the reference to be used, in order to assess the emission performance of the vehicles under investigation. In fact, for motorcycles there is only one reference that is the test and the results from the Type Approval procedure of the vehicle. But it is known that this procedure is not representative of actual use of the vehicle in real life. Cold start is not included in the procedure and the driving speeds (with 50 km/h maximum) and dynamics that are used are far from real-world behaviour. Therefore there is a possibility that the negative effects on emissions of non-compliant (especially tampered) vehicles will not even be distinguishable using the TA test. In order to address the issue of real-world emissions, a real-world test cycle was also introduced in the validation process.

In order to generate data on the actual relevance of the draft procedure regarding TA and real-world emission behaviour, the validation measurement programme included “loaded” emission tests over 2 different types of driving cycles being:

- TA driving cycle as described in ECE Regulation 40 and directive 97/24/EC Chapter 5
- Real-world driving cycles for motorcycles as developed by Fachhochschule Biel in Switzerland

These last real-world motorcycle driving cycles are developed by Fachhochschule Biel (FHB) in Switzerland and consists of a city-centre, a ring road and a rural part [2].

3.3.2 Motorcycle selection

The main question to be answered regarding the motorcycle selection for validation, is the aim of the validation. On one hand the validation should be appropriate for the vehicles that finally will be tested using the proposed procedure, but on the other hand the results gained should enable thorough evaluation of the proposed procedure. These two items are in fact contradictory when looking at the vehicle selection for validation.

One of the reasons for this situation is the fact that vehicles that will be dealt with under the proposed procedure will most probably not be the vehicles sold before official introduction of the procedure. This means that the vehicles to be dealt with will be vehicles sold later then 2003. Since motorcycle technology is rapidly developing (under pressure of tightened Regulations), the composition of vehicle fleet (technologies) on the road now, will have changed significantly by the time the procedure can be implemented. So one would like to validate the procedure on a set of vehicles representing the post 2003 situation, but these vehicles are not yet for sale.

The second reason for the contradiction in vehicle selection is the fact that the validation process should result in an evaluation of the effectiveness (technical and costs) of the procedure. In order to execute this evaluation, correlations have to be made based on an adequate set of data. Adequate in this context means using a wide spread in emission data set, ranging for very low values up to actual high emitters. Getting these data is only possible by testing a mix of new and old technologies, in combination with testing new and aged vehicles.

In order to obtain the wide spread data set needed, it was concluded that it would be most appropriate to base the vehicle selection on the actual (known) fleet composition in the year 2001 in Europe. This composition, on the one hand includes (some) new technology vehicles and, on the other hand does not leave out the vehicles older than 10 years. The complication caused by this selection; namely that the high emitters used will be most probably based almost only on very old technology, will be dealt with by evaluating all data within a technology bases framework. This means that the evaluations of the data will be made for 2-stroke, 4-stroke, catalyst and non-catalyst technology separately. Unfortunately the very latest technology, such as direct injection 2-stroke, could not be taken into account because the lack of sales of these vehicles.

Since the proposed procedure should be implementable in all European countries, an indication of the 2001 division of the different types of motorcycles over Europe was needed. In the related Artemis WP500 project, which deals with deriving representative emission factors for motorcycles, a study was started to give an overview of the current situation in Europe. The result of this study has been used in the CITA project to select the motorcycles to be tested and is summarised in the Table included in Appendix B.

3.3.3 Measurement equipment

As mentioned earlier it was decided by the project-working group to aim at a procedure in which the basic equipment from the passenger car road-worthiness test procedure could be used. Therefore the motorcycle test was set up to use a standard exhaust-gas measurement apparatus (under regulation 96/96/EC and according to the requirements indicated in OIML R 99 / ISO 3930). Looking at the level of possible exhaust emissions of motorcycles, using this apparatus should be possible, since the test equipment was designed to adequately measure emissions from 4-stroke engines with and without after treatment systems. The first motorcycles that most probably will be tested under the procedure to be developed will be equipped with similar technology. The only possibly problematic area is the measurement of 2-stroke engines, especially of older make. These engines tend to emit high concentrations of unburned fuel and lubricants, thereby potentially causing very high emissions of hydrocarbons. This situation causes 2 potential problems:

1. The fact that the emissions of HC are too high to be actually measured. This in fact is not a major problem, because if emissions are elevated over the maximum HC measurement range of the exhaust gas analyser, the vehicle is out of compliance anyway;
2. The unburned hydrocarbons and lubricant can cause system hang-up since they condense in the sample probe or in the test apparatus, causing the problem that the HC measurement of other motorcycles is incorrect and that the test equipment can be damaged permanently by the influence of high HC emissions.

In order to increase the applicability of the standard passenger car testing equipment for the (2-stroke) motorcycle application, problem 2 had to be solved. Together with EGEA experts, the topic was analysed in detail. It turned out the hang-up could be avoided by installing some kind of additional filter in the sample line before the actual measurement cells. In this sample line, some filters are normally already present, but they were installed to keep particulate matter and water from entering the measurement cells. Hydrocarbons (gaseous or droplets) would most probably not be filtered out completely.

The most promising option for solving the hang-up problem seemed to be some kind of active carbon filter, which in the end would absorb all hydrocarbons in the exhaust gas. For that reason this kind of filter would be installed only while testing vehicles suspected to by high emitters (old 2-stroke or tampered with). If a first measurement of CO (with the filter installed) showed no extreme CO levels, the measurement should be repeated without the filter installed measuring CO and HC. For vehicles with extreme CO levels, no repetition of the measurements is necessary, because of the vehicle is failing on CO already.

This option was investigated by EGEA in more detail, and it turned out that large active carbon filters in addition to HC, absorb CO and CO_2 as well. Saturation of these big (1 litre) filters with CO and CO_2 typically occurred after 3 to 5 minutes of sampling. Since no other type of HC-trap was available at the time that the validation programme of the study was started, it was decided to use this type of large active carbon filter. This ensured that the measurement apparatus used is protected when measuring vehicles suspected of being extreme high emitters. For optimal hang-up protection, the filter was mounted directly after the steel sample probe (see validation programme test protocol in Appendix D). To ensure that also no HC droplets enter the sample probe and cause any hang-up, it was prescribed to use a standard fuel filter to be placed before the HC trap in case of testing a suspected high HC emitter.

At the moment it is known that additional investigations performed by EGEA members in Italy and India on 2-stroke motorcycles showed that typical smaller filters did not show significant CO and CO_2 absorption. Therefore these filters are found useful for protection of the exhaust-gas measurement equipment during scanning suspected high emitting vehicles.

3.3.4 *Reproducibility*

One of the important issues while validating the proposed road-worthiness test protocol was to gather information on the reproducibility of the procedure. The reproducibility level is mainly influenced by:

- The way the desired test conditions can be applied to a vehicle. Creating stable and accurate idle engine speeds is rather demanding with sensitive hand controlled throttles, and rev counters that are either not present or not accurate or easily readable.
- The stability of the relevant engine and exhaust parameters. Parameters like engine (coolant) temperature, exhaust and catalyst temperature and environmental conditions (pressure, humidity and temperature) potentially have a large influence the emissions of motorcycles. Therefore correct preconditioning under stable meteorological conditions most probably is a must for reliable results.
- The repeatability of the measurement instruments set-up is an important issue as well. In fact not only the measurement cells are concerned here, but also the connections of the system to the exhaust pipes (backpressure and dilution) can influence the measurement results.

In order to address the issues mentioned, the following tests were incorporated in the validation set-up:

- Immediate subsequent repetitions of a certain idle tests (or parts), in order to find out about the overall repeatability.
- Two different types of preconditioning were used and analysed separately.

3.3.5 *Measurement sequence*

The emissions of vehicles in general are largely dependent on the actual operating conditions of vehicle, with engine/exhaust temperature being one of the most important issues here, as mentioned above. Therefore the effect of these conditions had to be investigated. In addition to the measurement sequence as proposed for the actual road-worthiness test, the validation programme asked for special attention for the test sequence because of the questions to be answered regarding reproducibility. Therefore the next sequence for the validation was selected:

- Preparation of the measurement procedure to be executed for the motorcycle containing:
  - visual inspection of the motorcycle to be tested and initial entries in the test report file
  - adjust chassis dynamometer to the correct inertia and road load setting
  - preconditioning of the motorcycle (driving it to operational temperature and let it cool down for at least 6 hours in a temperature conditioned room)
- Sampling and collection of emissions during driving the:
  - pre-conditioning driving cycle (2 times driving the subcycle of 195 seconds) as specified in directive 97/24/EC Chapter 5
  - TA driving cycle (UDC)
- Idle exhaust-gas measurement procedure after the TA driving cycle
- Preconditioning of the motorcycle by driving on the chassis dynamometer in order to minimise the influences of the idle tests on the emissions and to be sure the motorcycle is at operating temperature again and no exhaust gas sample is stored in the exhaust pipe.
- Driving the real-world driving cycles of FHB and sample emissions for the separate parts:
  - Zentrum (city-centre)
  - Peripherie (ring-road city driving)
  - Ueberland (rural)
- Idle exhaust-gas measurement procedure after the real-world driving cycles of FHB
- Noise emission test as prescribed in directive 97/24/EC Chapter 9
  - Stationary noise test
  - Motorcycle in-motion noise test

When the exhaust emissions (on components CO, HC or NO_x) of the motorcycle are exceeding the limits prescribed in the applicable directive, the motorcycle has to be serviced and the validation programme is repeated. This procedure is implemented in order to gain an insight into the different maintenance possibilities that can occur, their costs and the benefits of the maintenance on the emissions. The information is required for the cost-effectiveness study.

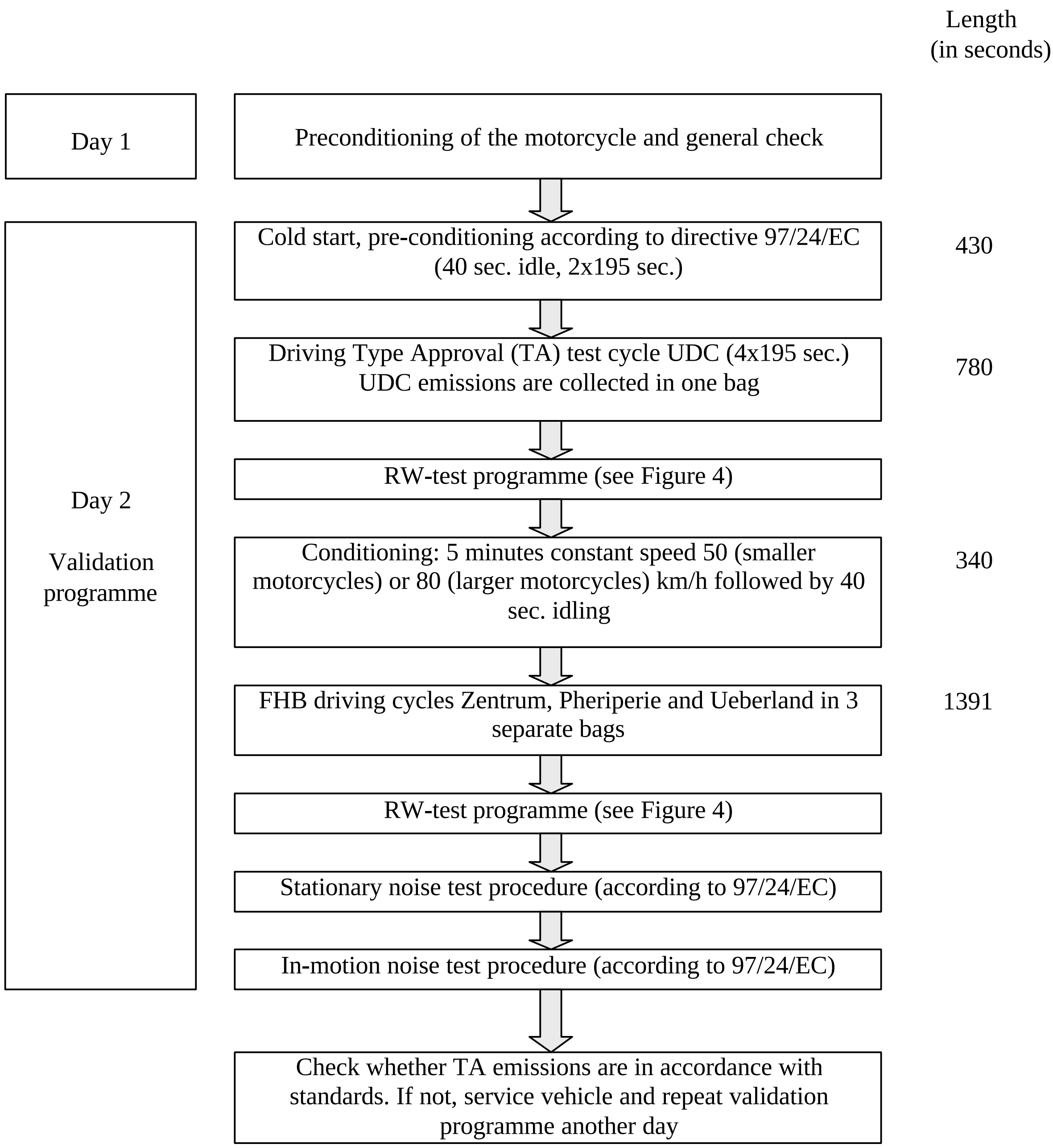

Figure 3: Validation test programme procedure

Note: After the conditioning period of driving at constant speed at 50 or 80 km/h, which will be ended by coasting from 50 (80) km/h to 0 km/h on the chassis dynamometer in neutral, the engine does not have to be turned off. Directly after the idle period of 40 seconds the next driving cycle sequence can be started.

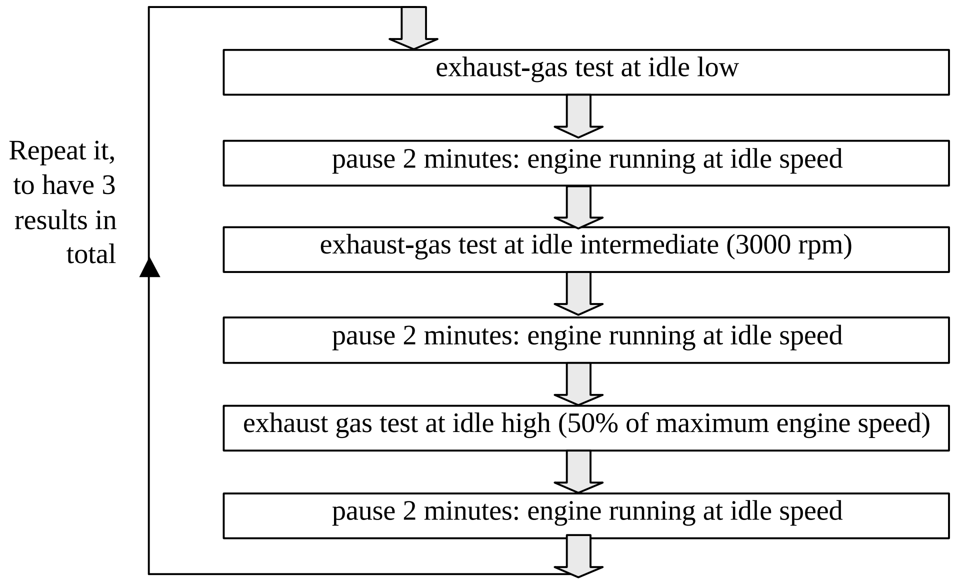

Figure 4: Flowchart of specific exhaust-gas test at idle procedure

Note 1: Measurement results have to be stored when emission level and engine speed is stable for minimal 2 seconds.
Note 2: This test procedure has to be repeated to have **3 results** (for repeatability) in total.

The detailed validation test programme protocol is included in Appendix D. In order to speed up the process of data processing and to be sure that the emission results are calculated using the same methodology, a test report file template has been developed. The vehicle data and the driving cycle and exhaust-gas at idle emission values of each single motorcycle that is tested in the validation programme has to be filled in. The format of that test report file template is included in Appendix E.

4 Discussion of results on the validation of the proposed procedure

In order to be able to prescribe a draft set-up for a final road-worthiness test procedure for motorcycles, the data gathered during the validation process of the proposed procedure has to be analysed and discussed. The analysis of the measurement data gathered in the 3 collaborating laboratories is presented here. The evaluation of the data on exhaust gas and noise is done separately. The conclusions of both subjects are gathered in Chapter 7.

4.1 Exhaust emission results

4.1.1 Introduction on data evaluation

It has been mentioned earlier that there are some major differences in engine and after treatment technology directly influencing the emission level of motorcycles. Therefore the evaluation of the emission data was executed for the four main technology groups separately. These groups are:

- motorcycles having a 2-stroke engine and without catalyst
- motorcycles with a 2-stroke engine and a catalyst
- motorcycles having a 4-stroke engine and without catalyst
- motorcycles with a 4-stroke engine and a catalyst

This main division is generally used throughout paragraph 4.1.

Since the TA limit values are different for the applicable regulation or directive, the evaluation of the results is occasionally divided in the ECE Regulation 40 (limits for ECE R 40-01) or directive 97/24/EC Chapter 5 in order to find better relations in the test results. The TA limit values for the Type I test (driving cycle) and for the Type II test (idle test) are given in paragraph 3.1.

4.1.2 Overview of motorcycles tested

Within the validation programme, a total of 112 motorcycles were tested. Table 5 lists the number of vehicles differentiated by technology classes and applicable regulation or directive. An extensive overview of the exact types of motorcycles tested and specific parameters (swept volume, age, odometer, etc.) is given in Appendix F.

The table shows a distribution of vehicles over the four classes, which is not in line with the desired distribution (as shown in Appendix C). Small 2-stroke vehicles equipped with a catalytic converter are particularly lacking in the distribution. This was partly caused by the early withdrawal of the Spanish association of periodic inspections (AECA-ITV), which would have been in a better position to obtain smaller vehicles for testing. It proved to be difficult for the remaining northern European laboratories to get hold of used small motorcycles.

Table 5: Overview of tested motorcycles

Category	Emission directive	Number of motorcycles tested
2-stroke w/o catalyst	**Both**	**17**
2-stroke w/o catalyst	ECE R40	12
2-stroke w/o catalyst	97/24/EC	5
2-stroke catalyst	**Both**	**1**
2-stroke catalyst	ECE R40	-
2-stroke catalyst	97/24/EC	1
4-stroke w/o catalyst	**Both**	**82**
4-stroke w/o catalyst	ECE R40	37
4-stroke w/o catalyst	97/24/EC	45
4-stroke catalyst	**Both**	**18**
4-stroke catalyst	ECE R40	2
4-stroke catalyst	97/24/EC	16

4.1.3 High emitters overview

The first evaluation that was executed was looking at the emission status (high emitter or not) of the vehicles obtained for testing. As mentioned earlier, it is of major importance to find a wide spread of technologies and actual emission levels in order to be able to evaluate the proposed procedure.

Within the validation test programme the Type I and Type II test as prescribed in ECE Regulation 40 and directive 97/24/EC Chapter 5 were executed on 112 motorcycles. In order to locate the 'high emitting motorcycles', the limits given in the regulation and the directive are used as summarised in Table 1, Table 2 and Table 3. A 'high emitter' is defined as a motorcycle producing emissions (in the TA test) which are exceeding the applicable emission limit. In Table 6 the 'high emitters' on the Type I test are summarised for each technology class and also separated in CO-, HC- and CO and HC 'high emitter'. Also the evaluation of the number of vehicles exceeding the limit for the applicable regulation or directive is included. In Table 7 the 'high emitters' are summarised for the Type II test. In that Table also the number of motorcycles found as 'high emitter' in the Type I *and* the Type II test are indicated.

In order to illustrate the results graphically, the high emitting motorcycles and the vehicles having emissions below the limits, the CO and HC values, relative to the applicable limit, are shown in Figure 5. Both red lines indicate the limit (100%: emission measured in validation programme = TA emission).

Table 6: 'high emitters' overview of Type I test (driving cycle on chassis dynamometer)

Type	All	2-stroke non-cat.	2-stroke cat.	4-stroke non-cat.	4-stroke cat.
CO 'high emitter'	25	5	1	16	3
HC 'high emitter'	19	13	1	5	-
CO and HC 'high emitter'	10	5	1	4	-
NO_x 'high emitter'	2	1	-	1	-
Total tested	121	18	1	84	18
Total 'high emitters'	30	13	1	17	3
Total % 'high emitters'	25%	72%	100%	20%	17%
ECE R40 tested	53	13	-	38	2
ECE R40 'high emitters'	15	10	-	5	-
ECE R40 % 'high emitters'	28%	77%	-	13%	-
97/24/EC tested	68	5	1	46	16
97/24/EC 'high emitters'	19	3	1	12	3
97/24/EC % 'high emitters'	28%	60%	100%	26%	19%

Note that the total number tested is not the same as the total number of vehicles in Table 5 since for some motorcycles 2 sets of tests (before and after maintenance) were executed.

Table 7: 'high emitters' of Type II test (idle test)

Type	All	2-stroke non-cat.	2-stroke cat.	4-stroke non-cat.	4-stroke cat.
Type II test 'high emitter'	13	3	1	9	-
Type II test 'high emitter' ECE R40	8	3	-	5	-
Type II test 'high emitter' 97/24/EC	5	-	1	4	-
Type I AND Type II test 'high emitter'	6	1	1	4	-
Type I AND Type II test 'high emitter' ECE R40	2	1	-	1	-
Type I AND Type II test 'high emitter' 97/24/EC	4	-	1	3	-

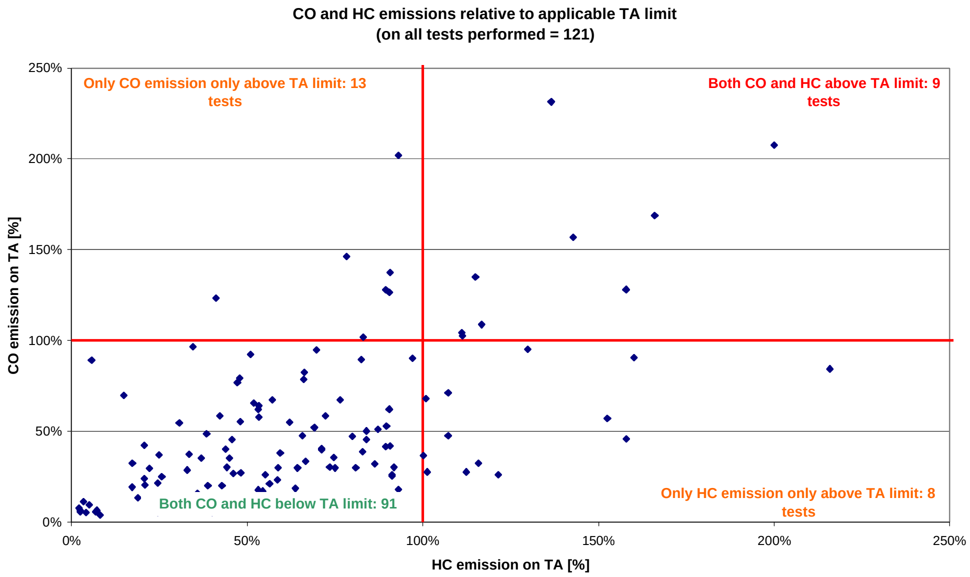

Figure 5: CO and HC emissions related to TA limits

The results presented in the above tables and graph lead to the following conclusions:

- The desired wide spread of emission levels under and over the TA limit has occurred.
- All 2-stroke CO high emitters are also high on HC. So, for these motorcycles it may be possible that the road-worthiness test procedure only consists of an idle test on hydrocarbons.
- The percentage of high emitters in the category of 2-stroke motorcycles is rather high (greater than 50%) in both ECE R40 and 97/24/EC.
- The percentage of high emitting 4-stroke motorcycles is rather high for the latest directive 97/24/EC compared to ECE R40
- There are only two high emitters on NO_x on the Type I test. Because of this low failure rate and since the exhaust-gas test equipment used for idle measurements on passenger cars is not able to measure NO_x, this component is excluded from further evaluation.
- The Type II test procedure only (low idle test) is not sufficient to locate all 'high emitters'.

4.1.4 *Correlation between Type Approval (TA) and Road-Worthiness test procedure*

The aim of the underlying project is to set up a procedure capable of finding vehicles not complying with the TA Type I test standards, but by executing a simpler test than the Type I test on a chassis dynamometer. If such a test procedure can be found, the definition of the emission levels measured during the simple test at which the vehicle does not comply with TA Type I limits is the major issue. The easiest way of finding these levels would be the use of a correlation between the TA test and the simple test results, and calculate the respective levels for the simple test from the correlation curve with the TA test results.

In order to find a defined correlation between the TA test result of a typical vehicle and its performance in the draft road-worthiness test, a data analysis was executed. In Figure 6 an example of such an analysis is given. In that figure three separate graphs are displayed. Each graph contains the measurements results from one of the prescribed 3 idle engine speeds, in this example, first for *all* motorcycles tested. The points and lines indicate the relation between the hot UDC test cycle (TA) and the road-worthiness session, split up for each of the 3 idle engine speeds executed. For the purpose of getting insight on the effects of preconditioning on the correlation, the average road-worthiness test results gathered after preconditioning using the UDC and the FHB driving cycles are presented.

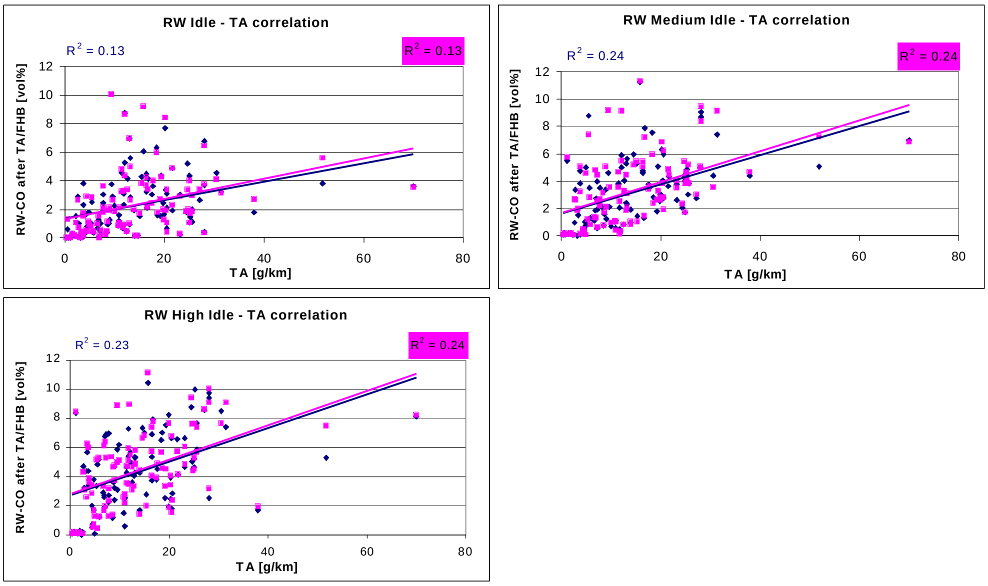

Figure 6: Correlation between TA emissions and road-worthiness tests for all motorcycles

As could be expected the correlations found when looking at all 4 technology types of vehicles at the same time, are not good. Therefore in Table 8 the correlation factors between TA and short test (road-worthiness test) for each separate class are presented. For the component HC, the same evaluation has been made. In Table 9 the correlation factors for HC are summarised. Note that a correlation factor lower than 0.7 means there is no significant relation between the analysed parameters.

Table 8: Correlation factors (R^2) for CO on TA and proposed road-worthiness test procedure for each technology class

RW after TA	R^2 idle	R^2 medium idle	R^2 high idle	Number of correct tested vehicles
All	0.13	0.24	0.23	102
2-stroke w/o cat.	0.31	0.26	0.10	15
2-stroke cat.	-	-	-	1
4-stroke w/o cat.	0.09	0.19	0.23	72
4-stroke cat.	0.29	0.66	0.29	14
RW after FHB	**R^2 idle**	**R^2 medium idle**	**R^2 high idle**	**Number of correct tested vehicles**
All	0.13	0.24	0.24	102
2-stroke w/o cat.	0.30	0.28	0.30	15
2-stroke cat.	-	-	-	1
4-stroke w/o cat.	0.23	0.21	0.24	72
4-stroke cat.	0.30	0.65	0.35	14

Table 9: Correlation factors (R^2) for HC on TA and proposed road-worthiness test procedure for each technology class

RW after TA	R^2 idle	R^2 intermediate	R^2 high	Number of correct tested vehicles
All	0.45	0.56	0.51	99
2-stroke w/o cat.	0.48	0.53	0.56	9
2-stroke cat.	-	-	-	-
4-stroke w/o cat.	0.04	0.15	0.08	75
4-stroke cat.	0.05	0.00	0.25	15
RW after FHB	**R^2 idle**	**R^2 intermediate**	**R^2 high**	**Number of correct tested vehicles**
All	0.40	0.37	0.41	99
2-stroke w/o cat.	0.41	0.42	0.47	9
2-stroke cat.	-	-	-	-
4-stroke w/o cat.	0.02	0.03	0.06	75
4-stroke cat.	0.15	* 0.00	0.19	15

* indicates that a negative correlation is found

As can be seen from the results of Table 8 and Table 9 (and the corresponding graphs as shown in Figure 6) correlations between TA- and RW-test even when looking at separate vehicle classes are still poor for emission components CO and HC. Looking at this direct TA/RW-test data comparison, the following conclusions can be drawn:

- The correlation found between the CO- and HC-emissions produced during the TA test cycle and the road-worthiness test procedure for the different engine speeds are in most cases not significant, even if the measurement results are evaluated using the technology class division. For some technology classes the correlation is even worse than 0.1 and in case of HC some negative correlation factors are found. These extremely low correlations found disable the option of calculating a threshold value from a direct relation between the emissions produced during the RW-test and driving cycle test.

- In some cases, a difference is found in the results of the RW-test executed after the TA and the FHB driving cycle. The observed differences are mainly dependent on the motorcycle preconditioning, motorcycle repeatability and sampling method. In paragraph 4.1.6 this subject will be discussed more in detail.

4.1.5 "Errors of omission and commission"-approach

Since no significant relation was found between the RW-test emissions and the TA driving cycle emissions, another approach had to be found in order to correctly identify high emitting vehicles using the RW-test. In an earlier project concerning the Inspection and Maintenance of passenger cars, executed on behalf of the European Commission, the same problem occurred. The problem than was solved by evaluating the data using an approach in which the threshold values were established by optimising the "errors of omission and commission" [3].

Figure 7 shows the basic concept of optimising the "errors of omission and commission".

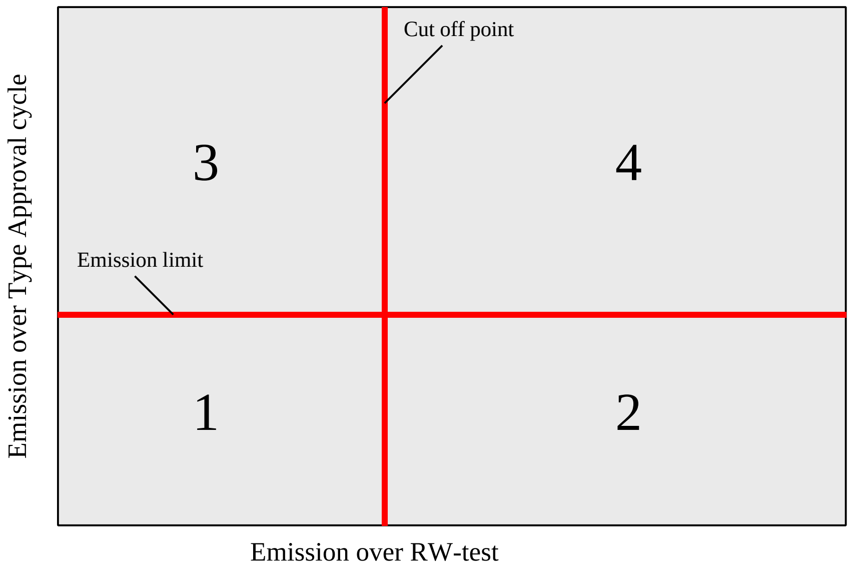

Figure 7: Basic approach

The figure shows four fields of performance of a vehicle. The motorcycles in group 1 are referred to as low polluters and the very high polluters in group 4 are referred to as vehicles to be sent to maintenance. The vehicles in group 2 are the errors of commission which are wrongly detected by the RW-test, while those in group 3 are the errors of omission which are wrongly *not* detected by the RW-test. The errors of commission and omission should be as few as possible with regard to legal protection of citizens and environmental benefit respectively.

Since there is one chart for each pollutant (in this case CO or HC because NO_x has been found not distinguishable) “overlapping” among vehicles’ pollutants is bound to occur (see also Table 6). This means that a particular vehicle could be placed either in different or in the same group according to its emissions. Therefore a vehicle is referred to as to be sent to maintenance when at least one pollutant lies in group 4. A vehicle is an error of commission when at least one pollutant lies in group 2, but no one in group 4 (in that case the vehicle would be referred to as to be sent to maintenance). A vehicle is referred to as a low polluter when all pollutants are located in group 1.

The basic concept of this methodology is to define limits for the RW-test in a way that the vehicles in group 2 and 3 are minimised. This “cut off point” optimisation procedure is executed by calculating the percentage of vehicles in group 2 and 3 while the value of the cut off point is changed. The errors of commission should not exceed 5% because higher values will not increase the environmental benefit enough to justify the additional total costs of the road-worthiness procedure.

The measurement data have been evaluated according to this procedure for each technology class separately and for each type of idle (RW) test. Applying the optimisation method to only low idle engine speed did not lead to the possibility to define a cut off point with which the errors of commission value was lower than 5%. Therefore the calculation was executed again using the results of all three engine speed idle tests. This evaluation clearly showed the need for combination of low and high idle speed tests in order to obtain errors of commission lower than 5%.

In Figure 8 the errors of omission and commission are indicated for motorcycles having a 4-stroke engine, are equipped with a catalyst and are type approved according directive 97/24/EC. For each of the technology classes the same evaluation has been made and the charts are presented in Appendix G. The optimum cut off points are summarised in Table 10. The last column of the table indicates whether the RW-test at that engine speed should be executed in the procedure or not.

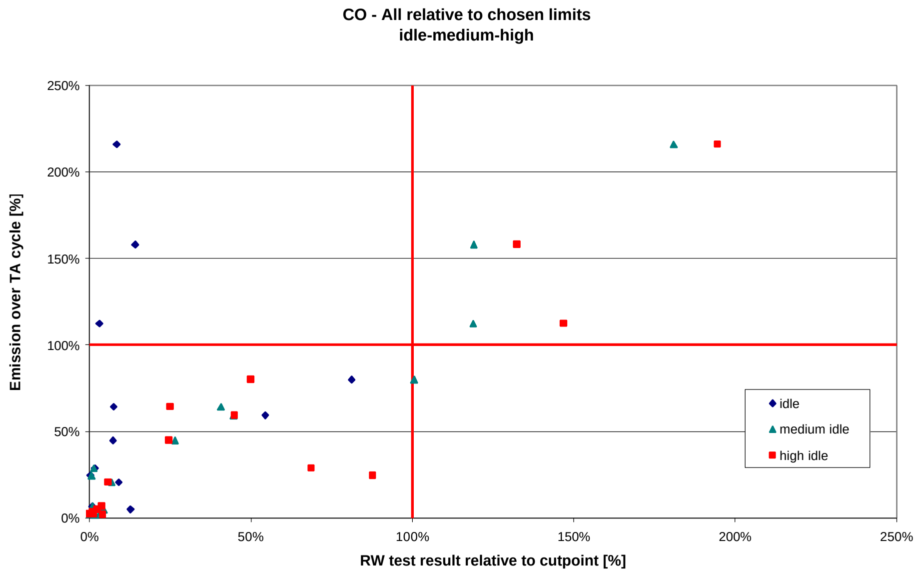

Figure 8: Errors of Omission and Commission after cut off point optimisation method (5% errors of commission) for 4-stroke motorcycles equipped with catalyst, type approved according to 97/24/EC

Table 10: Cut off points (thresholds) of all technology classes taking into account rule of 5% errors of commission

Technology class	RW-test	CO-cut off point [Vol.-%]	HC-cut off point [ppm]	Include idle test in proposed procedure
2-stroke w/o catalyst, ECE R40	Idle	4.5	8000	Yes
	Medium idle	5	8000	No
	High idle	5	7000	Yes
2-stroke w/o catalyst, 97/24/EC	Idle	4.5	6500	Yes
	Medium idle	3.5	4000	No
	High idle	4	4000	Yes
2-stroke with catalyst, 97/24/EC (1)	Idle	-	-	-
	Medium idle	-	-	-
	High idle	-	-	-
4-stroke w/o catalyst, ECE R40 (3)	Idle	4.5	-	Yes
	Medium idle	6.5	-	Yes
	High idle	8	-	Yes
4-stroke w/o catalyst, 97/24/EC (3)	Idle	4.5	-	Yes
	Medium idle	5	-	Yes
	High idle	7	-	Yes
4-stroke with catalyst, ECE R40 (2), (3)	Idle	-	-	-
	Medium idle	-	-	-
	High idle	-	-	-
4-stroke with catalyst, 97/24/EC (3) , (4)	Idle	4.5	-	Yes
	Medium idle	5	-	No
	High idle	5	-	Yes

Notes:
(1) Only one motorcycle tested in the validation programme, no cut off points can be calculated
(2) None of the tested vehicles were 'high emitters'
(3) It was not possible to define a HC cut off point for the 4-stroke ECE R 40 'high emitters' taking into account the rule of 5% errors of commission.
(4) In technology class 4-stroke with catalyst according to directive 97/24/EC Chapter 5 no high emitters on HC were available.

Based on the calculation of the cut off points for the 7 legislation/technology classes, it can be concluded that:

- Taking into account the rule of having not more than 5% errors of commission, cut off points can be found for 5 out of 7 classes of motorcycles. Not being able to calculate cut off points for 4-stroke with catalyst under ECE R40 does not in fact pose a problem, because these vehicles are not sold anymore, and therefore they will most probably never be tested using the developed RW-test. Not having data to calculate cut off points for 2-stroke with catalyst however is a principal problem, since these vehicles will be major in sales by the time the RW procedure could be applied. Therefore at the point of major sales of 2-stroke with catalyst under regulation 97/24/EC Chapter 5 (and the next steps of legislation) additional measurements and cut off point calculations should be executed, in order to be able to assess the emission performance of this group of motorcycles.

- For each of the vehicle classes (with sufficient data) cut off points for CO have been found for all 3 types of idle test. In the case of the 2-stroke motorcycles or the 4-stroke ones *with* catalytic converter, idle tests are best performed at two engine speeds (idle and high idle). When one of the idle test results exceeds the prescribed cut off point the vehicle is indicated as a 'high emitter'. For the 4-stroke motorcycles *without* catalyst idle tests are best performed at three engine speeds (idle, medium idle and high idle). Such a motorcycle is indicated as a 'high emitter' when the result of 2 or more of the idle tests exceeds the cut off point. This methodology leads to an error of commission value lower than 5% of the tested motorcycles. However, the decision of which tests have to be executed during an actual road-worthiness test and which limits should be applied has to be made by the Commission and the Member States.
- 2-stroke engines show additional cut off points for HC as well. Whether this test should also be executed has still to be decided since there still is the problem of possibly having the exhaust-gas test equipment for HC (permanently) damaged.
- Which test to be used for which vehicle type has to be decided yet, taking into account items like optimal correlation on the one hand and simplicity of the RW procedure on the other hand. The overall conclusions will deal with this decision.

4.1.6 Reproducibility and preconditioning of the Road-Worthiness test procedure

After deciding on an actual cut off point for motorcycles, the next major issue is the quality of the measurement of data used for the cut off point. Therefore the reproducibility of the RW-test procedure has to be evaluated. The reproducibility of the measurements is also an indication for the accuracy of the results, which is really important since the idle test results are used to indicate if a motorcycle needs maintenance or not. In order to assess the reproducibility of the test results, the relative maximum spread (being the maximum difference between the average of the three consecutive measured value and the maximum measured value) has been calculated for the three individual results of the idle tests at the three different engine speeds. The results of this calculation are displayed in Figure 9 and Figure 10 for CO and HC respectively. Note that in these graphs only the results of the measurements executed after the UDC driving cycle (TA) and, for HC, measured *without* HC trap are included. The evaluation of the relative maximum spread of the RW-test measurement data executed after the FHB driving cycles shows a corresponding relation.

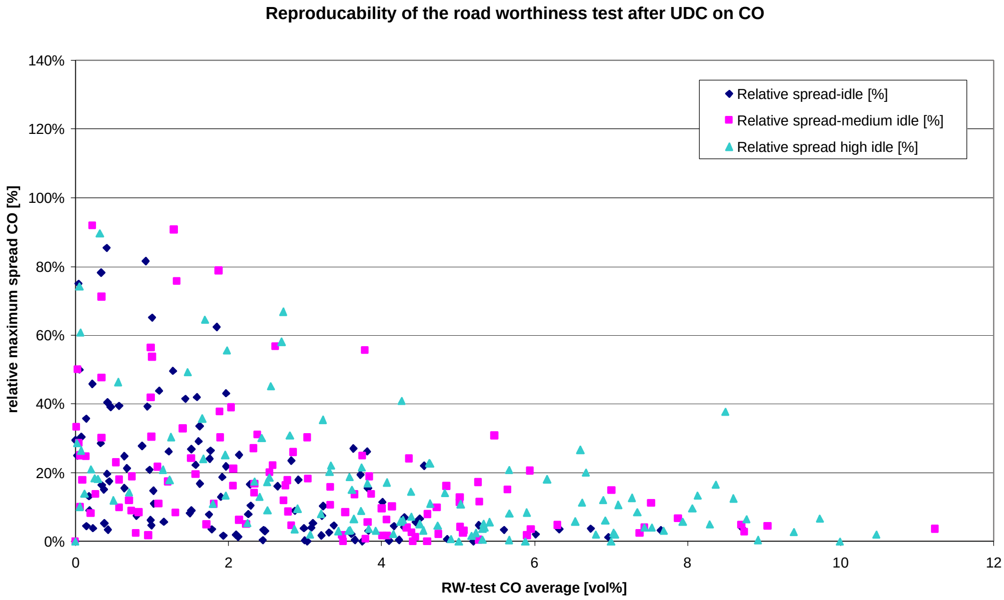

Figure 9: Relative maximum spread related to average absolute CO value

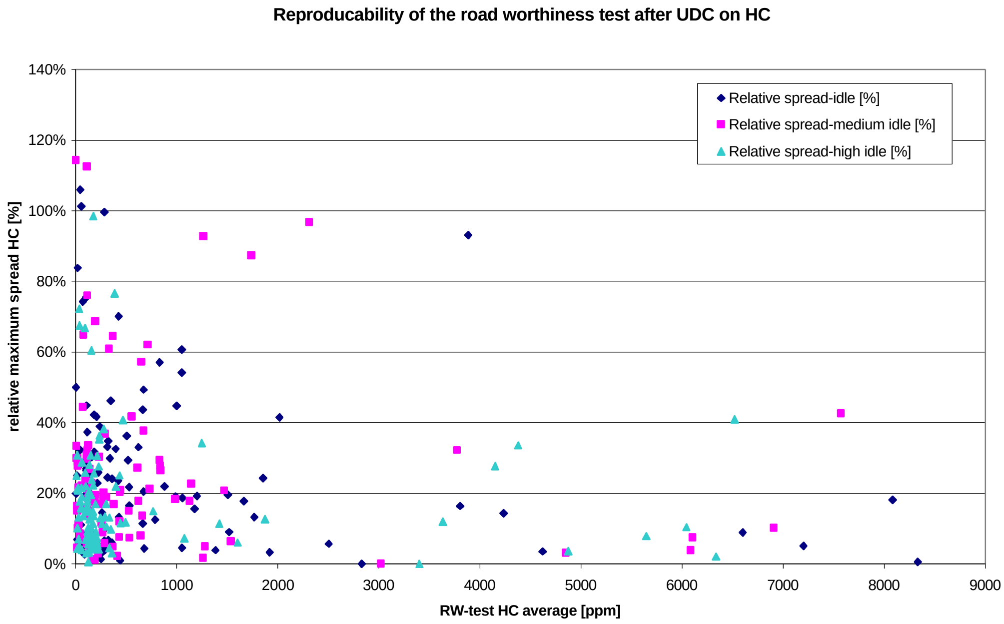

Figure 10: Relative maximum spread related to average absolute HC value

From Figure 9 and Figure 10, the conclusion can be drawn that the current RW-test procedure has a good reproducibility (<20% maximum relative spread) at the CO and HC concentrations which are around or over the cut of points that have been calculated. Of itself this is a satisfactory results and a good basis for executing correct road-worthiness testing.

However, the reproducibility of the RW-test results is not dependent on one factor only but is build up of the following parameters:

- Reproducibility of the motorcycle itself
- Repeatability and accuracy of the RW-test equipment
- Preconditioning of the motorcycle
- Other important issues

In order to gain more insight in the factors influencing reproducibility, the following paragraphs discusses the separate influence of each of the parameters.

4.1.6.1 *Reproducibility of the motorcycle*

During the validation programme, the MTC laboratory performed some extra measurements in order to gain insight in the reproducibility of motorcycle emissions. Therefore, at MTC three consecutive measurements over the FHB driving cycles were executed using a 2-stroke motorcycle *without* catalyst, one 4-stroke *without* catalyst and again a 4-stroke motorcycle but then equipped *with* a catalytic converter. In order to check the spread in the emission values, the absolute emission level and the maximum spread of the three consecutive measurements of the CO and HC emissions for these motorcycles are summarised in Table 11. In Appendix L, the results are illustrated in a graph.

Using the measurement results of MTC it is concluded that for the motorcycles without catalyst the repeatability of the emission is rather good (maximum spread below 3% in most cases). For motorcycles *with* catalyst the repeatability is a little less good (higher than 3% in most cases but less than 11%). This is probably caused by the lower absolute emission level of these types of motorcycles that are more difficult to measured accurately.

Table 11: Maximum spread of motorcycle emissions on FHB driving cycles

	Driving cycle	**Average CO emission**	**Maximum spread CO [%]**	**average HC emission**	**Maximum spread HC [%]**
2-stroke w/o catalyst	Zentrum	16.8	1.1%	11.2	1.4%
	Peripherie	15.9	2.8%	9.1	2.7%
	Ueberland	16.1	0.5%	6.2	2.3%
	FHB total	16.2	0.7%	7.9	1.9%
4-stroke w/o catalyst	Zentrum	22.3	1.6%	2.6	7.2%
	Peripherie	20.5	0.1%	1.7	2.0%
	Ueberland	16.2	2.4%	1.2	1.4%
	FHB total	18.5	1.5%	1.6	2.5%
4-stroke with catalyst	Zentrum	8.9	10.8%	1.5	9.6%
	Peripherie	5.7	3.6%	0.9	4.3%
	Ueberland	3.3	4.6%	0.5	1.4%
	FHB total	5.0	6.1%	0.8	4.5%

Since this conclusion is based on three motorcycles only, it has been decided to evaluate more data in order to have an indication on the reproducibility of the emission of motorcycles. Since the validation programme at the TÜV Nord laboratory was executed measuring emissions in bags and also online, this data could be re-analysed in order to check the reproducibility of the emissions. Therefore the use of the online emission results of the TA driving cycle enabled separating the emissions for each of the 6 subcycles driven.

Assessing the data the following strategy is chosen:

- Calculate the cumulative emission result for each subcycle
- Check if the emissions related to the subsequent subcycle are stabilised (indicating that the engine is on operating temperature)
- Calculate the average value and determining the maximum spread of the emission results for each motorcycle over the results for which the engine (and its emissions) was on stabilised operating condition.

The results of that data evaluation are summarised in Table 12. In Appendix L these are illustrated in a graph.

Table 12: Spread on emissions for the tested motorcycles at the TÜV Nord laboratory

	CO	**HC**	**Number of vehicles tested**
2-stroke without cat.	< 8 %	< 6 %	7
2-stroke with cat.	< 4 %	< 7 %	1
4-stroke without cat.	< 12 %	< 10 %	32
4-stroke with cat.	< 16 %	< 15 %	5

From the analysis it can be concluded that, in general, the CO emissions show a good repeatability (maximum spread < 16%) of the measurement result for all technology classes. For the HC emissions there is a difference between 2-stroke and 4-stroke engines. Generally the HC emissions are reproducible within 7% for 2-stroke motorcycles and within 15% for 4-stroke vehicles. The difference found can be explained by the differences in absolute level of HC emissions for both types. Since the HC emission level of 2-stroke motorcycles is much higher, compared to the HC emission of 4-stroke motorcycles, this component can be measured more accurately.

4.1.6.2 Repeatability and accuracy of the RW-test equipment

A second inaccuracy in the RW-test results is caused by the measurement hardware used. Both the specification and accuracy of the RW-test apparatus and the extra equipment needed to accurately measure the engine speed of the motorcycle must be considered.
In the OIML R 99 / ISO 3930 publication, three classes of exhaust-gas measurement apparatus are specified (0, 1 and 2). The main difference between these classes is the allowed maximum permissible errors. In Table 13 these errors are indicated for each of the three classes on components CO and HC.

Table 13: Maximum permissible errors for exhaust-gas measurement equipment

Class		**CO**	**HC**
0	a*)	± 0.03 Vol.-%	± 10 ppm
	b*)	± 3 %	± 5 %
1	a*)	± 0.06 Vol.-%	± 12 ppm
	b*)	± 3 %	± 5 %
2	a*)	± 0.15 Vol.-%	± 20 ppm
	b*)	± 5 %	± 5 %

Note:
*) whichever is greater:
a: absolute error of indication of the instrument
b: relative error of indication of the instrument

Within the validation programme, equipment of class 1, and in some cases class 2, was used. This means that for some of the results the maximum error for the RW-test equipment should be within ± 5 % on both CO and HC.

The accuracy of the equipment used to measure the engine speed of the motorcycle also has an influence on the repeatability of the measurement emission results. No detailed measurements on that topic have been executed but it is expected that the influence is not that large (less than 1%).

It can be concluded that the error due to the measurement equipment used is limited and stable as far as can be concluded, based on the data from the equipment suppliers.

4.1.6.3 Engine preconditioning

Since the actual engine temperature and conditioning of the engine can also play an important role, during the evaluation attention was paid to the effects of preconditioning before the RW-test. The road-worthiness test was performed both after the UDC and the FHB driving cycle to find out if the test results are dependent on these parameters. In Figure 11 the relation between the average CO result of the road-worthiness procedure for all of the three engine speeds after the UDC and after the FHB driving cycle is displayed. Appendix H contains the same figure for HC. In Table 14 the correlation coefficients (R^2) are given for each of the technology classes for component CO and HC. Note that the number of points included represents the number of both tests *correctly* executed. This means that when the results of the 6 individual tests (3 times after UDC and 3 times after FHB) differed too much from each other (looking at these values separately) the data are not included in this evaluation. All HC emission results measured when the HC trap was included in the sample line have also not been taken into account.

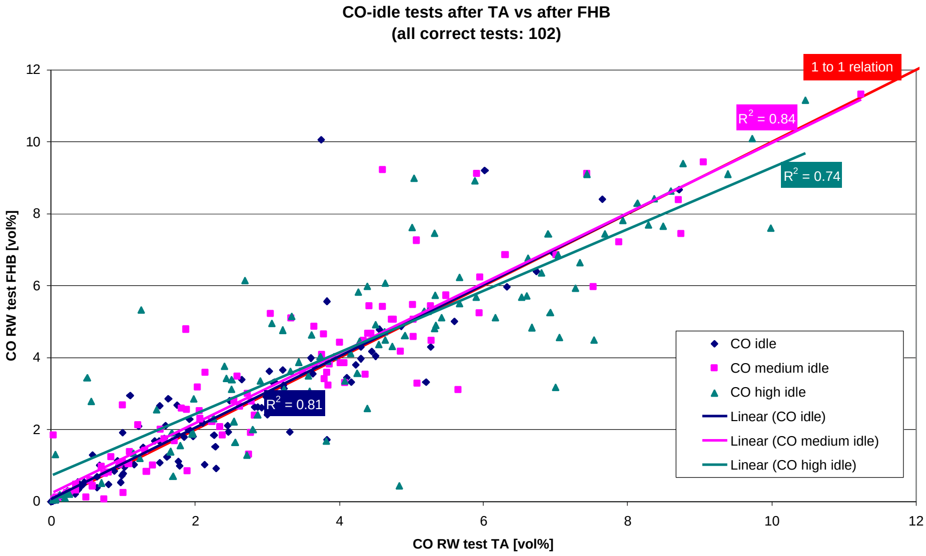

Figure 11: Relation between the CO results of the RW-test after TA and FHB driving cycles

Table 14: CO and HC correlation factors between road-worthiness test after TA and FHB for each engine technology group and for all of the engine speeds

CO				
All Labs	**R^2 idle**	**R^2 medium idle**	**R^2 high idle**	**Number of correct tests**
All	0.81	0.84	0.74	102
2-stroke w/o cat	0.57	0.59	0.37	15
2-stroke cat	-	-	-	1
4-stroke w/o cat	0.90	0.86	0.75	72
4-stroke cat	0.95	0.96	0.86	14

HC				
All Labs	**R^2 idle**	**R^2 medium idle**	**R^2 high idle**	**Number of correct tests**
All	0.81	0.89	0.93	97
2-stroke w/o cat	0.93	0.91	0.91	10
2-stroke cat	-	-	-	0
4-stroke w/o cat	0.87	0.77	0.94	73
4-stroke cat	0.33	0.96	0.94	14

Especially for the 4-stroke engines, there is a good correlation between the road-worthiness measurements after the TA and after the FHB driving cycle on both components and most engine speeds. For the 2-stroke engines the correlation on HC is good; for CO it is poor.

Based on the evaluation it can be concluded that:

- There is no significant difference between both tested preconditioning set ups, but the engine of the vehicle should be warmed up to operating temperature before the test can start. After the TA test the engine is on operating temperature and therefore in the same condition as during the test executed after the FHB driving cycle.

- For 2-stroke engined motorcycles the relation on CO is bad. The same conclusion is made for the idle test of the 4-stroke engine with catalyst. It seems that other issues concerning taking a correct sample are more important in that case. These are explained in the next paragraph.

4.1.6.4 Other issues concerning reproducibility of the measurements

Besides the main factor of influence described in the previous paragraphs, there are also some other issues that are influencing the repeatability and reproducibility of the measurements. These other issues are:

– *Motorcycles engine temperature*
Hands-on experience during the validation programme showed that the temperature of a motorcycle's engine itself has an effect on the measurement results of the RW-test. For a 2-stroke motorcycle without catalyst and a 4-stroke vehicle with catalyst extra measurements were executed in order to have an indication of this effect (see Table 15). The measurements were executed with the engine at operating temperature and at a temperature where the cooling fan of the motorcycle was working. The idle emissions of the 4-stroke motorcycle equipped with a catalytic converter were nearly zero (less than 0.1 Vol.-%) in both procedures. Since the absolute result is in the range of the inaccuracy of the test equipment, the results are not included in the table. A significant effect was found only on the CO emission value of the 2-stroke motorcycle.

Table 15: Influence of engine temperature on idle test result

Motorcycle type	**CO-average result on operating temperature [Vol.-%]**	**CO-average result when cool-fan is working [Vol.-%]**	**% difference**
2-stroke w/o catalyst	3.37	3.63	8

Based on the results presented and the hands-on experience learned from the validation programme, the following recommendations can be made:

- Some kind of extra external cooling should be available to ensure that:
  - the engine temperature does not rise above the normal operating temperature. This is valid for air-cooled and liquid cooled engines without cooling fan;
  - The cooling fan of the motorcycle should be prevented from starting working during the test. This is valid for liquid-cooled engines having a cooling fan;
- In order to gain an insight into the influences of the engine temperature on the emission during the idle test, extra measurements are necessary.

- *Battery condition*
  As loading the vehicle battery with its own generator can impose a major additional load on the engine, especially compared to the load of an idling engine, attention should be paid to testing with a fully loaded battery only. Under normal circumstances the prescribed preconditioning of the motorcycle should avoid having battery-loading effects during idle testing. But in order to rule out the effect of battery loading during the test, the motorcycle should not be turned off after preconditioning (as electric starting will drain the battery significantly). In addition to keeping the engine running after preconditioning, any other electrical consumer (lights, radio etc.) should be switched off.

- *Connection of the measurement tube to the exhaust pipe*
  In order to solve measuring problems due to the way the measurement probe is connected to exhaust pipe, the use of an extension pipe was investigated. It is highly recommended to use an extension pipe with an airtight connection to the exhaust pipe of the motorcycle. This solves the following measuring problems:
  - Decrease the influence of air pulsation when measuring
  - Avoid the problem that the probe can not be inserted far enough into the outlet before it strikes some of the partitions integrated into the muffler of the exhaust pipe.

  One should note that the connection should be airtight in order to let no dilution air enter the extension pipe causing incorrect measurement results.

  In order to speed up the RW-test and the reproducibility of the measurements it is recommended that when a motorcycle has two separate exhaust pipes both have airtight extensions. Both extension pipes should have an airtight connection to a common device in which the exhaust gas sample is collected. In that device the probe can be mounted and the sample can be taken.

- *Suction of exhaust gases*
  In most cases a suction system is used in order to stop exhaust gases entering the working area. When this system is not connected correctly to the exhaust pipe, i.e. it creates too much suction; the measurement result can be influenced, especially while measuring 2-stroke motorcycles.

  During the validation programme another problem concerning this item was experienced. For some motorcycles, the layout of the exhaust system consists of two separate exhaust pipes (or even more) which are connected to each other close to the point that the exhaust gas leaves the cylinder. When the RW-test is executed, it is not possible to analyse both exhaust pipes at the same time. Therefore the sample probe was inserted in one exhaust pipe together with external suction and on the second exhaust pipe, only external suction was connected. When the suction of the second, not sampled, exhaust pipe is too high, it causes:
  - (a part of) the exhaust gas from the sampled exhaust pipe to flow to the second one which is not sampled
  - due to the suction and the pulsation of the exhaust gas flow, dilution air can flow into the sampled exhaust pipe

  Therefore it is important to prescribe exactly the connection between measurement device and exhaust pipe(s). A solution of collecting the exhaust gas sample in one device as has been discussed in the paragraph above (*connection of the measurement tube to the exhaust pipe)* can be also be used in this case.

- *Measurement problems of the engine speed*
  No (correct) signal to measure engine speed found
  It has been experienced that for some motorcycles it is hard to find a reliable signal or place to measure a correct engine speed. Especially for super-sport bikes and scooters for which the engine is completely enclosed, it is very labour intensive to find an appropriate and reliable signal. In some cases one will have to rely on the vehicles own rev counter. If this instrument is present however, using it for testing will most probably be no major problem, since the tests executed show no major dependence on the actual revs during measurement.

  Hard to keep the engine revs on the prescribed and stable speed
  For some of the tested motorcycles it was very hard to keep the engine stable at the prescribed engine speed. This problem was especially encountered while testing 2-stroke motorcycles and motorcycles with an automatic transmission. For the first group, the power curve of the engine was the influencing factor. In one case the high idle test was hard to execute since, with minimum movement of the throttle, the engine speed was directly increased. For vehicles with an automatic transmission, above idle speed, the rear wheel starts rotating. Due to its rotational inertia it will increase the speed of the engine, without the throttle position being changed. Because of this influence it is hard to keep the engine speed at the specified value.

- *Tampering and maintenance level*
  Since the RW-test procedure is designed and validated for motorcycles operating at more or less original configuration, tampered with or badly maintained vehicles may have very different characteristics to the original vehicles. During the validation programme, no vehicles were found that had been tampered with in such a way that they caused problems during the measurements. Also, badly maintained vehicles (very few in numbers) did not cause problems while measuring. Under both abnormal situations the complete measurement set-up clearly detected the vehicles as being high emitters, without any faults in the equipment. The carbon canister (for protecting the instruments from extreme polluters) only had to be used during the RW-test of some smaller 2-stroke motorcycles.

  The limited amount of tampering found (in fact only replacement exhausts) is most probably due to the fact that modern motorcycles are overpowered for driving in normal traffic, and therefore there is little need for tampering in order to gain performance. Tampering with exhaust, which is done more for visual or acoustic reasons, had almost no effect on the emissions of 4-stroke engines (especially the older ones). The lack of tested vehicles in the small 2-stroke class, due to the withdrawal of the Spanish partner and the fact that most of these motorcycles were obtained from local dealers or national importers, most probably underestimates the problem of tampering. These small 2-stroke vehicles are not overpowered generally and measures taken on the exhaust will in fact influence the emissions of the motorcycle, since 2-stroke engine emissions are quite sensitive to changes in back pressure induced by the exhaust system.

4.1.7 *Correlation between Type Approval (TA) and real-world tests*

It is known that real-world driving behaviour of motorcycles is very different from the driving pattern used for TA testing. Since the road-worthiness procedure should in fact detect faulty vehicles that are driving in real-world practice, attention was paid to the representativity of the TA test for real-world driving on motorcycles. In order to assess the topic, correlations were made between emissions measured with the TA (UDC) cycle and the corresponding FHB real-world motorcycle driving cycles. The results of that evaluation are presented in Figure 12 (CO only) and Table 16 (CO, HC and NO_x).

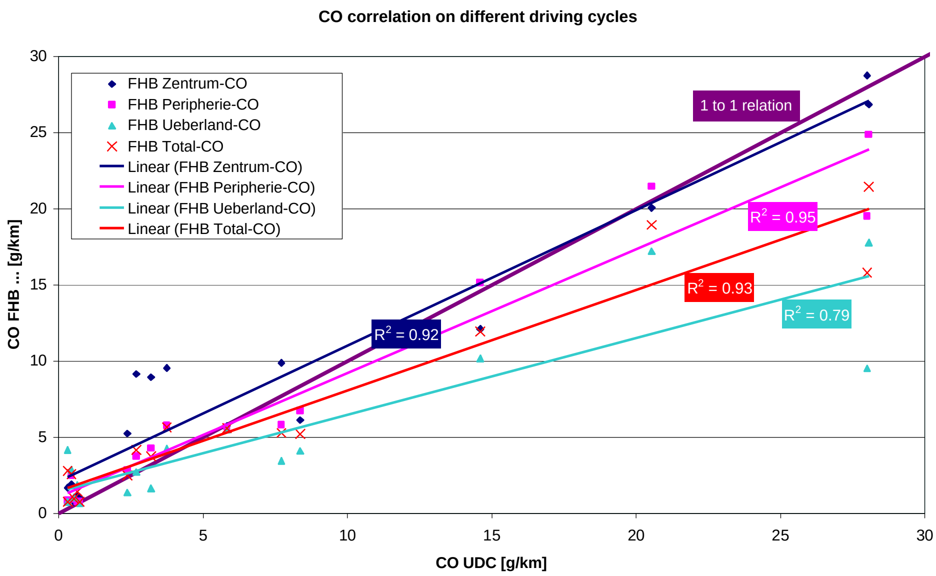

Figure 12: Correlation between TA (UDC) and real-world driving cycles (FHB) for 4-stroke motorcycles with catalyst

Table 16: Correlation factors for all emission components for each technology class

Correlation UDC with	CO				
	2-stroke w/o cat.	2-stroke cat.	4-stroke w/o cat.	4-stroke cat.	All
FHB Zentrum	0.75	-	0.89	0.92	0.88
FHB Peripherie	0.77	-	0.88	0.95	0.88
FHB Ueberland	0.70	-	0.66	0.79	0.68
FHB Total	0.75	-	0.80	0.93	0.81
Correlation UDC with	HC				
	2-stroke w/o cat.	2-stroke cat.	4-stroke w/o cat.	4-stroke cat.	All
FHB Zentrum	0.86	-	0.66	0.78	0.88
FHB Peripherie	0.86	-	0.90	0.94	0.92
FHB Ueberland	0.83	-	0.77	0.93	0.91
FHB Total	0.86	-	0.85	0.93	0.93
Correlation UDC with	NO_x				
	2-stroke w/o cat.	2-stroke cat.	4-stroke w/o cat.	4-stroke cat.	All
FHB Zentrum	0.31	-	0.47	0.55	0.89
FHB Peripherie	0.73	-	0.64	0.46	0.71
FHB Ueberland	0.74	-	0.45	0.61	0.61
FHB Total	0.46	-	0.56	0.57	0.66

From the assessment of correlations between TA testing and real-world driving it can be concluded that there is no major under or over estimation of real world emissions using the TA test. Only for vehicles equipped with a catalytic converter the under or over estimation for all emission components is relatively high. The average trend of the emissions when the FHB emission result is compared with the emissions produced during the TA test is that:

- For CO it is higher on the TA driving cycle when the absolute emission value is above the limit of 97/24/EC Chapter 5 (being 13 g/km). If the actual emission level is lower, the emission results of the real-world driving cycle are in most cases higher, going up to factors of up till 4 when the vehicle is equipped with a catalytic converter. So high emitters on CO tend to be rather stable as being a high emitter, whereas vehicles that comply with 97/24/EC Chapter 5 TA standards are slightly underestimated on their real world emission, when using the TA procedure.
- For HC the emissions produced during the FHB driving cycles are for all technology classes lower than that produced during the TA driving cycle. So TA testing slightly overestimates the HC emission during real world driving.
- The NO_x emissions of 4-stroke motorcycles are, at maximum, a factor of 1.5 higher on the FHB driving cycles than on the TA cycle. For 2-stroke motorcycles, on average the NO_x emission of FHB is slightly lower than that of the TA test.
- The correlation found for NO_x is low. This can be explained by the fact that the absolute emission level of this component is rather low, and can not be measured accurately using the equipment dedicated for passenger cars.

The main conclusion that can be drawn for the comparison between real world and TA testing is that there is no major over or under estimation of real world emissions using the TA test for older legislative categories of motorcycles. This means that the emission behaviour of motorcycles now in the fleet and on the market is in most cases not significantly different on the TA driving cycle compared to the emission produced during real world driving. But, the assessment shows clearly that, in the near future the difference will become bigger as emission limits are decreasing and engine and after-treatment technology is getting more and more complex. Therefore it is recommended that the cut off point analyses and the cost-effectiveness analyses for the moment are executed based on TA measurement data because for the TA test emission limits are available whereas they are missing for the real-world driving cycles.

4.1.8 *Relation between emissions produced during initial TA and validation programme TA test*

In this paragraph the emissions of the motorcycles produced during the actual initial Type Approval of the motorcycle and the emission produced on the TA test within the validation programme are evaluated. This extra data evaluation is used to explain following topics:

- do the motorcycles still comply to the emissions produced during Type Approval?
- access the deterioration for motorcycle emissions.

The TA gaseous emission of a particular motorcycle are taken from the annual editions of 1991 to 2001 of the Kraftfahrt-Bundesamt Kraftstoffverbrauchs- und Emissions-Typprüfwerte von Kraftfahrzeugen [4]. These editions give an overview of the Type Approval emissions on noise and exhaust gas over these years. Since not all the motorcycles had a Type Approval or were not (yet) integrated in this publication, the TA emission values were applicable for only 74 of the tested motorcycles.

In Figure 13 the relation between the TA situation and deteriorated emissions is illustrated. The figure also contains two boxes defined by a purple line and a blue line indicating the maximum TA limits for ECE Regulation 40-01 and directive 97/24/EC Chapter 5 respectively. The same figures have also been generated for the HC and NO_x emissions. Since TA emission values were not available for all the motorcycles tested, only 74 vehicles are included in the charts.

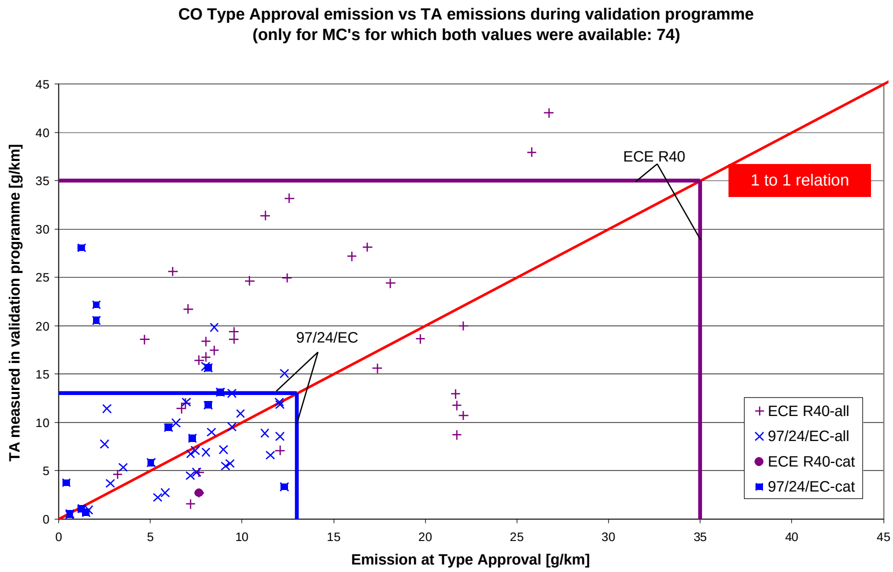

Figure 13: Relation between emission during Type Approval and in validation programme

For CO, 45 of the 74 motorcycles have increased emissions, for HC there are even more with increased emissions (49) whereas for NO_x ‘only’ 20 exceeded the emissions produced during the Type Approval. Using this evaluation it can be concluded that most motorcycles are producing more CO and HC emissions than during Type Approval, which in fact can be explained by the fact that engines and exhaust gas after-treatment systems deteriorate in use. In some cases this deterioration leads to the qualification ‘high emitter’, as indicated by the blue and purple spots above the horizontal applicable limit line.

The general conclusions derived from the exhaust gas data evaluation are discussed in Chapter 7.

4.2 Noise emissions

Within the validation programme, noise measurements were executed in order to check whether the draft road-worthiness procedure is able to find high noise emitting motorcycles. The noise emission tests were executed according to the method prescribed in directive 97/24/EC Chapter 9. This method consists of a stationary and an in-motion noise test. A summary of the test procedure is included in Appendix J. The aim of the validation test programme was to check if there is a correlation between the stationary and the in-motion noise emissions. If such a correlation exists to a sufficient degree, the stationary test can be used to predict the emission level measured in the in-motion test.

This section reports and analyses the results of the noise emission measurements. First, the motorcycles that were tested are summarised in paragraph 4.2.1. After that, in paragraph 4.2.2, a first indication is given for the relationship between the noise values emitted during the stationary and in-motion tests during Type Approval of the motorcycles. Paragraph 4.2.3 discusses the issue of reproducibility of noise measurements on motorcycles in order to be able to define a possible threshold value that can be used in the proposed road-worthiness procedure. Paragraph 4.2.4 analyses the relationship between the noise emitted during the in-motion tests of the motorcycles tested in the validation programme and the stationary noise measurement results according to the method prescribed in directive 97/24/EC Chapter 9 and the Swedish protocol. In that paragraph, the results of the stationary and in-motion tests are also compared with the noise emission during Type Approval. The main conclusions and recommendations of that evaluation are also discussed in paragraph 4.2.4. The general conclusions of the noise part of the study are summarised in Chapter 7.

4.2.1 Overview of tested motorcycles

Within the validation programme, a total of 118 motorcycles were tested on stationary and/or in-motion noise. Table 17 summarises the numbers of each type of vehicle that were tested ***correctly*** on noise and whether Type Approval stationary and in-motion noise emission information was available. Since the issue of deterioration can play an important role regarding the noise produced, the range of ages and odometer values are also listed. In Appendix F all motorcycles that were tested within the validation programme are summarised.

Table 17: Overview of correctly tested motorcycles on noise emissions

	Original exhaust system	Replacement exhaust silencing system (RESS)	Stationary tested	In-motion tested	TA stationary available	TA in-motion available
All	112	6	94	35	113	104
2-stroke w/o catalyst	17	1	17	8	18	18
2-stroke with catalyst	1	0	1	1	1	1
4-stroke w/o catalyst	76	5	65	19	76	68
4-stroke with catalyst	18	0	11	7	17	17
Model year range (All)	1984-2002	1984-1999	1984-2002	1989-2002	1989-2002	1989-2002
Odometer range [km] (All)	150-80000	8100-118000	150-118000	150-67250	150-118000	150-118000

It was not possible to perform the in-motion test on all motorcycles due to bad weather or lack of an appropriate test site. Including one motorcycle for which the TA limits are not available, this means that all noise emission values are available (TA-stationary, TA-in-motion, measured-stationary and measured-in-motion) for only twenty-nine motorcycles. Unfortunately, no motorcycles equipped with a legal or illegal Replacement Exhaust Silencing System (RESS) were included within this group of 29 motorcycles. In hindsight, this is an unfortunate omission of the validation programme since these vehicles are the potential ones having high noise emissions.

On 10 motorcycles, stationary noise measurements were also executed according to the Swedish protocol (same procedure as 97/24/EC Chapter 9 only with a different value of the engine speed, see Appendix B). When the engine speeds of the tested motorcycles for both test protocols are compared, it was concluded that:

- the engine speed determination according to the Swedish method, in most cases, resulted in a higher value than the engine speed calculated using the method prescribed in directive 97/24/EC Chapter 9
- the minimum absolute engine speed difference found was 400 rpm; the maximum absolute difference was 2650 rpm.

Within the validation programme only 6 of the tested motorcycles had a Replacement Exhaust Silencing System (RESS), being 5% of the tested motorcycle fleet. Two of these six motorcycles had a legal RESS (homologated as a replacement exhaust as prescribed in directive 97/24/EC Chapter 9, indicated by a Type Approval code) whereas the other 4 have an illegal RESS (4% of the total tested motorcycles). In the report made by IMMA [1], it is concluded that 48% of the motorcycles with engine capacity of 80 to 175 cm^3 and 27% of the motorcycles with engine capacity greater than 175 cm^3, have *illegal* RESS. Main reasons for this difference can be explained by the fact that:

- most motorcycles tested in the validation programme (72%) were supplied by importers or local dealers. 11% of the motorcycles were obtained from rental companies whereas 17% of the vehicles were supplied by private owners;
- motorcycles with a smaller swept volume are underrepresented in the validation programme. As is concluded in the IMMA report [1], these vehicles have more illegal RESS than motorcycles with swept volume higher than 175 cm^3. If more of these types of motorcycles (for which a greater part is equipped with an illegal RESS) had been tested in the validation programme, the number of vehicles actually tested having an illegal RESS would have been higher.

4.2.2 Relation between stationary and in-motion noise using the Type Approval values

Within the validation programme, the noise emission values produced during the Type Approval of the specific motorcycle were included in the test report file of the motorcycle (taken from the Publications of KBA [4]). The option of having this data at the disposal of the project provides an alternative data set to check for the relation between stationary and in-motion noise. In Figure 14 the relation between both tests is displayed. The applicable limits for the in-motion tests as given in directives 78/1015/EEC and 97/24/EC Chapter 9 are also indicated. These limits are listed in paragraph 3.1 and they are dependent on the swept volume of the motorcycle (= 175 cm^3 and > 175 cm^3 indicated by the two lines).

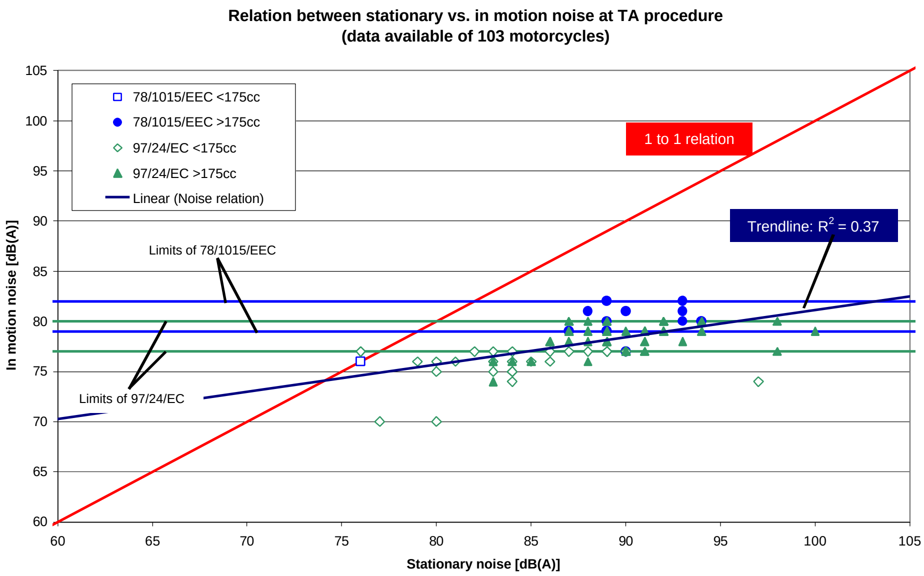

Figure 14: Relation between stationary and in-motion noise test using TA emissions

From the chart it can be concluded that there is no significant relationship between the in-motion and the stationary noise emissions. For each emission value measured in one of the tests, the graph shows a large spread in values measured in the other test procedure. Therefore it can be concluded that it is not possible to use the absolute value of the noise emission measured in the stationary test only as being representative for the in-motion noise emissions. However, on average, as it is illustrated by the given trend-line, the stationary and the in-motion noise have a correlation. Since no high noise emitters are included in this figure (naturally TA values are always below the limit), the possibility of using the stationary noise emission value to identify high emitters by only measuring the stationary noise emission value needs to be considered further. It will be analysed later in paragraph 4.2.4.1 in which the validation programme data is discussed.

4.2.3 Reproducibility on noise emission testing

In order to be able to define a possible threshold value that can be used in the proposed road-worthiness procedure to identify a motorcycle as a high emitter on noise, an indication about the reproducibility of the stationary noise measurements is needed. Information about reproducibility can also be used to define whether the main aim of the road-worthiness test on noise should be:

- to identify extraordinarily high noise emitters only; or
- to identify high noise emitters using a stricter threshold value (nearer to the directive limits).

Before it is possible to choose the main aim, the reproducibility of measuring noise needs to be assessed. The reproducibility of the stationary noise measurements can be dependent on following topics:

- Repeatability of executing the noise test on one specific vehicle
- Differences in motorcycles of the same type
- Deterioration of the motorcycles
- Preconditioning of the motorcycle
- Accuracy of the noise measurement equipment
- Test site conditions
- Ambient conditions

The topics that need extra explanation are discussed in the section below.

- *Repeatability of executing the noise test on one specific vehicle*
  In order to have an indication about the repeatability of the stationary noise emission test results, the noise data measured in the validation programme have been evaluated. Since the procedure consisted of executing three consecutive measurements on one specific motorcycle and these results are available; it is possible to determine the maximum deviation by calculating the maximum available deviation measured relative to the arithmetic average value of the three measurements. In Figure 15 the results are illustrated. As can be seen, for most measurements executed (91% of the total) the maximum spread is below 1 dB (A). For 70 motorcycles that were tested according the stationary noise test in the validation programme, three results were available.

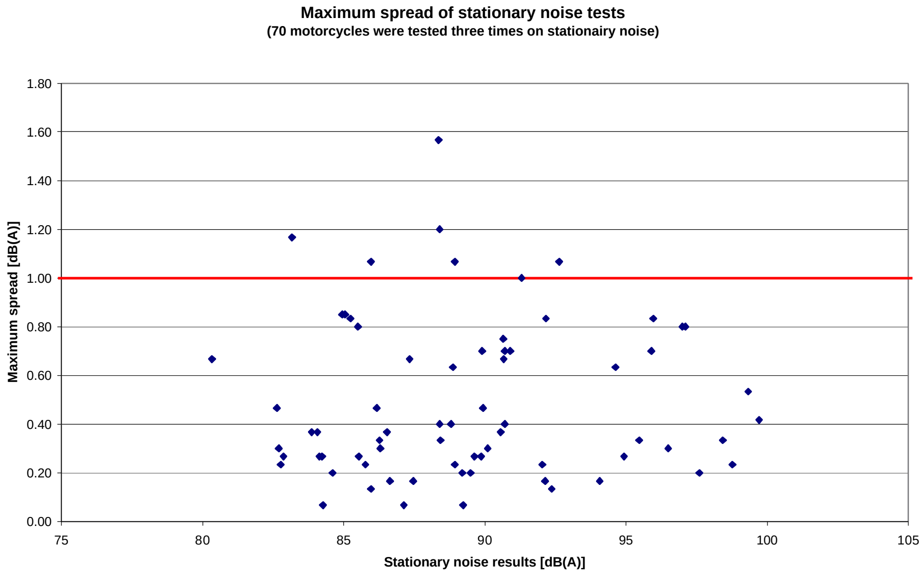

Figure 15: Maximum spread of the stationary noise emission results

– *Differences in motorcycles of the same type*
During the production of motorcycles, there are many factors that make it possible for two motorcycles of the same type to have different noise emissions. To allow for these variations, an extra tolerance of 3 dB (A) is added to the sound level measured at the time of Type Approval. This value is specified in the applicable directives as the 'conformity of production' (C.O.P.) tolerance (see directive 97/24/EC Chapter 9 Annex V).

– *Accuracy of the noise measurement equipment*
In directive 97/24/EC Chapter 9, it is prescribed that the noise measurements should be executed using a precision sound level meter as is specified by the International Electrotechnical Commission (IEC) in publication 179. That publication has been superseded by publication IEC 651. Within the validation programme all laboratories used a sound level meter that meets the class 1 requirements or higher. In Table 18 the tolerances for the sound level meter classes are specified.

Table 18: Sound level meter types according to IEC 651

Class 0	Laboratory reference standard	± 0.4 dB
Class 1	Intended for laboratory use and for field use where the acoustical environment can be closely specified and/or controlled	± 0.7 dB
Class 2	Suitable for general field applications	± 1.0 dB
Class 3	Intended primarily for field noise survey applications to determine whether an established noise limit has been significantly violated	± 1.5 dB

– *Engine speed measurement equipment*
During the stationary noise test, the engine speed has to be adjusted to a specified value. The engine speed should be measured with a maximum error of 3% in order

to execute the test at the correct engine speed. The influence on the noise emission value when the engine speed does not meet the given tolerance is not (yet) known.

- *Preconditioning of the motorcycle*
  Before the tests on noise can be executed, the engine of the motorcycle should be warmed up to operating temperature. No extra measurements were executed during the validation programme to qualify the influence of the engine temperature on the measured noise level.

- *Test site conditions*
  The conditions of test site should meet the requirements prescribed in the directives 78/1018/EC and 97/24/EC Chapter 9. This means that for the stationary test there must be no reflecting objects that could cause any disturbance within 3 metre of the vehicle to be tested. Also, the flat surface has to be highly reflective; it is prohibited to use surfaces that have been covered with any kind of sound damping material or that have a sound damping structure. For the in-motion test reflective objects within 50 metres of the test site are not allowed. The road surface covering the test site must conform to the requirements of Annex VII of directive 97/24/EC Chapter 9. The laboratories that participated in the validation programme did not have a test track at their disposal that meets the requirements as are given in the directive exactly. Therefore they had to opt for another solution in order to be able to execute the in-motion noise test. Each individual laboratory looked for a test site which had specifications that are close to the given requirements and which was located nearby the laboratory itself. Two of the four participating laboratories did actually find such a test track site. In order to make a correction on the noise emission results for the test track used, the German laboratories executed some extra measurements. With some of the motorcycles, noise tests were performed on the test track used in the validation programme and on a test track as prescribed in the directive. In the German case this did lead to no correction for the stationary noise emission values and a correction of 1 dB(A) for the in-motion noise results.

- *Ambient conditions*
  The sound level of the surrounding area (interference noises and wind influence) has to be at least 10 dB (A) lower than the measured value. For the in-motion test, the noise level differences within the rectangle in which the in-motion test is executed may not exceed 1 dB (A).

It can be concluded that a lot of influences are present that can lower the reproducibility of noise emission tests. Within the German inspection programme and the German and Dutch legislation on enforcement, a reproducibility tolerance of 5 dB (A) is used in order to eliminate the possibility of a vehicle being wrongfully qualified as a high noise emitter.

In order to have a correct indication of the overall reproducibility of the noise measurements, it is recommended that another study should be undertaken to investigate at least the following:

- Testing of the same type of motorcycles at one location with differing characteristics (i.e. model year, odometer etc.)
- Testing of the motorcycles by different persons and on different locations (laboratories, central inspection agencies, garages etc.)
- Testing motorcycles pre-conditioned in different ways

4.2.4 *Noise emission results derived from the measurement programme*

This paragraph is divided in two parts, being the presentation of the:
1. Relationship between the noise emissions measured in the validation programme
2. Definition of an alternative procedure to identify high noise emitting motorcycles

4.2.4.1 *Relation on noise emissions measured in the validation programme*

Within this paragraph the relationship between the stationary and in-motion noise emissions measured during the validation programme is discussed. Since there are two methods of stationary noise testing available (according to directive 97/24/EC Chapter 9 and the Swedish variant), both noise emission results are compared with the in-motion noise measurement value. The result of this evaluation is illustrated in Figure 16 together with the limits for the directives 78/1015/EEC and 97/24/EC Chapter 9 as well as the limit of 103 dB(A) that is applicable for the stationary Swedish method. Using Figure 16 it is concluded that:

- 80% of the motorcycles tested do exceed the applicable Type Approval limit on in-motion noise
- if the conformity of production excess value of + 3 dB(A) as prescribed in 97/24/EC directive Chapter 9 is used, 18 of the 35 motorcycles (51%) are exceeding the in-motion noise limit in the validation programme.
- the stationary noise emission result measured according to the Swedish method is always higher than the result when measured according directive 97/24/EC Chapter 9. This is possibly caused by the higher engine speed on which the stationary idle test is executed comparing the Swedish method with the engine speed definition of directive 97/27/EC.
- the correlation between the in-motion noise value and both stationary measurement procedures is not significant. Again, the values measured in one test procedure show a large spread compared to the values measured in the other test procedure;
- if the correlation between the in-motion noise and of the stationary test executed according the Swedish method and the procedure prescribed by 97/24/EC Chapter 9 are compared, neither give a good indication of whether the motorcycle is a high emitter on the in-motion noise test. However, the trend found indicates again that extraordinarily high emitters can possibly be found;
- the location of the stationary and in-motion noise values in the chart is completely different from the location of the combinations of the TA values (comparing Figure 14 and Figure 16). These differences are the result of the topics discussed in paragraph 4.2.3.

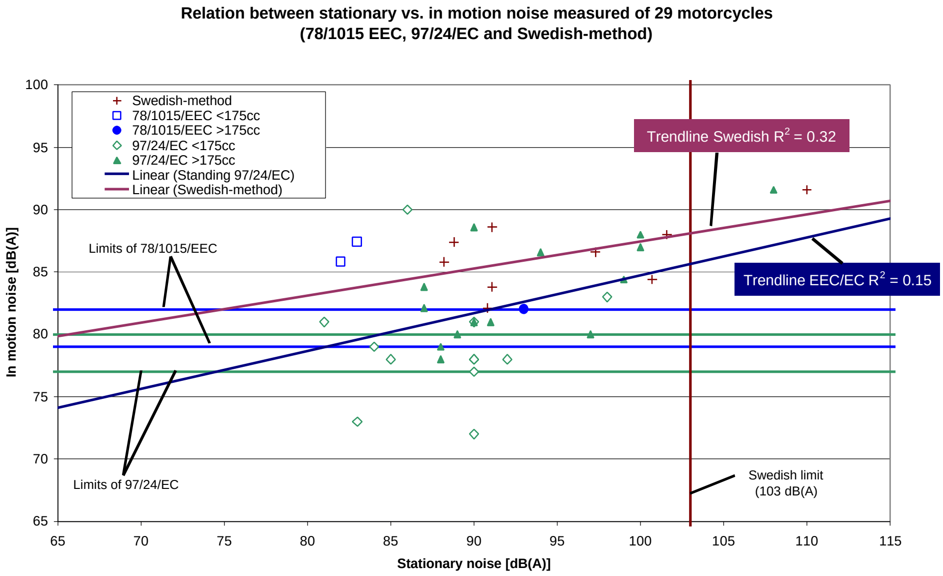

Figure 16: Relation between stationary (78/1015/EEC or 97/24/EC Chapter 9 and Swedish method) and in-motion noise in validation programme

Note: Noise results were available for all tests (TA-stationary, TA-in-motion, measured-stationary and measured-in-motion) for only 29 of the motorcycles tested.

4.2.4.2 *Definition of an alternative procedure to identify high noise emitting motorcycles*

The results discussed in paragraph 4.2.2 and 4.2.4.1 leads to the conclusion that no direct relationship exists between the noise emission values measured in the stationary and the in-motion test but that the trend found can possibly identify extraordinarily high noise emitting vehicles. Therefore an alternative approach has to be found in order to be used in a road-worthiness test procedure.

In current enforcement and periodic inspection programmes in different European countries, it is common practice to make a relationship between the stationary noise test result of the Type Approval and the stationary noise measured during inspection. As mentioned in paragraph 3.1, Germany, Italy, the Netherlands and Spain are countries that set the limit that is not to be exceeded as + 5dB(A) (stationary excess noise limit) over the stationary TA noise emission value.

As mentioned earlier, an in-motion test result was not available for **any** of the motorcycles having a legal or illegal RESS. This means that the possibility of drawing any conclusions regarding noise from motorcycles, which are tampered with, was eliminated.

The procedure to locate high noise emitting motorcycles is based on the method of calculating the difference between stationary noise emission measured during (periodic) inspection and the value measured during Type Approval. The data of the validation programme has been assessed using following methodology:

- the difference between the measured value and the value during TA of stationary noise test is calculated. When the difference is higher than the given excess noise limit of +5 dB(A) the vehicle is identified as a high emitter on stationary noise;

- in addition, the difference between the in-motion noise value measured during the validation programme and the applicable Type Approval limit is calculated. The applicable Type Approval limits are indicated in Chapter 3. In order to eliminate the factors that influence the test result reproducibility and to take into account the possible differences in vehicles in this case also an excess noise limit of +5dB(A) is defined.

Both results lead to the possibility of identifying high noise emitting motorcycles as summarised in Figure 17. A distinction is made between the applicable directives and as well as whether the motorcycles have a manual or an automatic transmission.

The following conclusions can be drawn:

- Differences between the measured stationary/in-motion noise values and TA values do not have an explicit one to one relationship. The differences calculated for one type of noise test are in some cases completely different from the differences found for the other type of noise test.
- When a stationary excess noise limit value of + 5dB(A) is taken into account on all available stationary noise test results, in total 23% of the tested motorcycles are identified as being high emitters on noise. As this excess noise limit is also taken into account for the in-motion noise tests, the percentage of high noise emitting motorcycles is 37%.
- Only one extraordinarily high noise emitting motorcycle was found (exceeding the TA values by 19 and 13.6 dB(A) on stationary and in-motion tests respectively.
- For motorcycles with automatic transmission, the difference in stationary noise values is in most cases relatively high compared to the difference of the in-motion test values. It seems that some unidentified problems occur during stationary noise tests on motorcycles having this type of transmission. This subject will be discussed in the recommendations part of this report.
- Using the basic approach of "errors of omission and commission" as described in paragraph 4.1.5, and a noise excess limit of +5dB(A) for the stationary and the in-motion test, it is concluded that:
  - 15 of the 29 vehicles that are identified as low noise emitters by the stationary noise test are really low emitters on the in-motion noise test
  - The number of "errors of omission" (number of vehicles not identified as a high emitter by the stationary test but being one on the in-motion noise test) is 2.
  - 6 vehicles (=21%) are qualified as errors of commission (identified as high emitter on the stationary test but are in fact they not a high noise emitter on the in-motion test). Five of these vehicles are equipped with an automatic transmission.

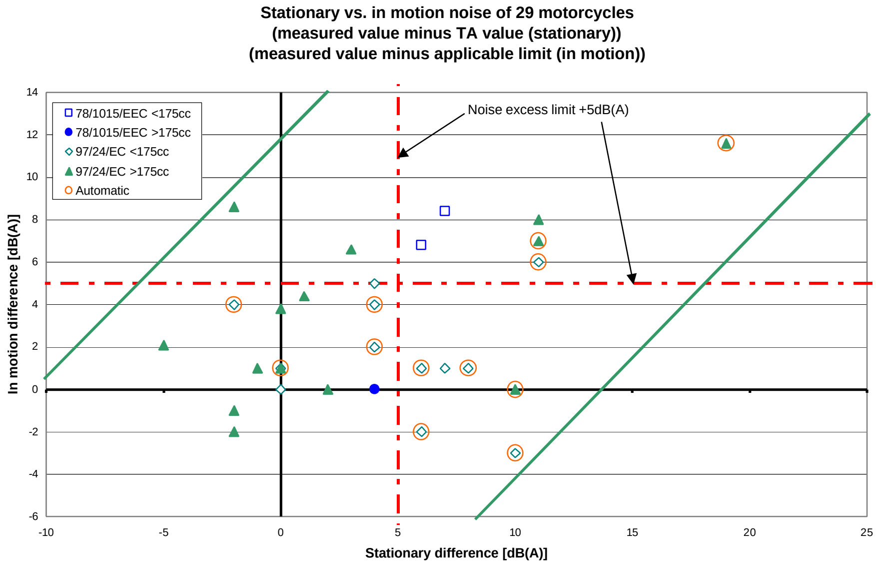

Figure 17: Differences in stationary and in-motion noise emission

The above analysis shows that the approach suggested may be capable of identifying a motorcycle that is a high emitter on in-motion noise when only a stationary test is executed (the bandwidth of the relation is indicated by the two diagonal lines).

The percentage errors of commission is 21% of the tested vehicles when the excess value of + 5 dB(A) is used. This number should be as small as possible with regard to legal protection of citizens and environmental benefit (there is no advantage since the motorcycle in fact is not a high emitter). Given the high level of errors of commission, it is concluded that the second option as mentioned in paragraph 4.2.3, namely defining strict threshold values to identify high noise emitters, is not possible. The main aim of the road-worthiness test procedure should therefore be to identify only extraordinarily high noise emitting vehicles. Using the noise measurement results of the validation programme and defining an excess limit value of +10 dB(A), the procedure is capable to lead to no errors of commission. This higher excess value therefore seems to be more feasible to be used in the road-worthiness test procedure but, on the other hand, is extremely high.

Unfortunately, within the validation programme, only one motorcycle was tested having an extraordinarily high noise level on both the stationary and the in-motion test. Therefore no conclusion can be derived from the validation programme in order to define a threshold value to be used to identify extraordinarily high noise emitting motorcycles.

It is also remarkable that 5 out of the six motorcycles that are 'errors of commission' are equipped with an automatic gearbox. It seems that other influences have a major effect on the noise level that is emitted during the stationary noise test procedure.

In the light of this analysis, extra measurements are needed to gain insight into:

- the location in the stationary and the in-motion noise test results of actual high noise emitting motorcycles (e.g. having illegal RESS etc.) in Figure 17;
- the reproducibility of the noise measurements when they are executed on the same types of motorcycles at different locations and by different persons in order to check whether the noise excess limit of +5dB(A) is valid (or that it is better to choose for a higher value);
- the unidentified problems that cause the differences in the results of the motorcycles equipped with an automatic gearbox. Possible causes could be:
  - the deterioration of the motorcycle: the automatic transmission and the rotating rear wheel are producing extra noise during the stationary noise measurement compared to the time the Type Approval was executed;
  - the limited time in which an inspection programme has to be executed: in the validation programme it was learned that for these types of motorcycles it can be very difficult to:
    - find a signal location in order to measure the engine speed accurately
    - keep the engine speed at the prescribed value and stable: the behaviour of the automatic clutch of such transmissions makes it more difficult to keep the engine speed stable.

These extra measurements on noise are needed in order to define a more reliable and representative definition of the stationary noise excess limit to be prescribed for the road-worthiness test procedure.

5 Cost-effectiveness evaluation

This Chapter discusses a procedure for cost-effectiveness evaluation. In paragraph 5.1 the methodology to assess the cost-effectiveness is described. The parameters and figures needed to start the calculation are also indicated in that paragraph. In paragraph 5.2 a calculation example is given in order to assess the cost-effectiveness for the Dutch situation. **Due to the fact that a lot of needed input variables are based on assumptions and estimates, no conclusion can be drawn from that calculation example.**

The cost-effectiveness evaluation has only been executed for the exhaust gas emission. When a cost-effectiveness study for noise has to be assessed, the proposed methodology as prescribed in paragraph 5.1 can be used as well.

5.1 Methodology

5.1.1 General outline

This section describes the methodology used to calculate the cost-effectiveness of a possible inspection method as described in this report. The method has been copied from the sub-report 7 (“Cost-Effectiveness”) of April 1998, of the EU project “The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency” [5]. The present report contains a numerical example of this methodology, but not an actual calculation.

The methodology is outlined in the flowchart of Figure 18. The fixed inputs consist of the composition of a nation’s motorcycle fleet and its emission factors (top box column two), as well as the cost of maintenance per vehicle, which is dependent on the cost of labour in the country considered (top box column three). The variable inputs consist of the type of inspection programme chosen and the number of vehicles subject to the programme (column five). This last item depends on the choice of the first year that vehicles are subjected to the programme (e.g. after three years from new) and the frequency of the inspection (annually or biannually).

The selectivity of the inspection programme and the average effect of maintenance on the vehicles identified as faulty (column one) are taken from the results of this project and are reported elsewhere in this report. For the present section they are treated as fixed input.

The selectivity of the inspection programme chosen (column one) together with the actual number of faulty vehicles in the fleet (column two) determines the number of vehicles identified as faulty (column two).
Since the average effect of maintenance has been defined in a different way from the previous car project, the selectivity of the programme may have two different values in the present calculation:

- The basic figure is the real (‘true’) percentage of faulty vehicles in the fleet. This figure represents the maximum that can be improved (second box in column two).
- From this is derived the percentage of faulty vehicles *detected by the programme*. This consists of the actual percentage minus the percentage ‘errors of omission’

inherent to the programme chosen (see section 1.3 for the definition of errors of omission and errors of commission). This represents the *actual percentage that will be improved* (third box in column two).

- On the other hand there is the percentage of vehicles that the programme (rightly or wrongly) *indicates as faulty*. This consists of the real percentage minus the ‘errors of omission’, but plus the ‘errors of commission’ inherent to the programme chosen. This figure represents the *percentage that will be subjected to repair* (arrow from the second to the third column).

The number of vehicles *detected as faulty*, multiplied with the average effect of maintenance results in the total effect of maintenance in ton of pollutant avoided (column two). This is the first interim result.

The total cost of inspection is obtained by simply multiplying the cost of inspection per vehicle with the number of vehicles to be inspected (column four). The total cost of maintenance is obtained by multiplying the cost of maintenance per vehicle with the number of vehicles indicated by the programme as being faulty (column three). To the bare cost of maintenance should be added the cost of a re-inspection. Adding the total cost of inspection to the total cost of maintenance results in the overall cost of the I/M programme column four/five). This is the second interim result.

When the total cost of the Inspection and Maintenance (I/M) programme is divided by the total effect of maintenance one obtains the cost per unit of effect (kEuro / kton of pollutant avoided). This is the final result of the calculation (column two/three).

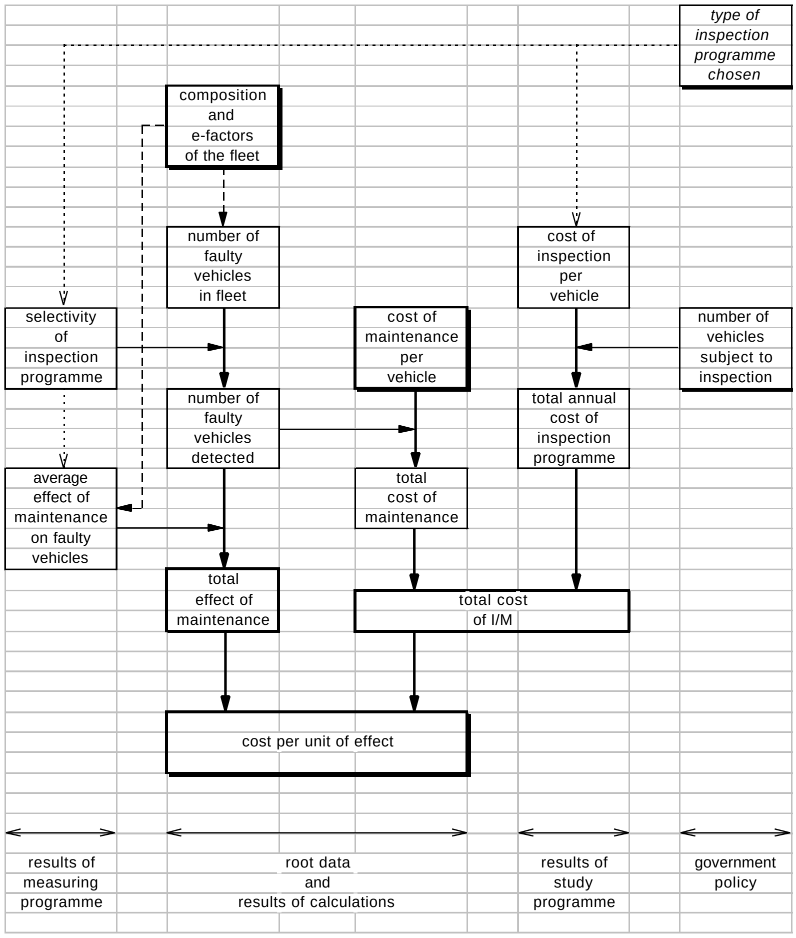

Figure 18: Flow chart of the cost-effectiveness calculation

5.1.2 *Types of inspection programme considered*

In this section the following types of inspection programme are considered:

- An unloaded test, consisting of any combination of idle, medium speed idle and high idle, as identified for each class of vehicle (see Table 10, paragraph 4.1.5). Also the preconditioning of the motorcycle before executing the test is included.
- The option indicated above has been calculated for the following two situations:
  - In the first situation it has been assumed that the system is based on a decentralised inspection programme (workshops can test).
  - In the second situation it has been assumed that the system is based on a centralised inspection system (separate inspection stations).
- Both options of test procedure and test-situations combinations are also calculated for two different years:
  - Situation in the year 2005
  - Situation in the year 2010

It is assumed that the proposed procedure comes into force only for vehicles complying with 97/24/EC Chapter 5, stage 1 and later. Together with that it is also assumed that a motorcycle is annually inspected after it reaches the age of 3.

5.1.3 Selectivity of the programme and average emission reduction potential

In the ideal situation, vehicles that fail the road-worthiness test would be vehicles that exceed the emission limits in the Type Approval test, whereas vehicles that pass the road-worthiness test would also pass the Type Approval test. In reality a 1:1 correlation should not be expected. The road-worthiness test and the Type Approval test are two different tests that do not measure exactly the same thing. So in practice four different situations may arise:

1. The vehicle passes the road-worthiness test and also passes the Type Approval test. These vehicles are correct and are identified as correct.
2. The vehicle fails the road-worthiness test and also fails the Type Approval test. These vehicles are faulty and are identified as faulty.
3. The vehicle passes the road-worthiness test, but fails the Type Approval test. These vehicles are not identified as faulty, although in fact they are faulty. These vehicles represent the so-called ‘errors of omission'; i.e. they are omitted from the identification of faulty vehicles.
4. The vehicle fails the road-worthiness test, but passes the Type Approval test. These vehicles represent the so-called ‘errors of commission’; they are committed of the crime, but are in fact innocent.

The errors of omission constitute an environmental problem: these vehicles should be repaired, but the necessity of repair is not recognised. For environmental reasons the relative share of errors of omission should be limited so as to keep the procedure sufficiently cost-effective. Otherwise there is no real problem. The errors of commission pose a legal problem. The owners are required to have their vehicle ‘repaired’, whereas in reality there is nothing wrong with it. This causes unnecessary costs and decreases the cost-effectiveness, but more important: it creates a certain degree of injustice. For this reason the relative share of errors of commission should be kept as low as reasonably possible. The magnitude of the shares of errors of omission and commission is determined by the ‘selectivity’ of the road-worthiness test.

In the calculations it has been assumed that the emission reduction potential equals the average emissions of the vehicles that are really incorrect, minus the average emissions of the vehicles that are really correct. The actual emission reduction is determined by the actual percentage of faulty vehicles that are detected. This equals the actual share of faulty vehicles minus the errors of omission (since they represent the share of undetected faulty vehicles). This approach assumes that all faulty vehicles, that are detected as such, are readjusted to their real potential. The total costs of repair and re-testing are determined by the total share of vehicles *indicated* as faulty. These include the errors of commission.

The selectivity of the inspection programme is given in Table 19 per motorcycle technology class. These figures are derived from the validation programme and have been determined using expert judgement.

Table 19: The percentage of motorcycles identified as faulty by the inspection programme

	2-stroke w/o catalyst	**2-stroke catalyst**	**4-stroke w/o catalyst**	**4-stroke catalyst**
faulty vehicles	50%	30%	21%	21%
'errors of omission'	25%	15%	10%	2%
'errors of commission'	5%	5%	3%	7%
detected by the inspection programme	25%	15%	11%	19%

The costs of repair will further vary with the degree of repair necessary. This is defined as:

- Minor repair: Only readjustment is necessary and the costs consist of labour only.
- Major repair: Replacement of parts is necessary. The costs consist of labour plus the cost of the replaced parts.
- Catalyst replacement: This is taken as a separate item. In practice some labour has to be added.

With regard to the calculation for the moment the percentages given in Table 20 for the relative frequencies have been assumed.

Table 20: Kind of repair assumed necessary

Type of repair	**2-stroke – w/o catalyst**	**2-stroke – catalyst**	**4-stroke – w/o catalyst**	**4 –stroke catalyst**
Minor	90 %	80 %	90 %	65 %
Major	10 %	15 %	10 %	30 %
Catalyst replace	-	5 %	-	5 %

The emission reduction potential for the components CO and HC has also been identified on the basis of the validation programme data assessment. The average exhaust gas emission of the low polluters and of the high emitters has been calculated for each technology class. It is assumed that after the repair activities the emission level of the high emitters will be the same as the level of the low polluters. This value is the emission reduction potential and these are summarised in Table 21. Since none of the 4-stroke motorcycles were high emitters on HC, no emission reduction potential is given for that component. In the validation programme only one 2-stroke motorcycle with catalyst was measured. Due to that fact, the emission reduction potential for the 2-stroke with catalyst class is assumed to be the same as for the class 2-stroke without catalyst.

Table 21: Emission reduction potential of the various technology classes for CO and HC

Emission reduction potential	**2-stroke – w/o catalyst**		**2-stroke – catalyst**		**4-stroke – w/o catalyst**		**4 –stroke catalyst**	
Component	CO	HC	CO	HC	CO	HC	CO	HC
Average low pollutants [g/km] {A}	3.84	2.91	3.84	2.91	6.54	-	5.29	-
Average high emitters [g/km] {B}	11.42	5.22	11.42	5.22	14.26	-	21.07	-
Average emission reduction potential [g/km] {B minus A}	7.58	2.31	7.58	2.31	7.72	-	15.78	-

The effect on NO_x has not been evaluated within this study. This is caused due to the fact that the exhaust gas analysing equipment normally used during inspection programmes is not able to measure NO_x. From the validation programme it has also been experienced that there were only two vehicles exceeding the NO_x limit.

5.1.4 *Costs of inspection and maintenance*

The costs of the inspection methods vary with the country, mainly on the basis of the hourly rates of the technicians involved. The costs of investment, amortisation, interest and buildings have been kept constant. The amortisation period has been chosen as 7 years. The interest has been assumed as 10% over the average loan. An example is given in Table 22. The number of vehicles tested is increasing over the years (more motorcycles comply with 97/24/EC) and the centralised option is assumed to be a more efficient inspection method. It should be noted however, that the number of tests to be executed in one hour, are relatively low. That is caused by the fact of labour-intensive activities to be executed on preconditioning, connection of the measurement equipment to the motorcycle and actual testing. The cost of Labour, of itself, is an issue for discussion as it is different over the European countries and therefore a main sensitivity of the total costs of the inspection programme.

Table 22: Calculation of the cost in Euro/vehicle of an inspection system

Category		decentralised		centralised	
		2005	**2010**	**2005**	**2010**
Fixed costs	investment	7000	7000	10000	10000
	amortisation	1000	1000	1429	1429
	interest	350	350	500	500
	housing	1500	1500	2000	2000
	subtotal	2850	2850	3929	3929
	vehicles/yr	140	340	2500	3750
	fixed cost/vehicle	20.36	8.38	1.57	1.05
Labour	labour/hr	50	50	75	75
	vehicle/hr	1	1	2	2
	labour/vehicle	50	50	37.50	37.50
Administrative	cost/vehicle	5	5	5	5
Total/vehicle	**Euro**	75.36	63.38	44.07	43.55

As mentioned in paragraph 5.1.3, three different types of assumed repair are defined. The costs of such repair have been assumed on the basis of car experience and a small survey among Dutch dealers and importers:
Minor repair: 75 Euro
Major repair: 200 Euro
Catalyst replacement:

- 600 Euro for a 2-stroke oxidation catalyst (inclusive minor repair)
- 1100 Euro for a 4-stroke 3-way catalyst (inclusive minor repair)

Note that to these repair costs the cost of a road-worthiness re-test has to be added.

5.2 Calculation example for The Netherlands

In analogy with the sub-report 7 (“Cost-Effectiveness”) of April 1998, of the EU project “The Inspection of In-Use Cars in Order to Attain Minimum Emissions of Pollutants and Optimum Energy Efficiency” [5], a numerical calculation example is given for the Netherlands. **Note that this is only a calculation example helping to explain the methodology. Since a lot of assumptions have been made on the side of costs, fleet composition and reduction potential, no claims can be laid on the given example.** An extra study is needed in order to have a more reliable result on cost-effectiveness.

5.2.1 The emission benefits

For the Dutch situation the composition of the fleet in 2005 and 2010 are assumed as follows:

Table 23: Composition of the Dutch fleet in 2005 and 2010 for vehicles to be inspected

		2-stroke – w/o catalyst	**2-stroke – catalyst**	**4-stroke – w/o catalyst**	**4 –stroke catalyst**
2005	number/1000	8	3	75	30
	km/yr	4000	4000	5000	5000
2010	number/1000	8	8.75	46	140
	km/yr	4000	4000	5000	5000

For the inspection set-up it has been assumed that only the vehicles that comply with directive 97/24/EC will be inspected. Together with that it is assumed that motorcycles of three years and older are subject to inspection and that the technical inspection is annually. This means that in 2005 approximately the following numbers would have been due to be inspected:

approximately 60 % of the 2-stroke without catalyst:	4800	
approximately 60 % of the 2-stroke with catalyst:	1800	
approximately 60 % of the 4-stroke without catalyst:	45000	
approximately 60 % of the 4-stroke without catalyst:	18000	
	69600	motorcycles subject to inspection

The number of vehicles identified as faulty are summarised in Table 19 and the emission reduction potential for the components CO and HC is given in Table 21. Applying these figures, the following potential reduction in CO can be calculated for 2005:

(Number of motorcycles · % detected as faulty · km/yr per motorcycle · emission reduction potential [g/km] = emission avoided per year)

4800 · 25% · 4000 · 7.58	= 36.38 ton/yr	(2-stroke without catalyst)
1800 · 15% · 4000 · 7.58	= 8.19 ton/yr	(2-stroke with catalyst)
45000 · 11% · 5000 · 7.72	= 191.07 ton/yr	(4-stroke without catalyst)
18000 · 19% · 5000 · 15.78	= 269.84 ton/yr	(4-stroke with catalyst)
Total	***505.50 ton/yr***	

The same calculation is done for HC. The results are given Table 24.

Table 24: The potential emission reduction in ton of pollutant per year

	CO	**HC**
Pollutant avoided in ton/yr	505.50	13.58

5.2.2 The costs

The cost of the inspection programme is given in Table 22. The costs of inspection in 2005 for the option of decentralised inspection amounts to:

4800 · 75.36 EUR	= 361.7 kEUR	(2-stroke without catalyst)
1800 · 75.36 EUR	= 135.6 kEUR	(2-stroke with catalyst)
45000 · 75.36 EUR	= 3391.2 kEUR	(4-stroke without catalyst)
18000 · 75.36 EUR	= 1356.5 kEUR	(4-stroke with catalyst)
Total	***5245.1 kEUR***	

The cost of repair is calculated from the number of vehicles that need one of the three maintenance options as indicated in Table 20 (taking into account the errors of commission as well) and the cost of repair as given in paragraph 5.1.4. After maintenance these motorcycles are inspected again, therefore the costs of a re-test are also added. An example of the repair and re-test costs for the situation of 2005 decentralised is given for the 4-stroke motorcycles equipped with a catalytic converter according the formula: **Number of motorcycles inspected · % detected as faulty · % specific repair needed · (repair + re-test costs)**

4-stroke with catalyst minor repair
18000 · 26% · 65% · (75 + 75.35) EUR = 457.4 kEUR
4-stroke with catalyst major repair
18000 · 26% · 30% · (200 + 75.35) EUR = 386.6 kEUR
4-stroke with catalyst replacement
18000 · 26% · 5% · (1100 + 75.35) EUR = 275.0 kEUR
Total ***1119.0 kEUR***

In Table 25 the costs of repair and re-test are given for each of the defined technology classes for the year 2005 and decentralised inspection agencies.

Table 25: Total costs of repair and re-test for all technology classes (in kEUR)

	2-stroke – w/o catalyst	**2-stroke – catalyst**	**4-stroke – w/o catalyst**	**4 –stroke catalyst**
Costs of repair	126.0	43.2	551.3	766.4
Costs of re-test	108.5	27.1	474.8	352.7
Total	234.5	70.3	1026.0	1119.0

This brings the total costs of the inspection and maintenance programme executed in 2005 for the decentralised inspection option to:

Total costs of inspection:	5245.1 kEUR
Total costs of repair and maintenance:	2449.9 kEUR
Total	***7695.0 kEUR***

5.2.3 The cost-effectiveness

The potential cost-effectiveness is obtained by dividing the total cost of inspection and maintenance by the potential amount of pollutant avoided. No attempt has been made to share the costs over different pollutants, since this would require a weighting of importance of the different pollutants, which is not available. On the other hand simply sharing the cost over the cumulative amount of tonnes avoided, irrespective the pollutant, would relate the cost-effectiveness mainly to the amount of CO avoided, since this is numerically the largest amount, although not necessarily the most important effect.

As mentioned earlier, it should be noted that the share of the labour costs is the main sensitivity of the total costs of the inspection programme. The results of the cost-effectiveness calculation for the Dutch example are given in Table 26 and Table 27 (decentralised and centralised inspection respectively).

Table 26: The result of the cost-effectiveness calculation for 2005 and 2010 and decentralised inspection agencies

the NETHERLANDS decentralised	year	Ton/yr Avoided	kEuro inspection	kEuro maintenance	kEuro/ton insp.+ maint.	percent repaired
CO	2005	505	5245	2450	15.22	18.4%
	2010	1967	10965	8205	9.75	22.8%
HC	2005	13.58	5245	2450	567	18.4%
	2010	28.18	10965	8205	680	22.8%

Table 27: The result of the cost-effectiveness calculation for 2005 and 2010 and centralised inspection agencies

the NETHERLANDS centralised	year	Ton/yr Avoided	kEuro inspection	kEuro maintenance	kEuro/ton insp.+ maint.	percent repaired
CO	2005	505	3067	2050	10.12	18.4%
	2010	1967	7534	7424	7.61	22.8%
HC	2005	13.58	3067	2050	377	18.4%
	2010	28.18	7534	7424	531	22.8%

In order to have a reference value for the calculated figures summarised in Table 26 and Table 27, the results of the cost-effectiveness study of the passenger car project are indicated in Table 28.

Table 28: Cost-effectiveness summary of the passenger car project (situation for the Netherlands in 1995 for otto-only vehicles on the test prescribed in directive 92/55/EEC)

the NETHERLANDS	I/M system	ton/yr avoided	kEuro/ton insp.+ maint.	percent repaired
CO	92/55/EEC	30.63	4.51	37.8%
HC	92/55/EEC	2.66	51.87	37.8%

It can be concluded that the methodology presented is very useful in order to calculate the cost-effectiveness of an inspection programme. Since the same calculation method is used within the passenger car project, the results of both studies can be compared to each other. However, due to the large number of assumptions made in the cost-effectiveness study of the motorcycle study, no conclusions can be drawn from it. In order to assess the cost-effectiveness more accurately a new study has to be started in order to get reliable information about:

- the actual composition of the fleet of a country which is subject to the inspection and maintenance programme;
- representative numbers for the emission reduction potential for 2-stroke motorcycles with a catalytic converter and future technology;

- hands-on experience for executing a road-worthiness test procedure and an indication on the time and investments needed for that;
- experience on the number of repair needed and costs of repair and maintenance;

6 Recommendations for formal procedure (draft amendment to road-worthiness directive 96/96/EC)

As directive 96/96/EC has not (yet) been amended to include motorcycles, it was one of the tasks of this study to draft an amendment text to be incorporated in the exhaust gas and noise emission test procedure. The task proved to be complicated by the fact that a number of questions even after execution of the underlying study still remain unanswered. These questions focus on the definition of actual limit values in relation to certain test conditions (type of idle revvings). An optimum between practicality of testing and accuracy of the results has still to be determined. Finding the answers will require further investigation. Nevertheless, an attempt has been made to draft the proposed test procedures that could be amended in annex II of directive 96/96/EC. This is set out in paragraph 6.1. All items indicated in brackets [] are not yet defined.

In drafting possible texts for the road-worthiness directive, appropriate existing texts, either in other parts of the directive or previously proposed by CITA to improve the provisions regarding visual inspection of emission equipment, have been used whenever possible. Once the further work suggested elsewhere in this report has been done, the proposed texts can be completed.

Despite of the recommended further work, a first draft amendment text is set-up leaving open the actual threshold values and idling speeds for testing. Because this draft set-up is very much in line with parts of exhaust gas testing at Type Approval, using a 4.5 Vol.-% threshold for CO at low idle speed could be applied for the time being. Following the same approach for noise justifies an excess noise limit value of 10 dB(A) at the stationary test. The effectiveness of this approach however still has to be determined.

6.1 DRAFT AMENDMENT TO DIRECTIVE 96/96/EC

6.1.1 Nuisance

6.1.1.1 Noise

6.1.1.1.1 Requirements applicable to all motorcycles as specified in directive 92/61/EEC Chapter I Article 1 point 2 categories (2) (two-wheel) and (3) (three-wheel) both having an engine capacity > 50 cm3 and a maximum design speed > 45 km/h.

6.1.1.1.1.1 Visual inspection of the exhaust system in order to check that it is complete, marked as being of an approved type and in a satisfactory condition and that there are no leaks.

6.1.1.1.1.2 Pre-condition engine to normal operating temperature, as defined by the manufacturer or, if this information is not available, to an engine block temperature of at least [80°C]. A 10 minute warm-up drive should be sufficient in most circumstances.

6.1.1.1.2 Measurement method

6.1.1.1.2.1 Noise evaluations are made according to the requirements prescribed in directive 97/24/EC Chapter 9 for stationary noise tests.

6.1.1.1.2.2 The engine speed for the test must be within ± 3% of the speed determined by an accurate rev counter.

6.1.1.1.3 Measuring equipment

6.1.1.1.3.1 Noise measurements are made using a precision sound level meter meeting the requirements of at least class 1 as specified by the International Electrotechnical Commission (IEC) in publication IEC 651.

6.1.1.2 Exhaust Emissions

6.1.1.2.1 Requirements applicable to all motorcycles as specified in directive 92/61/EEC Chapter I Article 1 point 2 categories (2) (two-wheel) and (3) (three-wheel) both having an engine capacity > 50 cm3 and a maximum design speed > 45 km/h.

6.1.1.2.1.1 The condition of the vehicle's battery should be good and it should be fully charged.

6.1.1.2.1.2 Visual inspection of the exhaust system in order to check that it is complete, marked as being of an approved type and in a satisfactory condition and that there are no leaks.

6.1.1.2.1.3 Visual inspection of any emission control equipment fitted by the manufacturer in order to check that it is complete and in a satisfactory condition and that there are no leaks.

6.1.1.2.1.4 Choke operation is not permitted during executing the test procedure and it has to be turned off.

6.1.1.2.1.5 Pre-condition engine to normal operating temperature, as defined by the manufacturer or, if this information is not available, to an engine block temperature of at least [80^{o}C]. A 10 minute warm-up drive should be sufficient in most circumstances. With motorcycles fitted with electric cooling fans, care should be taken not to warm the engine to the point that the fan is switched on.

6.1.1.2.1.6 The exhaust emissions from the motorcycle are sampled via a probe in a external pipe which is connected to the motorcycle exhaust(s) by (an) airtight connection(s). The external pipe must be of sufficient length and diameter to damp the effect of pulsations in the exhaust flow.

6.1.1.2.2 2-stroke motorcycles *not* fitted with an advanced emission control system such as a catalytic converter

6.1.1.2.2.1 The efficiency of the vehicle's emission control system is determined by measuring the CO and/or HC content of the exhaust gases under no-load conditions at [XXX] engine speeds, or procedures defined by the manufacturers.

6.1.1.2.2.2 The maximum permitted limit values are [YYY]

6.1.1.2.3 2-stroke motorcycles fitted with an advanced emission control system such as catalytic converter

6.1.1.2.3.1 The efficiency of the vehicle's emission control system is determined by measuring the CO and/or HC content of the exhaust gases under no-load conditions at [XXX] engine speeds, or procedures defined by the manufacturers.

6.1.1.2.3.2 The maximum permitted limit values are [YYY] .

6.1.1.2.4 4-stroke motorcycles *not* fitted with an advanced emission control system such as a three-way catalytic converter which is lambda-probe controlled

6.1.1.2.4.1 The efficiency of the vehicle's emission control system is determined by measuring the CO and/or HC content of the exhaust gases under no-load conditions at [XXX] engine speeds, or procedures defined by the manufacturers.

6.1.1.2.4.2 The maximum permitted limit values are [YYY]

6.1.1.2.5 4-stroke motorcycles fitted with an advanced emission control system such as a three-way catalytic converter which is lambda-probe controlled

6.1.1.2.5.1 The efficiency of the vehicle's emission control system is determined by measuring the CO and/or HC content of the exhaust gases under no-load conditions at [XXX] engine speeds, or procedures defined by the manufacturers.

6.1.1.2.5.2 The maximum permitted limit values are [YYY]

6.1.1.2.5.3 Measuring equipment

6.1.1.2.5.4 Vehicle emissions are tested using equipment that meet the requirements of at least class 1 as specified by ISO 3930. The minimum indicating range for CO is 9.99 Vol.-% and for HC 10000 ppm. The equipment used has to be designed to establish accurately whether the limit values prescribed or indicated by the manufacturer have been complied with. In the case of emission measurements on 2-stroke motorcycles, the equipment must be adequately protected against the adverse effects of high HC levels.

7 Conclusions and recommendations

In this Chapter the conclusions and recommendations derived from the experiences gained in the validation programme and the actual set-up of the proposed RW-test procedure are summarised. Also the cost-effectiveness study is discussed. The conclusions and recommendations are divided in six topics:

- General conclusions on the vehicles tested
- Exhaust gas emissions of motorcycles
- Noise emissions of motorcycles
- Cost-effectiveness results
- Recommendations derived from executing the validation programme
- Items to be investigated in the future

7.1 General conclusions on the vehicles tested in the validation programme

The fleet of vehicles tested in the underlying investigation prove to be not representative for the actual fleet in Europe. Therefore, based on this investigation, no detailed conclusions can be drawn about the actual situation on the road in Europe. It is very likely however that the situation on the road is worse then found in this study.

This situation is caused by the fact that most vehicles tested were supplied by local dealers or national importers (72%) whereas 11% of the motorcycles were hired from rental companies and only 17% were obtained directly from private owners. Only six of the motorcycles tested were equipped with legal or illegal Replacement Exhaust Silencing Systems (RESS).

Small 2-stroke vehicles with catalyst, in particular, are underrepresented in the distribution of the test programme. One of the reasons for this situation was the early withdrawal of the Spanish association of periodic inspections (AECA-ITV), which, as it was assumed, would be the main source of these types of vehicles to be tested in the validation programme.

Since only few tampered vehicles were tested within the measurement programme (only a few replacement exhaust pipes were found), it proved not possible to derive much information about tampering and the influence on exhaust gas and noise emissions. The difficulty of finding tampered vehicles was exacerbated by the problem of acquiring smaller 2-stroke motorcycles directly from private owners (instead from dealers or importers). These small vehicles from private owners are more likely to be tampered with (due to the relatively low power to mass ratio) and not to be well maintained.

7.2 Exhaust gas emissions of motorcycles

The conclusions of the exhaust gas emissions part of the study are divided in two parts:
- Conclusions derived from executing the validation programme
- Conclusions on the proposed road-worthiness procedure and threshold definition

Conclusions derived from executing the validation programme
The following conclusions can be drawn from the validation programme on gaseous emissions:

Exhaust gas emissions
In total 25% of the motorcycles tested emit above the TA limit on the Type I test (loaded driving cycle on a chassis dynamometer) on one or more emission components. On the Type II test (low idle test) however, only 11% of the vehicles exceeded the applicable limit of 4.5 Vol.-% CO. However, 5% of the motorcycles tested exceeded applicable limit of both the Type I **and** the Type II test. Most of the motorcycles that exceed the TA limit for the Type I test are 2-stroke vehicles (68%). When the number of high emitters is analysed by assigning them to the applicable regulation (ECE R 40-01) or directive (97/24/EC Chapter 5), it shows that a more significant share of high emitters is located in the class of motorcycles being type approved according to current legislation.

There is a significant relation between the TA driving cycle emissions (Type I test) and the emissions produced during driving in real-world circumstances. For some driving cycles, components and technology classes the correlation factor (R^2) is higher than 0.9. For NO_x however, a poor correlation is found, which can possibly be explained by the relatively low absolute emission level of this component. After assessment of the validation programme data, it can be concluded that the differences in emission levels between the TA and real-world test most probably will become higher in the future, particularly if new legislation is still based on a low performance driving cycle.

On the Type I test, most of the in-use motorcycles produced higher emissions than the values measured at the time of Type Approval. In the case of CO and HC for 2-stroke motorcycles, 80% of the vehicles have higher emissions. Motorcycles equipped with a catalytic converter were also tested in the validation programme. For these vehicles it became clear that the overall emission deterioration factor is higher than that for vehicles without catalytic converter.

In order to investigate the topic of reproducibility of testing motorcycles on emissions, three sets of influences have been defined. These are the repeatability of motorcycle emissions, the accuracy of the test equipment and other influences.

The reproducibility of motorcycle emissions on a single driving cycle (indicated by using the maximum spread of consecutive emission measurements on one motorcycle) has been evaluated. For CO the maximum spread for the vehicles tested is between 4 and 16%; for HC the maximum spread is between 6 and 15%.

The accuracy of the road-worthiness test equipment that is used in the study at the different laboratories is specified as class 1 equipment (OIML R 99 / ISO 3930) having a permissible error of 3% on CO and 5% on HC. This equipment seems to be accurate enough for the current state of technology (threshold values found between the range of 3.5 and 8 Vol.-% CO and 4000 and 8000 ppm HC).

Since both above mentioned influences seems to be rather small and the spread in the three consecutive idle test results can be rather high, special attention should be paid to the other items that have an influence on the reproducibility. These other influences are discussed in paragraph 7.5.

Conclusions on the proposed road-worthiness procedure and threshold definition
In order to derive possible threshold values, the relationship between the absolute emissions produced during the loaded driving cycle tests on a chassis dynamometer and the results of the (unloaded) idle tests were analysed. Unfortunately, no significant relationship between these results was found. Therefore another approach had to be found in order to identify motorcycles producing emissions above the applicable limit value of the Type I test. Figure 19 shows the basic concept of optimising the "errors of omission and commission".

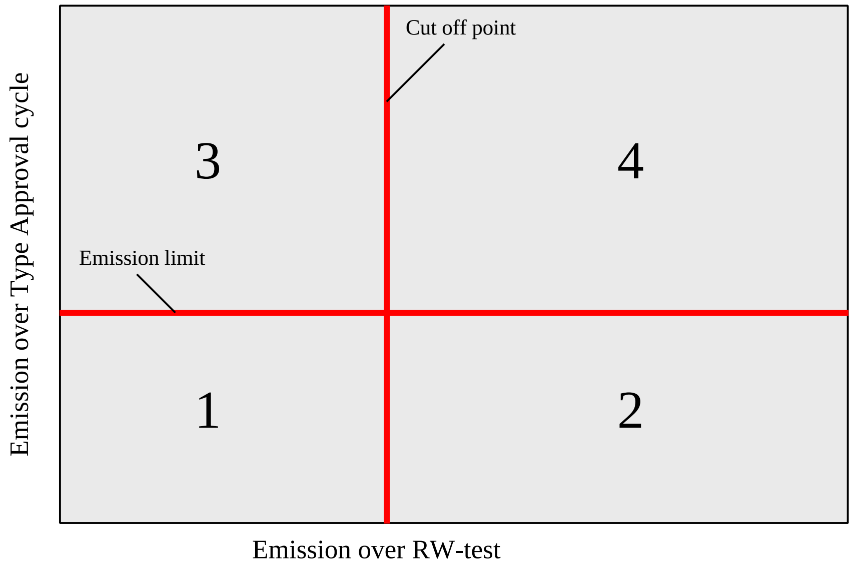

Figure 19: Basic approach

The approach of "errors of omission and commission" allows the calculation of so called 'cut off points' (values not to be exceeded during the idle test) for each technology class. In this work, the criterion of having the errors of commission below 5% was used in order to avoid significant amount of vehicles being classified non compliant, while they in fact were OK.

The evaluation of the data showed that it was not possible to define a cut off point for the low idle speed only (too many errors of commission). Therefore it was decided to calculate a cut off point taking into account all three idle speed test results. Using this approach enabled the definition of cut off points for the different technology classes taking into account the requirement of having the errors of commission to be lower than 5% related to the Type I test during type approval. The results of this analysis are summarised in Table 29.

Table 29: Cut off points (thresholds) of all technology classes taking into account rule of 5% errors of commission

Technology class	RW-test	CO-cut off point [Vol.-%]	HC-cut off point [ppm]	Include idle test in proposed procedure
2-stroke w/o catalyst, ECE R40	Idle	4.5	8000	Yes
	Medium idle	5	8000	No
	High idle	5	7000	Yes
2-stroke w/o catalyst, 97/24/EC	Idle	4.5	6500	Yes
	Medium idle	3.5	4000	No
	High idle	4	4000	Yes
2-stroke with catalyst, 97/24/EC (1)	Idle	-	-	-
	Medium idle	-	-	-
	High idle	-	-	-
4-stroke w/o catalyst, ECE R40 (3)	Idle	4.5	-	Yes
	Medium idle	6.5	-	Yes
	High idle	8	-	Yes
4-stroke w/o catalyst, 97/24/EC (3)	Idle	4.5	-	Yes
	Medium idle	5	-	Yes
	High idle	7	-	Yes
4-stroke with catalyst, ECE R40 (2), (3)	Idle	-	-	-
	Medium idle	-	-	-
	High idle	-	-	-
4-stroke with catalyst, 97/24/EC (3) , (4)	Idle	4.5	-	Yes
	Medium idle	5	-	No
	High idle	5	-	Yes

Notes:

(1) Only one motorcycle tested in the validation programme, no cut off points can be calculated

(2) None of the tested vehicles were 'high emitters'

(3) It was not possible to define a HC cut off point for the 4-stroke ECE R 40 'high emitters' taking into account the rule of 5% errors of commission.

(4) In technology class 4-stroke with catalyst according to directive 97/24/EC Chapter 5 no high emitters on HC were available.

For emission component CO, for new technology (4-stroke motorcycles equipped with a catalyst) the procedure seems to work even better since no errors of omission and commission are found. It will be necessary to see if this is still the case for the motorcycles coming on the market in a few years (that meet the more stringent limits).

Taking into account the rule of maximum 5% errors of commission, cut off points can be found for 5 out of 7 classes of motorcycles. Not being able to calculate cut off points for 4-stroke with catalyst under ECE R 40 does not in fact pose a problem, because these vehicles are not sold anymore. Therefore they will most probably never have to be tested using the proposed road-worthiness test. Not having data to calculate cut off points for 2-stroke with catalyst however is a problem, since these vehicles will be sold in high volumes by the time the RW procedure could be applied. Once major sales of 2-stroke with catalyst under regulation 97/24/EC Chapter 5 (and the next steps of legislation) have commenced additional measurements and cut off point calculations should be executed, in order to be able to assess the emission performance of this group of motorcycles.

For each of the vehicle classes (with sufficient data), cut off points have been found for all 3 types of idle test. In the case of the 2-stroke motorcycles (without catalyst) or the 4-stroke ones *with* catalytic converter, idle tests could be performed at two engine speeds (idle and high idle). When one of the idle test results exceeds the prescribed cut off point the vehicle is indicated as a 'high emitter'. For the 4-stroke motorcycles *without* catalyst idle tests should best be performed on three engine speeds (idle, medium idle and high idle). Such a motorcycle is indicated as a 'high emitter' when the result of 2 or more of the idle tests executed exceeds the cut off point. This methodology led to an error of commission lower than 5% of the tested motorcycles. However, the decision of which tests have to be executed during an actual road-worthiness test and which limits should be applied has to be made by the Commission and Member States.

2-stroke engines show additional cut off points for HC whereas for 4-stroke no cut off points could be defined since there are only few high emitters on HC in that technology class. Whether the HC emission should also be taken into account has yet to be decided since the additional value of testing on HC as well has not been established and since there is the possibility of the exhaust-gas test equipment being (permanently) damaged by ultra high HC emitters.

7.3 Noise emissions of motorcycles

The conclusions of the noise emissions are also divided in two parts:
- Conclusions derived from executing the validation programme
- Conclusions on the proposed road-worthiness procedure and threshold definition

Conclusions derived from executing the validation programme
Within the validation programme for in total 118 motorcycles a stationary and/or an in-motion noise test was executed. From the assessment of the test data gathered during the validation programme it can be concluded that eight motorcycles that were tested in the validation programme exceeded the applicable emission limit for in-motion noise.

Conclusions on the proposed road-worthiness procedure and threshold definition
There is no direct 1:1 correlation between the noise level emitted during the stationary test and the in-motion test. Assessment of the stationary and in-motion noise emissions produced at the time of Type Approval illustrated that for one noise level produced during the stationary test different noise levels are available for the in-motion noise test and vice versa. However, a relationship is available because as the noise emitted during the stationary test is increasing, the noise emitted on the in-motion test does also increase. Therefore it has been concluded that the stationary noise test can be used in order to identify high noise emitters.

Since the 1:1 correlation that has been looked for, did not give a satisfactory result, an alternative approach of finding high noise emitting motorcycles was suggested. This approach is based on calculating the difference between the stationary noise emission produced at the validation programme and at the time of TA as well as the difference between the in-motion noise measured in the validation programme and the applicable limit value. It seems to be capable of distinguishing between high and low noise emitting vehicles.

As mentioned in Chapter 4, the noise measurement results are affected by a lot of influences. Therefore it is concluded that a road-worthiness noise test should be defined that it is capable of identifying only extraordinarily high noise emitters and not for motorcycles having noise emission just above the applicable limit. When an excess limit of +5dB(A), which is in force in some European countries in order to enforce legislation, is applied to the stationary and in-motion measurement results of the validation programme, 21% of the motorcycles are identified as being a high emitter while they were, in fact, emitting under the limit on the in-motion test (errors of commission). When an excess limit value of 10 dB(A) is defined, no errors of commission are found, but on the other hand, this excess limit value is rather high.

The stationary noise emission value of the 10 motorcycles measured according to the Swedish protocol is in most cases higher than the noise emission testing according 97/24/EC Chapter 9. This is caused by the higher engine speed on which the motorcycle is tested. Because there are no reference values for noise available under this protocol (no vehicles were Type Approved according this method), it is not appropriate to be used in order to locate high noise emitting motorcycles.

7.4 Cost-effectiveness study

The methodology presented in Chapter 5 is found suitable in order to calculate the cost-effectiveness of an inspection programme. Since the same calculation method is used within an earlier passenger car project, the results of both studies can be compared to each other. For the Dutch situation, a rough calculation example for motorcycles is given. However, due to the large number of assumptions made in that cost-effectiveness example, no definite conclusions can be drawn. Therefore a new study should be started in order to get reliable information on:

- The organisation of road-worthiness testing in different countries.
- The actual composition of the fleet of a country which is subject to the inspection and maintenance programme.
- Representative numbers for the emission reduction potential for 2-stroke motorcycles with a catalytic converter and future technology.
- Hands-on experience with executing a road-worthiness test procedure and an indication on the time and investments needed for that.
- Experience on the number and types of repairs needed and costs for repair and maintenance.

7.5 Recommendations derived from executing the validation programme

The topic of reproducibility of the motorcycle exhaust gas emissions is strongly dependent on a lot of influences and therefore have a largely effect on the test results. One should note that these influences have to be minimised in order to have a reliable measurement result. The influences that have an effect on the reproducibility are:

- Pre-conditioning of the motorcycle
  - The engine of the motorcycle should be warmed up to operating temperature. In most cases a warm-up drive of 10 minutes meets this requirement.

  - Special attention needs to be paid to motorcycles equipped with an oxidation or a 3-way catalytic converter. Since the light-off temperature of the catalyst is important, the engine and complete exhaust system should be warm (operating temperature).
  - The manual or automatic choke should be off during executing the road-worthiness measurements.
- Other points of attention to improve the reproducibility when an idle test has to be executed are:
  - Temperature of the engine should be at normal operating temperature. An additional auxiliary cooling device can solve this problem.
  - The condition of the vehicle's battery should be good and it should be fully charged
  - Hardware to be used to improve the reproducibility of the measurements:
    - protection is needed for the exhaust gas measuring equipment when a high HC emitting motorcycle is tested. New developments and field tests executed by EGEA members showed that filters are available that are able to protect the measuring equipment from high hydrocarbons concentrations. These high concentrations can (permanently) damage the measurement equipment.
    - use of an external connection pipe in order to eliminate the effect of air pulsation, dilution of the exhaust emission with environment air and the problem that the sample probe can not be inserted far enough into the exhaust pipe
    - airtight connection of the extension pipe to prevent that environment air is entering
    - suction of the exhaust gas should not have any influence on the measurement result

In order to speed up the RW-test and to improve the reproducibility of the measurements it is recommended that when a motorcycle has two separate exhaust pipes, both extension pipes should be connected using an airtight connector to a common device in which the exhaust gas sample is collected. In that device, the sampling probe can be mounted and the sample can be taken.

The reproducibility of executing a stationary noise test is an important factor when defining a threshold value for noise, which reasonably identifies high noise emitting vehicles. A lot of influences are present that effects the noise level measured. The influences indicated below should be taken into account when executing a stationary and in-motion noise test:
- Preconditioning of the motorcycle
- Accuracy of the noise measurement equipment
- Test site conditions
- Ambient conditions

Following difficulties were experienced during executing the proposed road-worthiness test procedure in the validation programme:
- engine speed measurement and adjustment during road-worthiness test procedure, and
- testing of automatic transmission motorcycles is rather difficult. Since the rear wheel is directly connected to the engine, the motorcycle should be lifted in order to let the rear wheel rotate freely. This approach is also important in order to minimise the risk of accidents and injuries of the inspector.

7.6 Items to be investigated in the future

From the validation programme that has been executed, insight was gained into many influences and problems that would occur during the implementation of the proposed road-worthiness test procedure. However, some of the items mentioned are still open and need further investigation. These include:

Further evaluation of existing data
Based on further input from the European Commission, Members States and stakeholders in the field of motorcycle type approval and RW testing, the data set gathered in the underlying project can be evaluated further. This dedicated data evaluation seems to be necessary in order to determine the best (and most cost effective) approach towards RW testing of motorcycles. The variables in that evaluation will be the amount and the actual threshold value(s) and the idle speed(s) at which the measurements have to be executed.

Two-stroke motorcycles equipped with a catalytic converter
In relation to the European situation, small two-stroke motorcycles are underrepresented in the validation programme. Particularly motorcycles equipped with future technology (catalytic converter and direct injection) were not included. Because of this, no direct conclusions can be drawn for these motorcycles in order to define cut off points for the road-worthiness test procedure.
If these types of motorcycles are to be included in the road-worthiness test procedure, more should be known about their emissions during the TA driving cycle and the RW-test. Exhaust gas emission measurements on these types of vehicles are needed in order to define reliable cut off points based on actual measurements.

Tampering
Just like 2-stroke motorcycles equipped with a catalytic converter, tampered motorcycles are also underrepresented in the validation programme. Only a few motorcycles were found that had been equipped with a replacement exhaust pipe. Other items, like missing air filters, adjustment or replacement of carburettors, tuning etc. were not found at all. As a result, no representative information about tampering and the influence on the exhaust gas and noise emissions can be derived from the study.

Reproducibility
On the issue of the reproducibility of testing motorcycles on exhaust emissions and noise, some items are still open. From the validation programme no information can be derived that can give an indication of the reproducibility of performing the RW-test procedure when the same motorcycle is tested at different laboratories/garages. This item is very important since it directly indicates whether the proposed procedure and prescribed thresholds will work when the procedure comes into force. In this study no measurements were executed in order to get an indication in the spread in emission results for the same types of motorcycles and possibly deterioration factors. These items are also important in order to define a more reliable threshold value.

External influences
In Chapter 4, items were discussed that have an influence on the reproducibility of the exhaust gas and noise emission results of the RW-test. For some of these items the

influence is addressed but the actual effect of the influence on the reproducibility is not (yet) known. Additional research can help to identify the influence of these items. The information will also be of value in the definition of the RW-test procedure. If an item has been investigated and solutions are found to minimise its effects, it will increase the reproducibility of the RW-tests. These influences are:

- Influence of the cooling wind and ambient temperature
- Engine temperature during measuring emissions
- Deviation of the engine speed on the exhaust gas and noise emission measurement

Future legislation

As future legislation comes into force, the technology of motorcycles will dramatically change (i.e. four-stroke motorcycles will be equipped with three way catalysts and 2-stroke motorcycles with direct injection and/or catalytic converter). Since these types of motorcycles could not be included in the validation programme, additional measurements will have to be performed in order to validate the proposed RW-test and to calculate suitable cut off points.

Noise

In order to be able to define a reasonable threshold value for the noise road-worthiness test procedure, it is recommended that extra measurements are performed to gain insight into:

- The noise emission value of the stationary and in-motion test of extraordinarily high noise emitting motorcycles.
- The problems of measuring stationary and in-motion noise for motorcycles equipped with an automatic gearbox. The results of the validation programme indicate that for these types of motorcycles additional influences are present that have an effect on the noise emission measured. These could include:
  - The effect of deterioration of the motorcycle
  - Problems of finding a reliable signal to measure engine speed
  - Problems of keeping the engine on a stable engine speed during the test

8 References

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[6] ECE Regulation 40 and Amendment 1 "Uniform provisions concerning the approval of motorcycles equipped with a positive ignition engine with regard to the emission of gaseous pollutants by the engine"

[7] ECE Regulation 41 "Uniform provisions concerning the approval of motorcycles with regard to noise"

[8] Directive 78/1015/EEC "Motorcycles noise testing"

[9] Directive 97/24/EC on two- or three-wheeled motor vehicles Chapter 5 ("Measures to be taken against air pollution caused by two- or three-wheeled motor vehicles")

[10] Directive 97/24/EC on two- or three-wheeled motor vehicles Chapter 9 ("Permissible sound level and exhaust system of two- or three-wheeled motor vehicles")

Appendices

Appendix A: Enforcement of legislation on noise for mopeds and motorcycles
Appendix B: Definition of engine speed to use for stationary noise test in Sweden
Appendix C: Overview of current motorcycles fleet in-use in Europe
Appendix D: Validation programme procedure protocol
Appendix E: Test report template file
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Appendix L: Repeatability of exhaust gas emission measurements

A Enforcement of legislation on noise for mopeds and motorcycles

			B	D	DK	ES	F	GR	IRL	I	NL	UK
1. New MP*/ MC*	1.1 MP Type Approval		ECE R63 or National	National	ECE R63	ECE R9	ECE R63 or National (TPSI)	ECE R63	None	ECE R63 or National	National	ECE R63 or National or self certif.
	1.2 MC Type Approval		National ECE R41 EC stage 0	ECE R41 EC stage 2	EC stage 1	ECE R41 EC stage 2	EC stage 2	ECE R41 EC stage 2	None	National ECE R41 EC stage 1	EC stage 2	self certif. EC stage 1
	1.3 C.O.P.	for MP	Y	Y	N	N	N	N	N	N	Y	N / (1)
		for MC	Y	Y	N	N	N	N	N	N	N	N / (1)
		frequency	not defined	3-4/year							1st + every 2 year	
	1.4 Grey import	for MP	Y	Y	Y	N	Y	N	N	N	impossible	N
		for MC	Y	Y	Y	N	Y	N	N	N	Y	N
		method		theor.Y, often N	as 1.1, 1.2		Static				Motion R41	
2. In use	2.1 Regular check	for MP	N	N (2)	N	N	N	N	N	N	N	N (2)
		for MC	N	N (2)	Y	Y	N	N	N	N	N	N (2)
		frequency	-	every 2 yr.	when sold if > 5 yr	every 4 yr.	-	-	-	-	-	if > 3 yr. Every yr.
	2.2 Spot checks	for MP	Y	Y	N	Y	Y	Y	N	Y	Y	Y
		for MC	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
	If yes	method	static	by ear TUV / DEKRA (3) < Ref. + 5 db(A)	static	Static < Ref. + 5 dB(A)	Static	Static	-	Static < Ref. + 5 dB(A)	Static < Ref. + 5 dB(A)	Only Police Opinion; no test procedure
		penalty	Fine + rectification vehicle (5)	DM 110 + 3 points	Fine + rectification vehicle (5)	Confiscated until new test	FFR 300 rectification vehicle (5)	GRD 50.000	-	Fine + new test	NLG 150 (confisc.) (8)	Fine + rectification vehicle (5)
		effective ?	N	N	Y	Y	N	N	-	N	Y	N
		(why not)	Not frequent enough	Equipment and staff is available (9)			Not frequent enough	(6)		Not strict enough		Not frequent enough, no provis. (7)

Notes

(1) If homologated by UK (e13): Yes

(2) Safety items only, noise only if too loud or no marking

(3) Police does measures occasional, but sends owner to test institute (TUV/DEKRA)

			B	D	DK	ES	F	GR	IRL	I	NL	UK
3. Replacement	3.1 Limit MP		as 1.1	as 1.1	not allowed	as 1.1	Y TPSI	N	N	as 1.2	as 1.2	BS AU 193
Exhaust	3.2 Limit MC		ECE R 41	as 1.2	as 1.2	as 1.2	as 1.2	N	N	as 1.2	as 1.2	BS AU 193
Silencing	3.3 C.O.P.	for MP	N	Y		N	N	N	N	N	Y	N
System (RESS)		for MC	N	Y		N	N	N	N	N	Y	N
	if yes:	frequency		unknown							random check	
	3.4 Verification	appr. Marks		Y		N	Y	N	N	N	Y	Y
		by whom		KBA			Customs				ECD	(11)
	Effective ?		N	No, early never done			No regular verifications		N		Y	No time + resources
4. Illegal silencers	4.1 No approval	for MP	N	N	N	N	N	N	Y	No control	N	N
	allowed ?	for MC	N	N	N	N	N	N	Y	No control	N	N
	penalty			DM 110 + 3 points	confiscation parts, new test, fine		as 2.2	as 2.2 (6)			fine + confiscation of parts	fine
	4.2 Allowed to sell, etc.		N	Y	Y	Y	Y (12)	Y	Y	Y	N	Y
	If yes:	restricted?		racing only	N		only if license (12)			Racing only		Racing only
	If no	respected?								(10)	N	
	4.3 Allowed to advertise		Y	Y	Y	Y	N	Y	Y	Y	Y	Y
	If no	respected?					N					N

Notes

(4) Measured level should be lower as Reference level, 5 dB tolerance

(5) Vehicle rectification notice, vehicle has to be put in original state and tested within certain time

(6) Owner can ask appeal and replace parts before 2nd test

(7) The police has no legal provisions to measure noise level

(8) MP: NLG 150, confiscation depends on noise level; MC: NLG 250, no rectification or confiscation

(9) The knowledge about the endangering of noise is not spread in the German population

(10) Everybody is using racer silencers

(11) From 01.06.1996 either self certification to BS AU 193 or an EU approval

(12) Parts can not be displayed on dealer showroom and theoretically, can be sold only to holders of racing permit

B Definition of engine speed to use for stationary noise test in Sweden

Stroke length mm	Engine speed r/min	Stroke length mm	Engine speed r/min	Stroke length mm	Engine speed r/min
30	11000	57	5700	84	3900
31	10600	58	5600	85	3800
32	10300	59	5500	86	3800
33	10000	60	5500	87	3700
34	9700	61	5400	88	3700
35	9400	62	5300	89	3700
36	9100	63	5200	90	3600
37	8900	64	5100	91	3600
38	8600	65	5000	92	3500
39	8400	66	5000	93	3500
40	8200	67	4900	94	3500
41	8000	68	4800	95	3400
42	7800	69	4700	96	3400
43	7600	70	4700	97	3400
44	7500	71	4600	98	3300
45	7300	72	4500	99	3300
46	7100	73	4500	100	3300
47	7000	74	4400	101	3200
48	6800	75	4400	102	3200
49	6700	76	4300	103	3200
50	6600	77	4200	104	3100
51	6400	78	4200	105	3100
52	6300	79	4100	106	3100
53	6200	80	4100	107	3000
54	6100	81	4000	108	3000
55	6000	82	4000	109	3000
56	5800	83	3900	110	3000

C Overview of current motorcycles fleet in-use in Europe

In Table C-1 the most important classes with respect to their influence on emission behaviour are summarised. Next to each class the best estimate of the share of the total is given. The share of each class is determined from the fleet data available throughout Europe. The 2-wheelers with an engine displacement smaller than 50 cm^3 are taken apart from the fleet. In the table below the numbers between brackets represent the figures as the small 2-wheelers would have been in the fleet.

Engine						Age (1>2>3)			Type (1>2>3)					
Displacement [cm^3]	Share [%]	nr. Strokes [2/4]	Share %	Cat [Y/N]	Share %	0-3	3-10	>10	Moped	Scooter	Off road	Touring	Chopper	Sports
0-50	100 (39)	2	95	Y	5	1	2	3	2	1				
				N	95	2	1	3						
		4	5	Y	5	1	2	3	2	1				
				N	95	2	1	3						
51-125	30 (18)	2	35	Y	5	1	2	3		1		2		
				N	95	2	1	3						
		4	65	Y	5	1	2	3		1		2	3	
				N	95	2	1	3						
126-250	24 (14)	2	20	Y	5	1	2	3		1		2		
				N	95	2	1	3						
		4	80	Y	5	1	2	3		1		2	3	
				N	95	2	1	3						
251-500	5 (4)	4	-	Y	5	1	2	3		2		1	3	
				N	95	3	2	1						
501-750	21 (13)	4	-	Y	5	1	2	3				1	2	3
				N	95	3	2	1						
751-1000	12 (7)	4	-	Y	5	1	2	3				1	2	3
				N	95	2	1	3						
>1000	8 (5)	4	-	Y	5	1	2	3				1	2	3
				N	95	2	1	3						

Remarks:

- For engine capacities > 250 cm3, 2-stroke engines have not been taken into account.
- Since not sufficient data was available in Europe, the parameters down below are based on expert estimates:
  - the shares of motorcycles equipped with a catalytic converter
  - the distribution of vehicle age
  - the distribution over the different models

D Validation programme procedure protocol

Directives for testing in I&M measurement programme

Objective
In this document the procedure for the 2nd CITA Research Study Programme on Emission (Study 2 Motorcycle emissions) project is described. The measurements executed in this project have to be according to these directives. In case of an obscurity or incompleteness please contact TNO to discuss the found remark. Some parts of these directives have directly been taken from the Artemis WP500 round robin directives.

Driving cycles
In order to find correlation between driving cycles and 4-gas tests, two driving cycles have been selected to be used in the measurement programme. These are:
- Type Approval driving cycle (ECE R 40 - UDC)
- FHB driving cycles (defined by using specific parts Zentrum, Pheriperie and Ueberland)

The Type Approval test cycle (UDC) will be used for two main reasons. First it will serve as a reference to compare the emission results of other vehicles of the same type, which have already been tested for Type Approval to. Secondly it is helping to check the technical state of the vehicle. The FHB driving cycles are in because these are based on real-world driving on a motorcycle (an extra step in higher driving dynamics).

Chassis dynamometer settings
The regulations described in US-FTP '75 Part 86 subpart F (§ 86.529-98) directives are valid for this measurement programme.

Measuring order
To have a good insight in the condition of the motorcycles as they are on the road, it is *prohibited* to do any service or maintenance in the laboratory before the motorcycle is tested.

Before the first test take place, the motorcycle is conditioned in a temperature controlled soak or test room (and have to cool down) during the night according to the directive Chapter 5. The real measurements can start the next day.

The order of the driving cycles and 4 gas tests is prescribed in the flowchart of Figure D-1. The explained test programme is valid for all motorcycles.

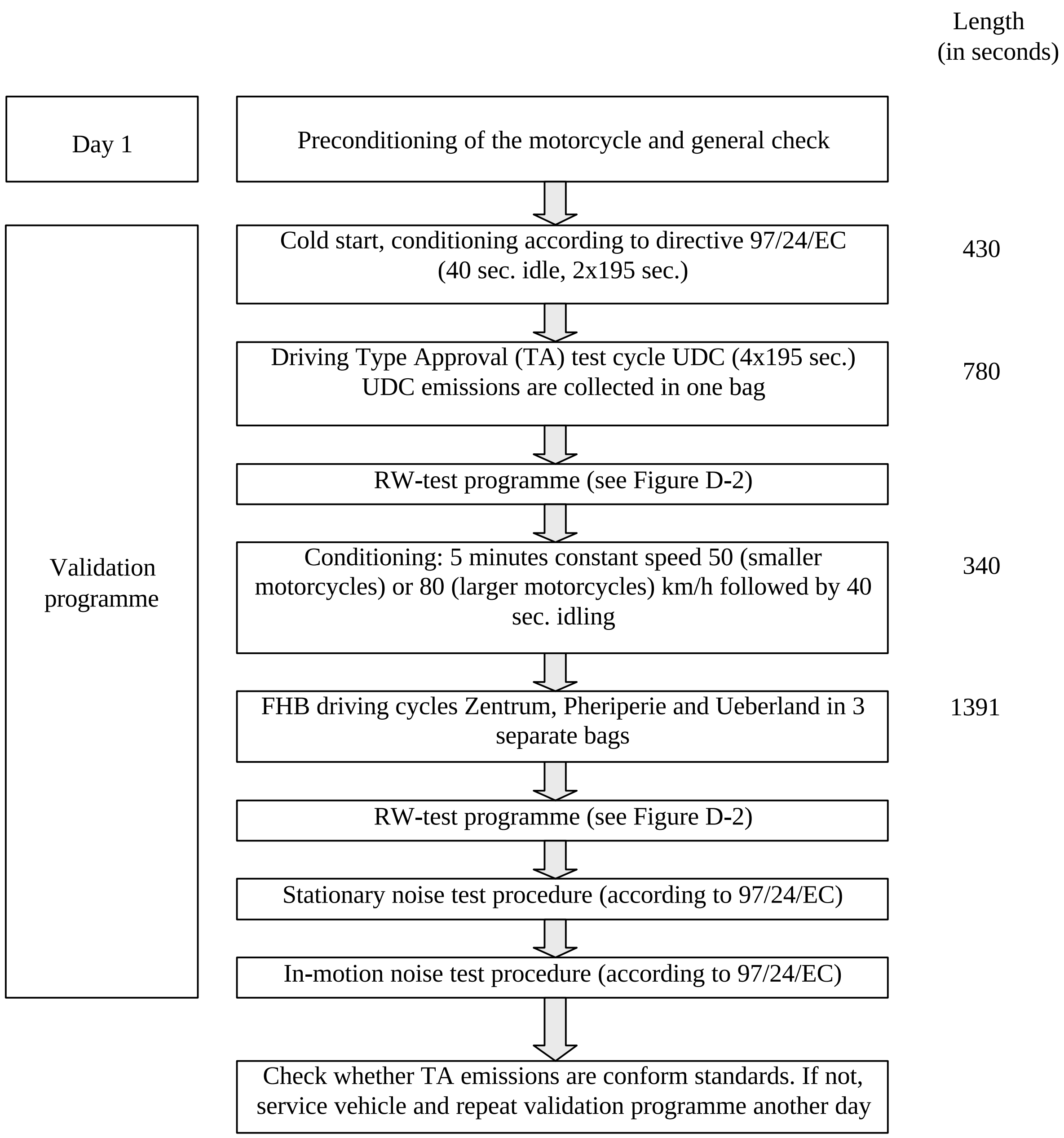


Figure D-1: Flowchart of measuring order per motorcycle

Note 1: After the conditioning period of driving at constant speed at 50 or 80 km/h, which will be ended by driving from 50 (80) km/h to 0 km/h on the chassis dynamometer in neutral, the engine does not have to be turned off. Directly after the idle period of 40 seconds the next driving cycle sequence can be started.

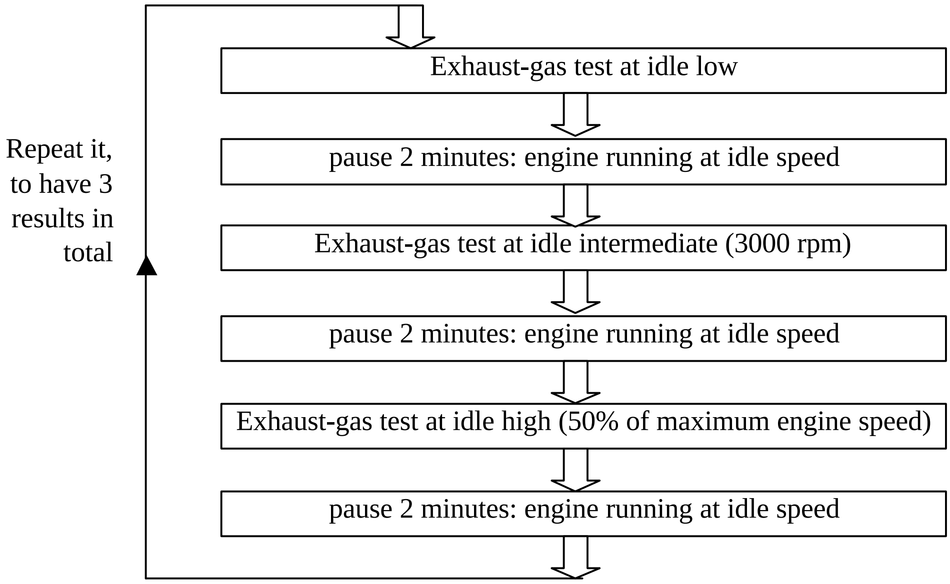


Figure D-2: Flowchart of specific exhaust-gas test at idle procedure

Note 1: Measurement results have to be stored when emission level and engine speed is stable for minimal 2 seconds.

Note 2: This test procedure has to be repeated to have 3 results in total.

Measurement results

The measurement results have to be collected in a digital logbook, to be opened within Microsoft Excel 97. For each laboratory, a single version will be created. Using the same layout will speed up the data processing and analysing after the measurements have been executed. In the logbook bag emissions (CO, HC, NO_x, CO_2) and fuel consumption (derived from carbon balance) of the driving cycles have to be collected. Also the results of the 4-gas tests can be entered in this logbook. TNO will supply this logbook which is conform the proposed protocol of TÜV Nord.

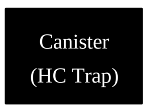
4-gas test equipment and procedure for 2 stroke motorcycles

After the presentation of Mr. Taubenreuter at the meeting of 4 October 2001, it has been decided to use the following test equipment configuration and measuring procedure.

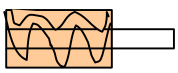
Used equipment:

4 gas tester:

Canister (HC trap):



Fuel filter:



Sample line:

The procedure: Before each motorcycle is tested, the fuel filter should be replaced by a new one (in order to start with a clean fuel filter). The canister should be cleaned by back flushing it with compressed air. After that the 4-gas tester should be calibrated with zero gas (residual test).

First check: level of HC emissions

Set-up of the measurement equipment:

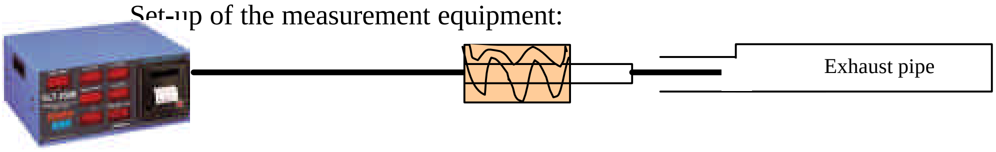


Figure D-3: Check 1 of 4 gas test

Check level of HC emission at idle speed by using the fuel filter. If the HC emissions are very high (exceeding range of 10.000 ppm and malfunction of the 4-gas tester) directly stop analysing, take away probe from the exhaust pipe and create a set-up like displayed in Figure D-4. Also be sure the probes are flushed with clean air and the 4-gas tester is calibrated (zero) again in order to remove all sniffed exhaust gas from the measuring system. In all other cases continue measurement.

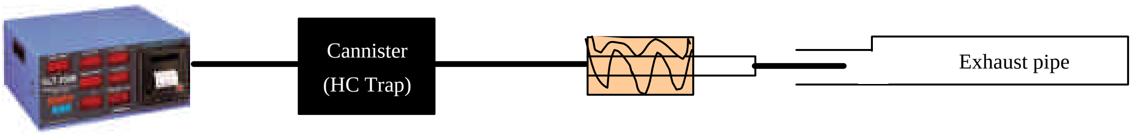


Figure D-4: Check 2.1 of 4 gas test

By putting the canister (including coal filter) into the system, the analyser will be protected from high concentrations of HC emissions and therefore there is no malfunction of the analyser to check the CO emissions.

Remark to both Figures: The distance between fuel filter and sample probe should be as short as possible in order to have not too much condensed HC in the sample lines.

4-gas test equipment for 4 stroke motorcycles

For 4 stroke motorcycles the set-up of the system is described in Figure D-5.

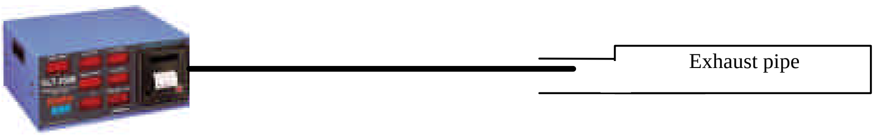


Figure D-5: System set up for 4-stroke motorcycles

Overall conditions

Fuel

Because the state of the vehicle on the road is very important in this project, no special fuel will be prescribed. Each vehicle has to be tested on normal commercial fuel. The fuel specification has also to be entered in the logbook of the motorcycle.

Oil for 2 stroke motorcycles

If needed, the by the manufacturer prescribed mixture oil will be used during the tests, conform the mixture ratio which is also prescribed by the manufacturer.

Preconditioning

For preconditioning of the motorcycles and the chassis dynamometer before starting the first test, directive 97/24/EC Chapter 5 is prescribed.

Conditioning of chassis dynamometer
From US directive Part 86 subpart F, paragraph §86.535-90 (f) is valid.
"If the dynamometer has not been operated during the two hour period immediately preceding the test, it shall be warmed up for 15 minutes by operating at 50 km/h (31 mph) using a non-test vehicle, or as recommended by the dynamometer manufacturer."

Maximum idling time in between measurements
If it is not possible to directly start the measurement after the vehicle has been conditioned, the idling time in between the conditioning and the measurement has to be less than 5 minutes. Otherwise differences can be found comparing the emission results of the different measurement days.

Tyre pressure
The requirements for tyre pressure will be taken from directive 97/24/EC Chapter 5:
"The tyre pressure must be that indicated by the manufacturer for performance of the preliminary road test to set the brake. However, if the diameter of the rollers is less than 500 mm, the pressure in the tyres may be increased by 30-50%". The drive wheel tyre pressure shall be reported with the test results.

Starting of engine
Since it is possible the engine of the motorcycle does not start directly, the engine starting procedure of the US-FTP (Part 86 -Subpart F, §86.536-78 (c)) is prescribed. This procedure is explained in the flowchart of Figure D-6.

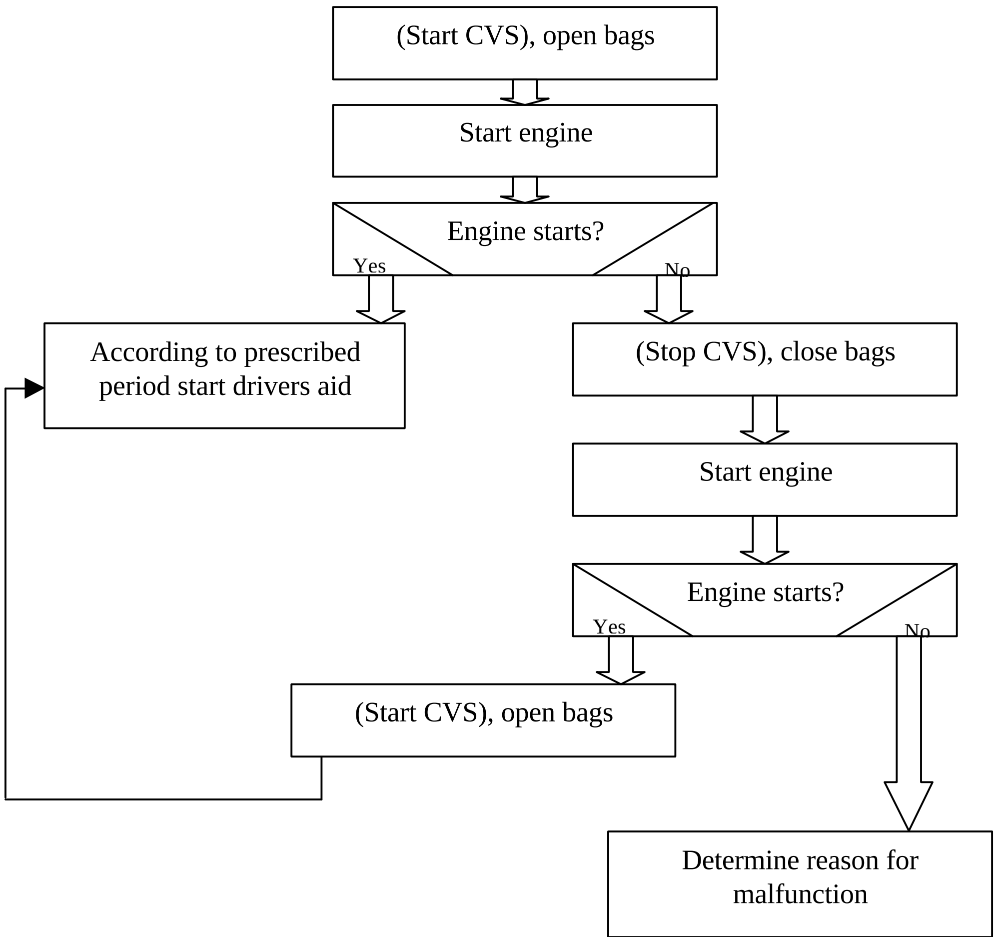


Figure D-6: Flowchart for starting the motorcycle engine

E Test report template file

<Enter Name of motorcycle>

CITA study on motorcycle emissions and noise - validation programme

Data input sheet for measurements CITA (motorcycle emissions)		
	Owner data	
Owner name		
Owner adress - street		
Owner adress - postal code		
Owner adress - city		
Owner adress - country		
Owner telephone number		
	Vehicle data general	
Manufacturer		
Type / Trademark		
Official type specification		
VIN		
Engine number		
Working principle (2 or 4 stroke)	4	
Engine capacity		[cc]
Maximum net power		[kW]
Engine speed at maximum net power		[rpm]
Maximum vehicle speed		[km/h]
Fuel system		[carburetor/injection]
Nr. of carburetors / Nr. of injectors		[-]
Choke		[manual/automatic/no]
Cooling system		[air/water]
Gearbox type		[manual/automatic/semi-automatic]
Number of gears		[-]
Wheelbase		[mm]
Tyre size front wheel		
Tyre size rear wheel		
Curb mass		[kg]
Power to mass ratio	not calculated	[kW/tonne]
Tank capacity		[liter]
Standing noise standard		[dB(A)]
Standing noise Swedish		[dB(A)]
Driving noise		[dB(A)]
Type approval code		
Oil mixture ratio (2 stroke only)		
	Vehicle data specific	
Odometer		[km]
Engine power reduction		[yes/no]
Method of reduction		
Manufacturer of reduction		
License plate number		
First registration/model year		
Series exhaust emission system		[yes/no]
when no, Exhaust system with national/EC approval		
when no, manufacturer of exhaust system		
when no, type number of exhaust system		
Lines (4 in 2 or 4 in 1)		[-]
After treatment system		[yes/no]
Method of after treatment system		
Spark plug manufacturer		
Spark plug type		

Visual inspection			
Emission system OK		[yes/no]	
Tyre pressure front		[bar]	
Tyre pressure rear		[bar]	

Measurements - Driving cycles			
Before/after maintenance and service		[before/after]	
Maintenance remarks			
Laboratory		[MTC/TNO/TUEV Nord/DEKRA]	
Inertia setting chassis dynamometer (kg)		[According US-FTP $86.529-98]	
Force setting chassis dynamometer (N)		[According US-FTP $86.529-98]	
Force at vehicle speed (km/h)		[According US-FTP $86.529-98]	
or by factors A, B and C(derived from on road coast down)	**prescribed**	**set on chassis dyno after zero**	
A			
B			
C			
Fuel specification	Commercial	[REF/Commercial] and type	

UDC results			
Date of test day		780 seconds, 4057 meter	
Operator		Insert used analyser ranges	
Test driver		in this column	
Ambient air pressure			[mbar]
Ambient temperature			[degree Celsius]
Relative humidity			[%]
UDC-Distance driven		at 20 C and 1 atm	[m]
Diluted exhaust-gas volume at normal conditions (0 degrees Celsius and 1 atmosphere pressure)	not calculated		[Nm^3]
UDC-CO bag emissions diluted exhaust gas			[ppm]
UDC-CO2 bag emissions diluted exhaust gas			[vol %]
UDC-HC bag emissions diluted exhaust gas			[ppm]
UDC-NOx bag emissions diluted exhaust gas			[ppm]
UDC-CO bag emissions dilution air			[ppm]
UDC-CO2 bag emissions dilution air			[vol %]
UDC-HC bag emissions dilution air			[ppm]
UDC-NOx bag emissions dilution air			[ppm]
Number of 'Driver out of tolerance' 97/24/EC			
Remarks			

Calculation area		
Dillution factor (DF)	not calculated	[-] according EC 97/24
1-1/DF	not calculated	[-] according EC 97/24
KH	not calculated	[-] according EC 97/24
H	not calculated	[-] according EC 97/24
Psat	not calculated	[kPa] according EC 97/24
UDC-CO emissions	not calculated	[values are calculated in [g/test] automaticly]
UDC-CO2 emissions	not calculated	[values are calculated in [g/test] automaticly]
UDC-HC emissions	not calculated	[values are calculated in [g/test] automaticly]
UDC-NOx emissions	not calculated	[values are calculated in [g/test] automaticly]
UDC-CO emissions	not calculated	[values are calculated in [g/km] automaticly]
UDC-CO2 emissions	not calculated	[values are calculated in [g/km] automaticly]
UDC-HC emissions	not calculated	[values are calculated in [g/km] automaticly]
UDC-NOx emissions	not calculated	[values are calculated in [g/km] automaticly]
Fuel consumption UDC	not calculated	[calculated using carbon balance method, according EC 93/116]

TA values and Emission limits UDC	**TA value**	97/24 EC	Li…
CO [g/km]		13.00	
HC [g/km]		3.00	
NOx [g/km]		0.30	
HC + NOx [g/km]		-	

Specify directive (ECE R40 (old) or 97/24 EC (recent))

Shift patterns measurements: Engine speed / vehicle speed ratio's	Engine speed	Vehicle speed	Ratio n/v
first gear			not calculated
second gear			not calculated
third gear			not calculated
fourth gear			not calculated
fifth gear			not calculated
sixth gear			not calculated

FHB Zentrum results			
Date of test day		401 seconds, 2462 meter	
Operator		Insert used analyser ranges	
Test driver		in this column	
Ambient air pressure			[mbar]
Ambient temperature			[degree Celsius]
Relative humidity			[%]
FHB Zentrum-Distance driven		at 20 C and 1 atm	[m]
Diluted exhaust-gas volume at normal conditions (0 degrees Celsius and 1 atmosphere pressure)	not calculated		[Nm^3]
FHB Zentrum-CO bag emissions diluted exhaust gas			[ppm]
FHB Zentrum-CO2 bag emissions diluted exhaust gas			[vol %]
FHB Zentrum-HC bag emissions diluted exhaust gas			[ppm]
FHB Zentrum-NOx bag emissions diluted exhaust gas			[ppm]
FHB Zentrum-CO bag emissions dilution air			[ppm]
FHB Zentrum-CO2 bag emissions dilution air			[vol %]
FHB Zentrum-HC bag emissions dilution air			[ppm]
FHB Zentrum-NOx bag emissions dilution air			[ppm]
Number of 'Driver out of tolerance' 97/24/EC			
Remarks			
Calculation area			
Dillution factor (DF)	not calculated	[-] according EC 97/24	
1-1/DF	not calculated	[-] according EC 97/24	
KH	not calculated	[-] according EC 97/24	
H	not calculated	[-] according EC 97/24	
Psat	not calculated	[kPa] according EC 97/24	
FHB Zentrum-CO emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Zentrum-CO2 emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Zentrum-HC emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Zentrum-NOx emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Zentrum-CO emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Zentrum-CO2 emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Zentrum-HC emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Zentrum-NOx emissions	not calculated	[values are calculated in [g/km] automaticly]	
Fuel consumption FHB Zentrum	not calculated	[calculated using carbon balance method, according EC 93/116]	

FHB Peripherie results			
Date of test day		467 seconds, 3834 meter	
Operator		Insert used analyser ranges	
Test driver		in this column	
Ambient air pressure			[mbar]
Ambient temperature			[degree Celsius]
Relative humidity			[%]
FHB Peripherie-Distance driven		at 20 C and 1 atm	[m]
Diluted exhaust-gas volume at normal conditions (0 degrees Celsius and 1 atmosphere pressure)	not calculated		[Nm^3]
FHB Peripherie-CO bag emissions diluted exhaust gas			[ppm]
FHB Peripherie-CO2 bag emissions diluted exhaust gas			[vol %]
FHB Peripherie-HC bag emissions diluted exhaust gas			[ppm]
FHB Peripherie-NOx bag emissions diluted exhaust gas			[ppm]
FHB Peripherie-CO bag emissions dilution air			[ppm]
FHB Peripherie-CO2 bag emissions dilution air			[vol %]
FHB Peripherie-HC bag emissions dilution air			[ppm]
FHB Peripherie-NOx bag emissions dilution air			[ppm]
Number of 'Driver out of tolerance' 97/24/EC			
Remarks			
Calculation area			
Dillution factor (DF)	not calculated	[-] according EC 97/24	
1-1/DF	not calculated	[-] according EC 97/24	
KH	not calculated	[-] according EC 97/24	
H	not calculated	[-] according EC 97/24	
Psat	not calculated	[kPa] according EC 97/24	
FHB Peripherie-CO emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Peripherie-CO2 emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Peripherie-HC emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Peripherie-NOx emissions	not calculated	[values are calculated in [g/test] automaticly]	
FHB Peripherie-CO emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Peripherie-CO2 emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Peripherie-HC emissions	not calculated	[values are calculated in [g/km] automaticly]	
FHB Peripherie-NOx emissions	not calculated	[values are calculated in [g/km] automaticly]	
Fuel consumption FHB Peripherie	not calculated	[calculated using carbon balance method, according EC 93/116]	

FHB Ueberland results			
Date of test day		524 seconds, 7309 meter	
Operator		Insert used analyser ranges	
Test driver		in this column	
Ambient air pressure			[mbar]
Ambient temperature			[degree Celsius]
Relative humidity			[%]
FHB Ueberland-Distance driven		at 20 C and 1 atm	[m]
Diluted exhaust-gas volume at normal conditions (0 degrees Celsius and 1 atmosphere pressure)	not calculated		[Nm^3]
FHB Ueberland-CO bag emissions diluted exhaust gas			[ppm]
FHB Ueberland-CO2 bag emissions diluted exhaust gas			[vol %]
FHB Ueberland-HC bag emissions diluted exhaust gas			[ppm]
FHB Ueberland-NOx bag emissions diluted exhaust gas			[ppm]
FHB Ueberland-CO bag emissions dilution air			[ppm]
FHB Ueberland-CO2 bag emissions dilution air			[vol %]
FHB Ueberland-HC bag emissions dilution air			[ppm]
FHB Ueberland-NOx bag emissions dilution air			[ppm]
Number of 'Driver out of tolerance' 97/24/EC			
Remarks			

Calculation area		
Dillution factor (DF)	not calculated	[-] according EC 97/24
1-1/DF	not calculated	[-] according EC 97/24
KH	not calculated	[-] according EC 97/24
H	not calculated	[-] according EC 97/24
Psat	not calculated	[kPa] according EC 97/24
FHB Ueberland-CO emissions	not calculated	[values are calculated in [g/test] automaticly]
FHB Ueberland-CO2 emissions	not calculated	[values are calculated in [g/test] automaticly]
FHB Ueberland-HC emissions	not calculated	[values are calculated in [g/test] automaticly]
FHB Ueberland-NOx emissions	not calculated	[values are calculated in [g/test] automaticly]
FHB Ueberland-CO emissions	not calculated	[values are calculated in [g/km] automaticly]
FHB Ueberland-CO2 emissions	not calculated	[values are calculated in [g/km] automaticly]
FHB Ueberland-HC emissions	not calculated	[values are calculated in [g/km] automaticly]
FHB Ueberland-NOx emissions	not calculated	[values are calculated in [g/km] automaticly]
Fuel consumption FHB Ueberland	not calculated	[calculated using carbon balance method, according EC 93/116]

First session (after UDC driving cycle)			
Idle speed (measured)		[rpm]	
CO emission unit		[vol %] / [ppm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			

Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
Remarks at CO and HC at idle speed			
Remarks at CO and HC at intemediate idle speed			
Remarks at CO and HC at high idle speed			

Second session (after FHB driving cycles)			
Idle speed (measured)		[rpm]	
CO emission unit		[vol %] / [ppm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 1			Please enter unit in cell B429
CO2 emission at idle line - 1			[vol %]
HC emission at idle line - 1			[ppm]
O2 emission at idle line - 1			[vol %]
NOx emission at idle line - 1			[ppm]
Lambda value			
Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 2			Please enter unit in cell B429
CO2 emission at idle line - 2			[vol %]
HC emission at idle line - 2			[ppm]
O2 emission at idle line - 2			[vol %]
NOx emission at idle line - 2			[ppm]
Lambda value			

Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
Intermediate Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
High Idle speed (measured)		[rpm]	
	RIGHT line	**LEFT line**	
CO emission at idle line - 3			Please enter unit in cell B429
CO2 emission at idle line - 3			[vol %]
HC emission at idle line - 3			[ppm]
O2 emission at idle line - 3			[vol %]
NOx emission at idle line - 3			[ppm]
Lambda value			
Remarks at CO and HC at idle speed			
Remarks at CO and HC at intemediate idle speed			
Remarks at CO and HC at high idle speed			

Noise measurements

	RIGHT line	**LEFT line**	
Standing noise (dB(A)) First			[dB(A)]
Engine speed at standing noise (rpm)-First			[rpm]
Standing noise (dB(A)) Second			[dB(A)]
Engine speed at standing noise (rpm)-Second			[rpm]
Standing noise (dB(A)) Third			[dB(A)]
Engine speed at standing noise (rpm)-Third			[rpm]
Remarks at standing noise measurement			
Driving noise (dB(A))			[dB(A)]
Engine speed at measuring starting point			[rpm]
Remarks at driving noise measurement			

F Overview of tested motorcycles within the validation programme

Nr.	Manufacturer	Type / Trademark	Laboratory	Working principle (2 or 4 stroke)	Directive	After treatment system	Engine capacity	Gearbox type	Cooling system	Odometer	First registration/ model year	Series exhaust emission system
1	Piaggio / Gilera	DANN 50	DEKRA	2	97/24/EC	no	49	automatic	liquid	146	2001	yes
2	MBK (F)	SA09	TUEV Nord	2	97/24/EC	yes	49	automatic	air	1903	2000	yes
3	Yamaha (E)	SB04	TUEV Nord	2	97/24/EC	no	101	automatic	air	4206	2000	yes
4	Honda	SJ 100 Bali EX (Roller)	TUEV Nord	2	97/24/EC	no	101	automatic	air	5022	2000	yes
5	Piaggio / Italjet	Formula 125 Twin	DEKRA/TNS	2	ECE R40	no	115	automatic	liquid	642	2001	yes
6	Gilera	Runner SP 125 cc	TNO	2	ECE R40	no	124	automatic	liquid	1065	2001	yes
7	Piaggio	Hexagon 125	TNO	2	ECE R40	no	124	automatic	liquid	8877	1997	yes
8	Piaggio (I)	TPH 125 / M02 Tech for fun 125	TUEV Nord	2	ECE R40	no	124	automatic	air	6111	1996	yes
9	Yamaha	DT 125 R 3MB	MTC	2	ECE R40	no	124	manual	liquid	43201	1989	yes
10	Yamaha	DT 125 R3MB	MTC	2	ECE R40	no	124	manual	liquid	37026	1989	yes
11	Aprilia	RS 125	TNO	2	ECE R40	no	125	manual	liquid	8127	1999	yes
12	Honda	Pantheon	TUEV Nord	2	97/24/EC	no	125	automatic	liquid	9182	1998	yes
13	Honda	Pantheon 150	TNO	2	97/24/EC	no	150	automatic	liquid	852	1998	yes
14	Gilera	Runner 180	TNO	2	ECE R40	no	176	automatic	liquid	15173	1998	yes
15	Piaggio	Hexagon 180	TNO	2	ECE R40	no	176	automatic	liquid	8256	1998	yes
16	Piaggio	Gilera	DEKRA/TNS	2	ECE R40	no	176	automatic	liquid	417	2001	yes
17	Gilera	Runner FXR	MTC	2	ECE R40	no	176	automatic	liquid	3881	1998	yes
18	Aprilia	RS250	MTC	2	ECE R40	no	250	manual	liquid	35276	1998	yes

Nr.	Manufacturer	Type / Trademark	Laboratory	Working principle (2 or 4 stroke)	Directive	After treatment system	Engine capacity	Gearbox type	Cooling system	Odometer	First registration/ model year	Series exhaust emission system
19	San Yang Motorcycles (SYM)	Super Duke 125	TNO	4	97/24/EC	no	124	automatic	air	16813	1998	yes
20	Yamaha	Majesty YP 125	TNO	4	97/24/EC	no	124	automatic	liquid	2244	2001	yes
21	Yamaha	Teo's 125	TNO	4	97/24/EC	no	124	automatic	liquid	1317	2001	yes
22	Daelim	Daelim VS 125 F	TUEV Nord	4	97/24/EC	no	124	manual	air	4581	1999	yes
23	Suzuki	CF42A / AN 125	TUEV Nord	4	97/24/EC	no	124	automatic	air	1874	2000	yes
24	Piaggio (I)	Vespa ET4 125	TUEV Nord	4	97/24/EC	no	124	automatic	air	9351	1996	yes
25	MBK	Skyliner 125	DEKRA/TNS	4	97/24/EC	no	124	automatic	liquid	7063	2000	yes
26	Hyosung	CruiseAmerican Classic	DEKRA/TNS	4	ECE R40	no	124	manual	air	1785	1996	yes
27	Kwang Yang Motor Co.	Zing 125	DEKRA/TNS	4	97/24/EC	no	124	manual	liquid	4206	1999	yes
28	Peugeot	Peugeot	DEKRA/TNS	4	97/24/EC	yes	124	automatic	liquid	1693	2000	yes
29	Vespa	ET4	TNO	4	97/24/EC	no	124	automatic	air	19595	1998	yes
30	Aprilia	Leonardo 125	TNO	4	ECE R40	no	125	automatic	liquid	3718	1998	yes
31	Yamaha (J)	DE01	TUEV Nord	4	97/24/EC	no	125	manual	air	2393	1998	yes
32	Honda	Rebel	TUEV Nord	4	97/24/EC	no	125	manual	air	8808	1998	yes
33	Honda	JF07 / @125	TUEV Nord	4	97/24/EC	no	125	automatic	liquid	4059	2000	yes
34	Kymco	Dink 125	TUEV Nord	4	97/24/EC	no	125	automatic	liquid	1517	2001	yes
35	BMW	C1	TUEV Nord	4	97/24/EC	yes	125	automatic	liquid	1727	2001	yes
36	Peugeot	G2A	DEKRA/TNS	4	97/24/EC	no	150	automatic	liquid	788	2001	yes
37	Aprilia	Leonardo 150	TNO	4	ECE R40	no	151	automatic	liquid	13222	1998	yes

Nr.	Manufacturer	Type / Trademark	Laboratory	Working principle (2 or 4 stroke)	Directive	After treatment system	Engine capacity	Gearbox type	Cooling system	Odometer	First registration/ model year	Series exhaust emission system
38	Aprilia	Leonardo 150	DEKRA/TNS	4	97/24/EC	no	151	automatic	liquid	11245	1997	yes
39	Yamaha	Maxster 150	TNO	4	97/24/EC	no	152	automatic	liquid	897	2001	yes
40	BMW	C1	TNO	4	97/24/EC	yes	176	automatic	liquid	1492	2002	yes
41	Yamaha	Majesty 250	TNO	4	ECE R40	no	249	automatic	liquid	25369	1998	yes
42	Yamaha	Majesty YP 250	TNO	4	97/24/EC	no	249	automatic	liquid	25369	1999	yes
43	Suzuki (J)	AR Marauder 250	TUEV Nord	4	97/24/EC	no	249	manual	air	5248	1999	yes
44	Honda	MF 04 / Foresight	TUEV Nord	4	97/24/EC	no	249	automatic	liquid	1180	2000	yes
45	Yamaha	YP 250 Majesty (Roller)	TUEV Nord	4	ECE R40	no	249	automatic	liquid	17723	1997	yes
46	Suzuki	GN 250	TUEV Nord	4	ECE R40	no	249	manual	air	23715	1993	yes
47	Honda	Foresight 250	TNO	4	97/24/EC	no	249	automatic	liquid	4434	1999	yes
48	Piaggio	X9 250	TNO	4	97/24/EC	no	249.4	automatic	liquid	4711	2001	yes
49	Aprilia	PD	DEKRA/TNS	4	97/24/EC	no	250	automatic	liquid	251	2002	yes
50	Suzuki	Burgman 400	TNO	4	97/24/EC	no	385	automatic	liquid	6941	2001	yes
51	Suzuki	AU / Burgman 400	TUEV Nord	4	97/24/EC	no	385	automatic	liquid	6092	1999	yes
52	Suzuki	GSF 400 (Bandit)	TUEV Nord	4	ECE R40	no	398	manual	liquid	12650	1995	yes
53	Honda	CB450S (20 kW)	TNO	4	ECE R40	no	447	manual	air	29565	1984	yes
54	Suzuki	GS 500	TNO	4	97/24/EC	no	487	manual	air	1193	2001	yes
55	Suzuki	GS 500 E	TNO	4	ECE R40	no	487	manual	air	19533	1992	yes
56	Suzuki	GS 500 E	TUEV Nord	4	ECE R40	no	487	manual	air	44278	1990	yes

Nr.	Manufacturer	Type / Trademark	Laboratory	Working principle (2 or 4 stroke)	Directive	After treatment system	Engine capacity	Gearbox type	Cooling system	Odometer	First registration/ model year	Series exhaust emission system
57	Kawasaki	GPZ 500	TNO	4	ECE R40	no	498	manual	liquid	1120	1995	yes
58	Honda	CB500S (25 kW)	TNO	4	97/24/EC	no	499	manual	liquid	11860	2001	yes
59	Yamaha	XT 500 E	TNO	4	97/24/EC	no	499	manual	air	323	1999	yes
60	Honda	Silver Wing 600	TNO	4	97/24/EC	no	582	automatic	liquid	6523	2001	yes
61	Yamaha	XJ600S N	MTC	4	ECE R40	no	598	manual	air	28111	1996	yes
62	Suzuki	GSX 600R	TNO	4	97/24/EC	no	599	manual	liquid	30069	2001	yes
63	Yamaha	FZS 600 S (Fazer)	TNO	4	ECE R40	no	599	manual	liquid	14412	2001	yes
64	Yamaha	XJ 600 N	TNO	4	ECE R40	no	599	manual	air	1297	1999	yes
65	Honda	CBR 600 FS	TNO	4	97/24/EC	yes	599	manual	liquid	3500	2001	yes
66	Suzuki	Bandit 600 S	TNO	4	97/24/EC	no	600	manual	liquid	25420	2000	yes
67	Suzuki	GSX 600 F	TNO	4	97/24/EC	no	600	manual	air	1237	2001	yes
68	Honda	CBR 600 F	TUEV Nord	4	ECE R40	no	600	manual	liquid	21866	1998	yes
69	Honda	CB600F2Hornet	MTC	4	97/24/EC	no	600	manual	liquid	14416	2000	yes
70	Honda	NT 650 V1 Deauville	TNO	4	97/24/EC	no	647	manual	liquid	7364	2001	yes
71	Honda	XL650 VY	TNO	4	97/24/EC	no	647	manual	liquid	14041	2000	yes
72	Honda	XL650 V1	TNO	4	97/24/EC	no	647	manual	liquid	2016	2001	yes
73	BMW	F650GS	TNO	4	97/24/EC	yes	652	manual	liquid	4513	2001	yes
74	BMW	F650GS	TUEV Nord	4	97/24/EC	yes	652	manual	liquid	6325	2000	yes
75	Belgarda (I) (Yamaha)	SZR 660	TUEV Nord	4	ECE R40	no	659	manual	liquid	10732	35509	yes
76	Honda	CB 750F2 (sevenfifty)	TNO	4	ECE R40	no	747	manual	air	47334	1992	yes
77	Honda	CB 750	TUEV Nord	4	97/24/EC	no	747	manual	air	16196	1999	yes
78	Honda	VFR750F	TNO	4	ECE R40	no	748	manual	liquid	117583	1992	no

Nr.	Manufacturer	Type / Trademark	Laboratory	Working principle (2 or 4 stroke)	Directive	After treatment system	Engine capacity	Gearbox type	Cooling system	Odometer	First registration/ model year	Series exhaust emission system
79	Suzuki	GSX 750 F	TNO	4	ECE R40	no	748	manual	liquid	68452	1993	yes
80	Yamaha	XJ 750 Seca	TNO	4	ECE R40	no	748	manual	air	32191	1984	no
81	Honda	VFR 750	DEKRA/TNS	4	ECE R40	no	748	manual	liquid	12473	1997	yes
82	Suzuki	GSX750 / AE	TUEV Nord	4	97/24/EC	no	750	manual	air	6717	1998	yes
83	Suzuki (J)	GSX 750	DEKRA/TNS	4	ECE R40	no	750	manual	air	11816	1998	yes
84	Honda	VFR 800 FI	TNO	4	97/24/EC	yes	781	manual	liquid	4906	2002	yes
85	Honda	VFR 800FI	MTC	4	97/24/EC	yes	781	manual	liquid	5506	1998	yes
86	BMW	247E / R80GS	TUEV Nord	4	ECE R40	no	785	manual	air	4845	1984	yes
87	BMW	247E R80GS	TUEV Nord	4	ECE R40	no	797	manual	air	15867	1991	yes
88	Yamaha	TDM 850	TNO	4	ECE R40	no	849	manual	liquid	7947	1999	yes
89	Yamaha	TRX 850	TNO	4	ECE R40	no	849	manual	liquid	20445	1998	yes
90	Harley Davidson	Sportster 883	TNO	4	ECE R40	no	883	manual	air	165	2000	yes
91	Triumph	900 Legend	TUEV Nord	4	97/24/EC	yes	885	manual	liquid	12574	2000	yes
92	Ducati	900 SS	TNO	4	ECE R40	no	904	manual	air	28371	1994	yes
93	Kawasaki	GPZ 900 R Ninja	TUEV Nord	4	ECE R40	no	908	manual	liquid	49650	1994	yes
94	Honda	CBR 900 RR Fireblade	TNO	4	97/24/EC	no	929	manual	liquid	9054	2001	yes
95	Suzuki	RF900R	MTC	4	ECE R40	no	937	manual	liquid	43878	1996	yes
96	Triumph	Sprint RS	MTC	4	97/24/EC	no	955	manual	liquid	10839	2000	yes
97	Honda	XL1000VX Varadero	TNO	4	97/24/EC	no	996	manual	liquid	12143	2000	yes
98	Yamaha	YZF R1	TNO	4	97/24/EC	no	998	manual	liquid	20965	2001	yes
99	Yamaha	YZF-R1 RN01	MTC	4	97/24/EC	no	998	manual	liquid	1894	1998	yes
100	Honda	VTR1000SP1	TNO	4	97/24/EC	no	999	manual	liquid	9478	2001	yes
101	Yamaha	FZR 1000 Genesis Exup	TNO	4	ECE R40	no	1002	manual	liquid	46563	199	no

Nr.	**Manufacturer**	**Type / Trademark**	**Laboratory**	**Working principle (2 or 4 stroke)**	**Directive**	**After treatment system**	**Engine capacity**	**Gearbox type**	**Cooling system**	**Odometer**	**First registration/ model year**	**Series exhaust emission system**
102	Kawasaki	ZZR 1100	TNO	4	ECE R40	no	1052	manual	liquid	67300	1990	yes
103	Kawasaki	ZZR 1100	TNO	4	ECE R40	no	1052	manual	liquid	50000	1997	no
104	BMW	R1100GS	TNO	4	ECE R40	yes	1085	manual	air	29530	1998	yes
105	BMW	R1100S	TNO	4	97/24/EC	yes	1085	manual	air	5456	2001	yes
106	BMW	R 1100 S	TUEV Nord	4	97/24/EC	yes	1085	manual	air	24803	1999	yes
107	BMW	R1100RT	MTC	4	97/24/EC	yes	1085	manual	air	23360	1998	yes
108	BMW	K1100RS	TNO	4	ECE R40	yes	1092	manual	liquid	80000	1993	yes
109	BMW	K1100LT	TUEV Nord	4	ECE R40	no	1093	manual	liquid	54448	1994	yes
110	BMW	K 1100 RS	MTC	4	ECE R40	no	1093	manual	liquid	67249	1993	yes
111	BMW	R1150RS	TNO	4	97/24/EC	yes	1130	manual	air	8637	2001	yes
112	BMW	R1150RT	MTC	4	97/24/EC	yes	1130	manual	air	401	2001	yes
113	Honda	CB1100SFX11	MTC	4	97/24/EC	yes	1137	manual	liquid	3486	2001	yes
114	Suzuki	Bandit 1200	TNO	4	97/24/EC	no	1157	manual	air	25513	2001	yes
115	Yamaha	FJ 1200	TNO	4	ECE R40	no	1188	manual	air	42809	1986	no
116	Yamaha	FJ1200 / 3YA	TUEV Nord	4	ECE R40	no	1188	manual	air	17383	1996	yes
117	Buell	X1 LIGHTNING	MTC	4	97/24/EC	yes	1199	manual	air	5621	2001	yes
118	Suzuki	GSX1400	TNO	4	97/24/EC	no	1402	manual	air	4667	2002	yes

G Cut off point (threshold) optimisation assessment

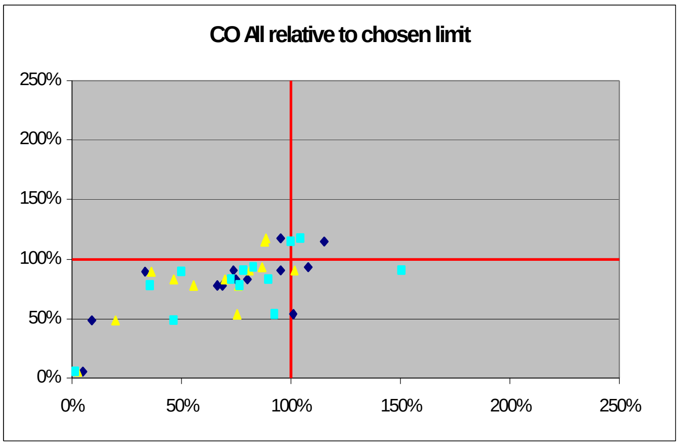
In this Appendix the cut off point optimisation procedure results are summarised.

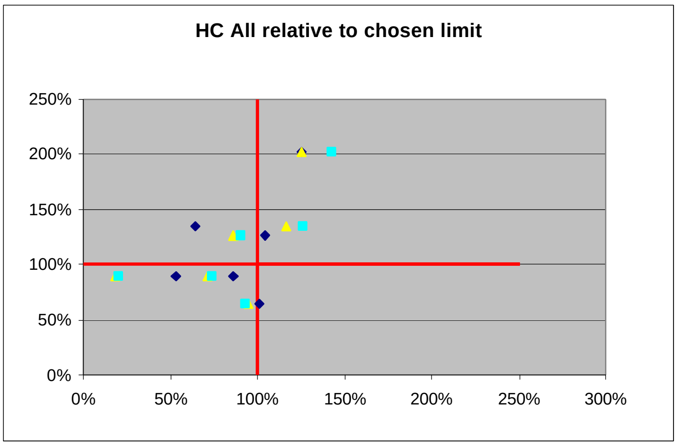
For each of the technology classes and the applicable directive, an assessment is made using following strategy:

- Calculate the relative emission value of the Type Approval driving cycle (TA limit of the applicable directive = 100%)
- Find a cut off point for the RW-test results for which the errors of commission is below 5%
- Check if improvements can be made in order to identify high emitters, when idle tests (idle-medium and high speed) are combined

The results of that evaluation are given in the figures below. In order to directly check if a vehicle is identified as a high emitter using the calculated cut off points, is made visible when also the calculated cut off point is made relative (cut off point = 100%). Doing that also creates the possibility to include all of the three idle engine speed test results in one chart.

2-stroke motorcycle without catalyst TA according ECE Regulation 40





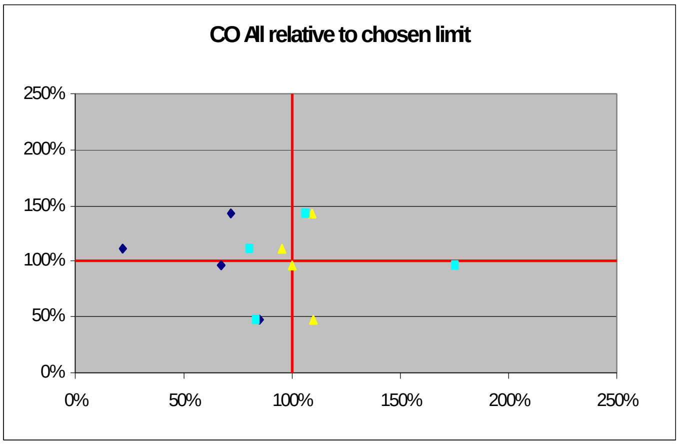
Cut off points found for this type of motorcycle:

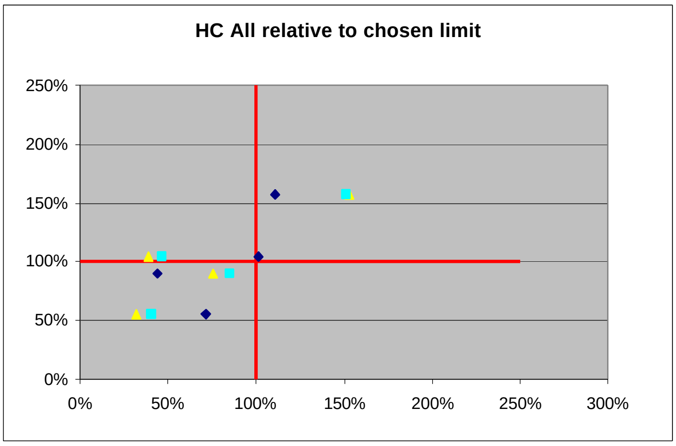
Engine speed	**idle**	**medium idle**	**high idle**
CO	4.5	5	5
HC	8000	8000	7000

When the CO limits are used on the engine speeds 1 error of commission, 0 of omission, 2 high emitters and 10 low pollutants are found. Since there are only 6 correct RW-test results for component HC (in the some of the measurements the HC canister was used) using these limits cause 1 error of commission, 1 of omission, 2 low pollutants and 2 high emitters. Following considerations have to be taken into account:

- the HC limit on the high idle test is lower than the one of the idle test
- how to handle with the HC emissions of 2-stroke motorcycles since these can (permanently) damage the equipment.

2-stroke motorcycle without catalyst TA according 97/24/EC





Cut off points found for this type of motorcycle:

Engine speed	**idle**	**medium idle**	**high idle**
CO	4.5	3.5	4
HC	6500	4000	4000

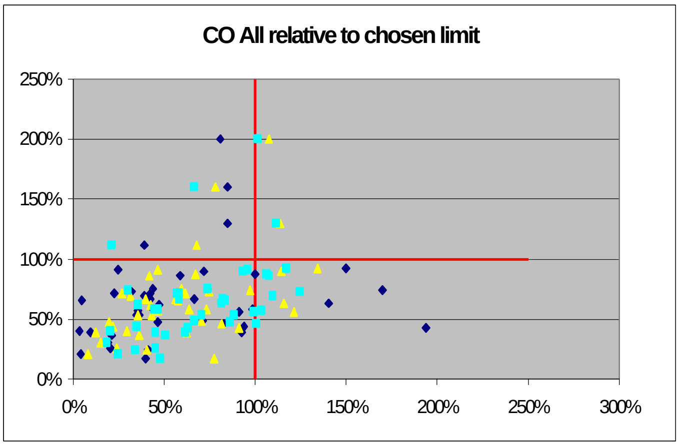
When idle and high idle test on CO are executed using the limits found, 1 error of omission, 1 of commission, 1 high emitter and 1 polluter are found. For component HC there are two low pollutants, one and 2 high emitters found. It has to be decided if the limits can be used as they have been specified here since:

- not many vehicles were tested and the conclusion is based on only 4 motorcycles
- the CO and HC limits on the high idle test is lower than the one of the idle test
- the number of errors of commission is above 5% (due to the fact not many vehicles were tested)
- how to handle with the HC emissions of 2-stroke motorcycles since these can (permanently) damage the equipment.

2-stroke catalyst

Since only one vehicle has been tested within the validation programme, no conclusion can be drawn for these types of vehicles.

4-stroke motorcycle without catalyst TA according ECE Regulation 40

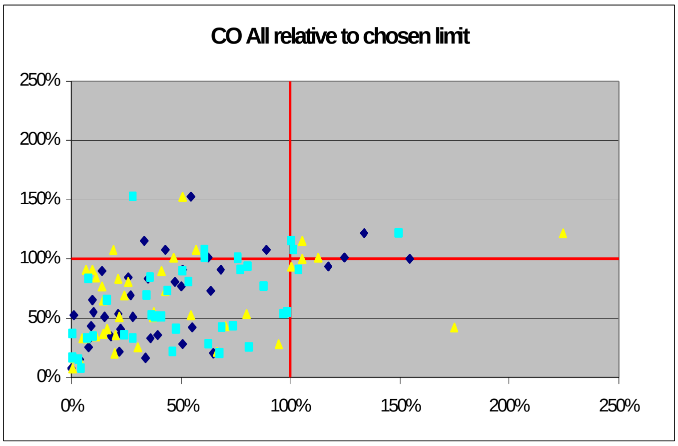


Engine speed	**idle**	**medium idle**	**high idle**
CO	4.5	6.5	8

When more than 1 of the three RW-tests performed exceed the given limit, the motorcycle is disapproved.

Using this method, found 2 errors of commission, 2 of omission, 2 high emitters and 34 low pollutants

4-stroke motorcycle without catalyst TA according 97/24/EC

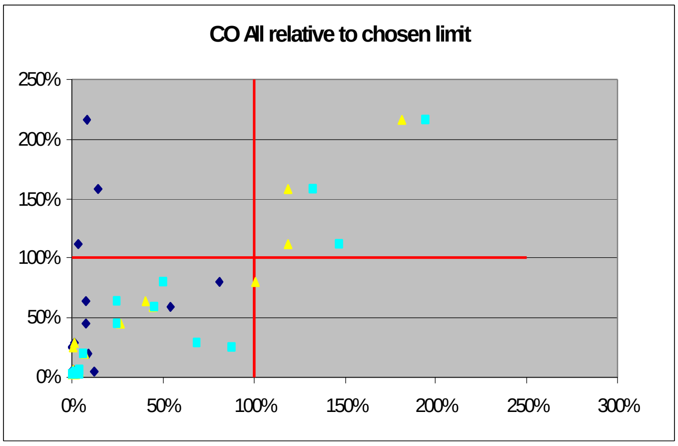


Cut off points found for this type of motorcycle:

Engine speed	idle	medium idle	high idle
CO	4.5	6.5	8

When more than 1 of the three RW-tests performed exceed the given limit, the motorcycle is disapproved.
Using this method found 2 errors of commission, 2 of omission, 2 high emitters and 34 low pollutants.

4-stroke motorcycle with catalyst TA according ECE Regulation 40 or 97/24/EC



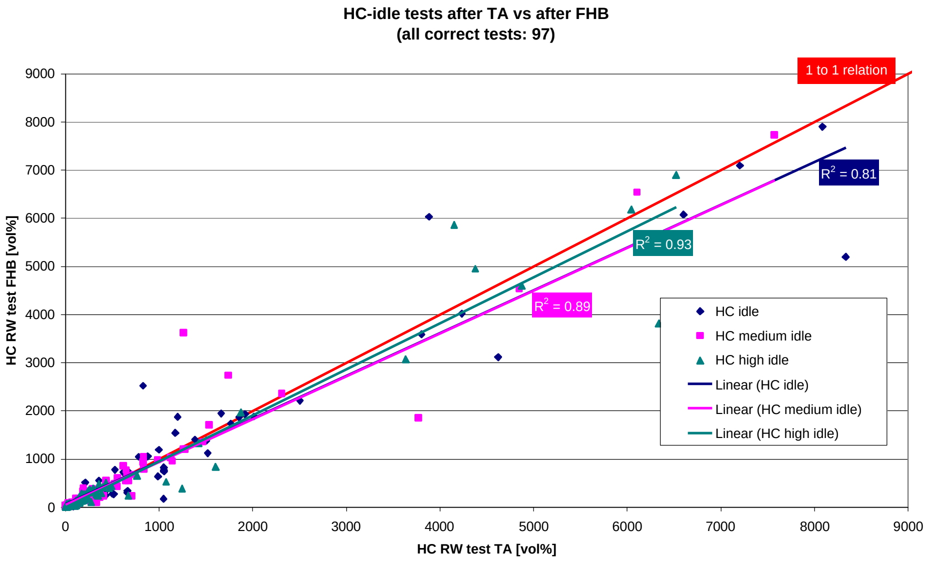
Engine speed	idle	medium idle	high idle
CO	4.5	5	5

For these motorcycles the conclusion is drawn that:

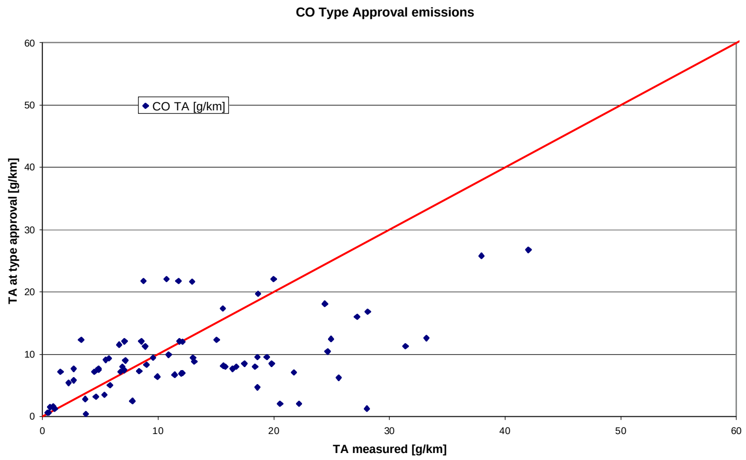
- The idle and high idle emission tests give a reliable conclusion about the current state of the emission level during driving.
- For the 97/24/EC Chapter 5 and ECE Regulation 40 type approved motorcycles the CO-emission on the high idle test should not exceed 5 Vol.-%
- If the test result of the high idle test exceeds the limit, the vehicle is disapproved.

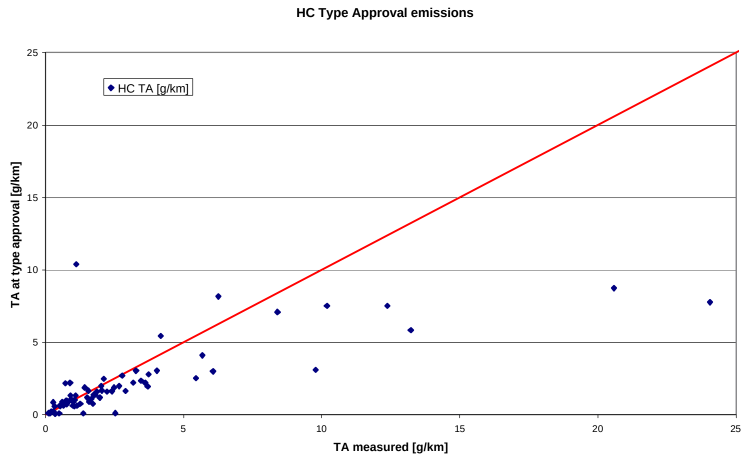
Using this method 0 error of commission, 0 of omission, 3 high emitters and 13 low pollutants were found.

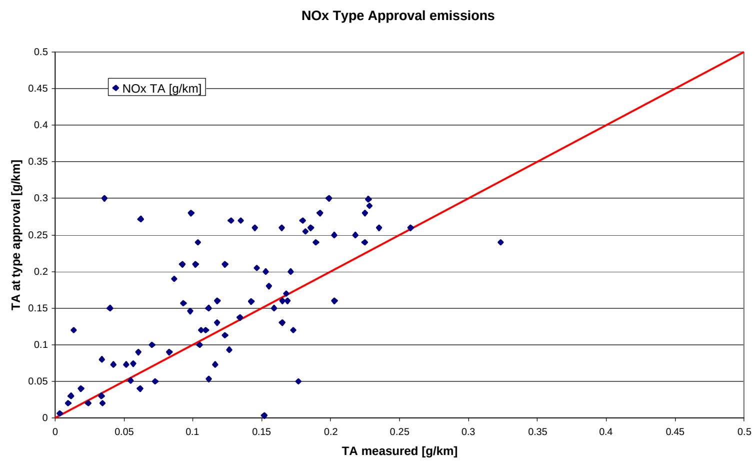
H Graph on HC repeatability



I Emission on Type Approval test measured versus the Type Approval itself







J Stationary and in-motion test prescription according to 97/24/EC Chapter 9

Stationary test

Positioning of measurement equipment

Measurement should be equipment placed at:

50 +/- 2,5 cm from exhaust orifice

At the same height as the orifice or 0,2 m above ground

At a horizontal angle of 45 +/- 10° to the flow direction

See also next figure:

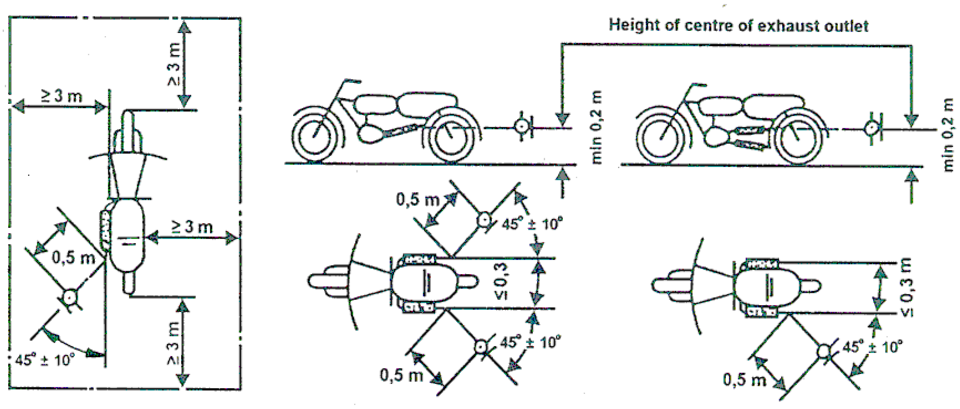


Figure J-1: Positioning of measurement equipment for a stationary test

Measurements have to be carried out in a solid foundation without any plants, and on a reasonably flat surface that is free from sound-absorbing cover. There must be no acoustically disturbing objects within 2m of the microphone.

Needle deviations caused by interference noises and wind influence must be at least 10 dB(A) lower than the measured values.

Measurement procedures

The speed of the engines has to be kept constant at the following values:

½S if S is more than 5000 rpm

¾S if S is less or equal than 5000 rpm

S is the engine speed at maximum power

Motorcycle in-motion test

This test is carried out in a test site as defined in the next figure.

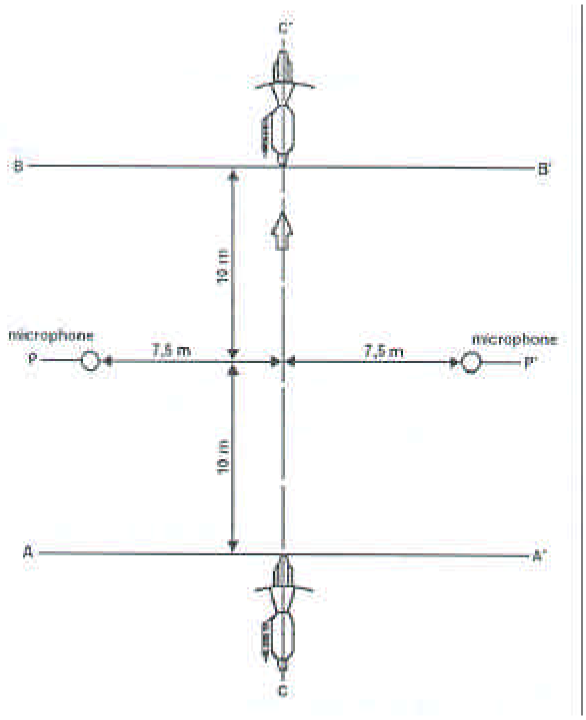


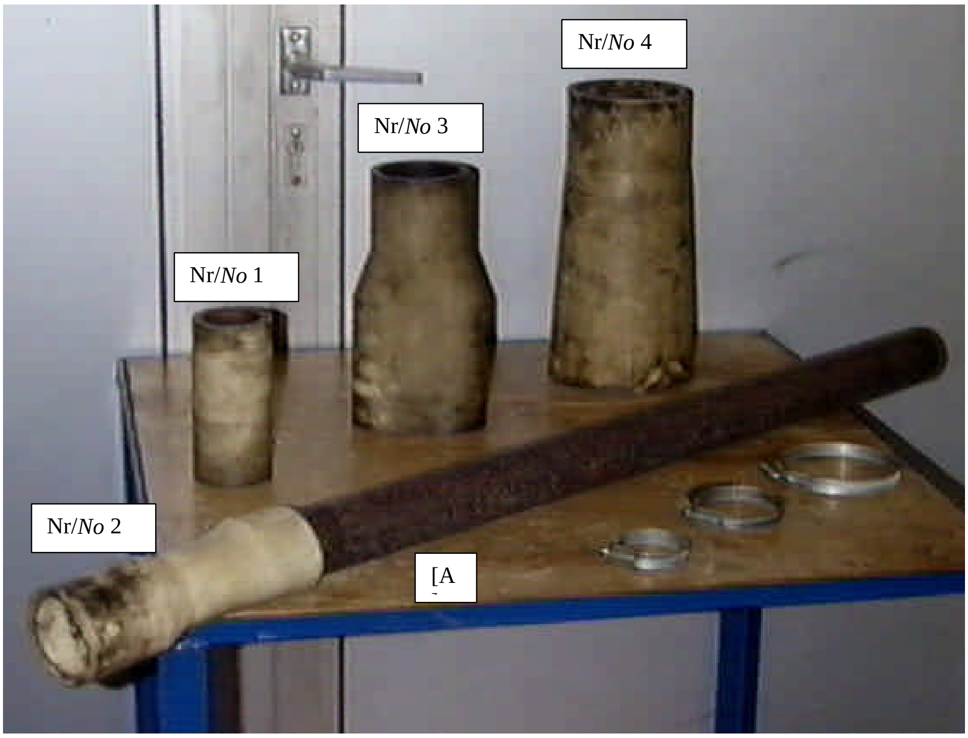
Figure J-2: Test site for motorcycle in-motion test

The sound value will be the maximum indicated value obtained while the vehicle passes between the lines AA’ and BB’. At least two measurements on each side of the vehicle are made. There are different speeds of approach according to the vehicle type and the gearbox.

K Specification of the adapter set used by TÜV Nord for airtight connecting of an extension pipe

TÜV NORD
STRASSENVERKEHR

Motorrad - Adapter - *motorcycle - adapter*



Teile für die Beruhigungsstrecke [A] der Prüffahrzeuge
Parts of the stabislised pipe [A] for test vehicles

Material - *material* of [A] : Stahl - steel

Adaptermaterial - *material* of adapter : Silikonkautschuk, mit ca. 60° Shore, naturfarben,hochelastisch mit Hitzeschutzstabilisator
Silicon rubber, with ca. 60° *Shore, natural coloured, high elastic with heat protection stabilizer*

TÜV NORD
STRASSENVERKEHR

Beruhigungsstrecke [A] - *stabilised pipe [A]*

Material - *material* : Stahl - steel

Maße - *dimension* in mm

Länge - *length* : 850

Innen ∅ - *internal diameter* : 52 [d_1]

Außen ∅ - *external diameter* : 58 [d_2]

Adapter Nr. - *adapter no* : 1

Maße - *dimension* in mm

Länge - *length* : 150

Innen ∅ - *internal diameter* : 50

Außen ∅ - *external diameter* : 70

Adapter Nr. - *adapter no* : 2 hinten / *back*

Maße - *dimenssion* in mm

Länge - *length* : 220

Innen ∅ - *internal diameter* : 50

Außen ∅ - *external diameter* : 70

Adapter Nr. - *adapter no* : 2 vorne - *front*

Maße - *dimension* in mm

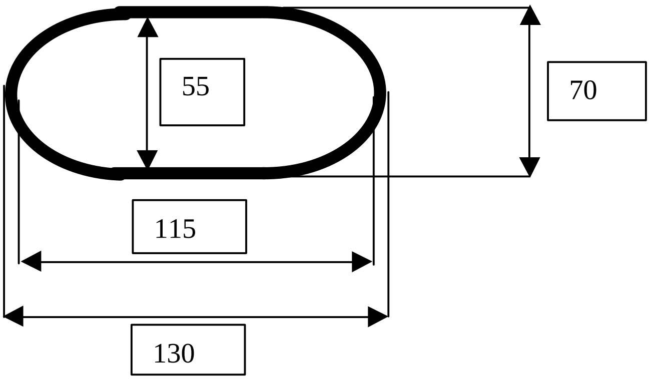
Länge - *length* : 220

Innen ∅ - *internal diameter* : 63

Außen ∅ - *external diameter* : 78

Adapter Nr. - *adapter no* : 3 vorne - *front*

Maße - *dimension* in mm



Adapter Nr. - *adapter no* : 3 hinten - *back*

Maße - *dimension* in mm

Länge - *length* : 250

Innen ∅ - *internal diameter* : 75

Aussen ∅ - *external diameter* : 90

STRASSENVERKEHR

Adapter Nr. - *adapter no* : 4 vorne - *front*

Maße -*dimension* in mm

Länge - *length* : 300

Innen ∅ - *internal diameter* : 130 auf - *to* 100

Außen ∅ - *external diameter* : 150

Adapter Nr. - *adapter no* : 4 hinten - *back*

Maße - *dimension* in mm

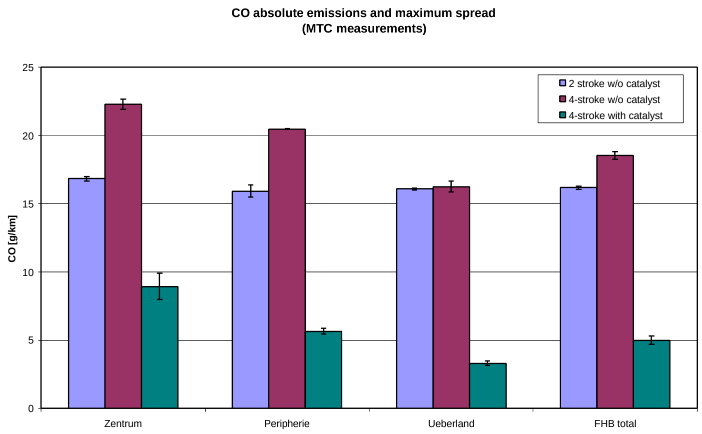
Länge - *length* : 300

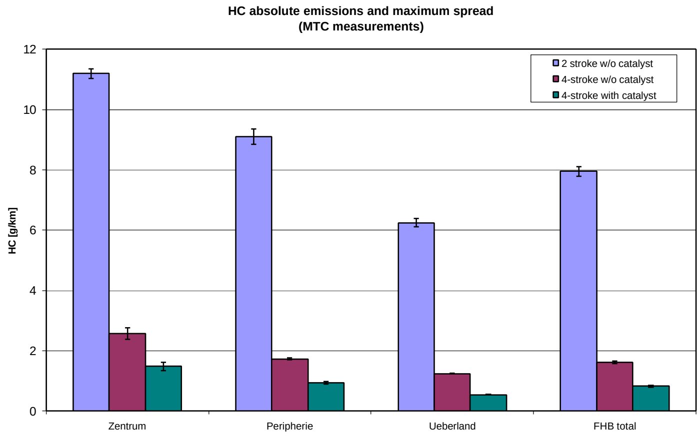
Innen ∅ - *internal diameter* : 100 auf - *to* 130

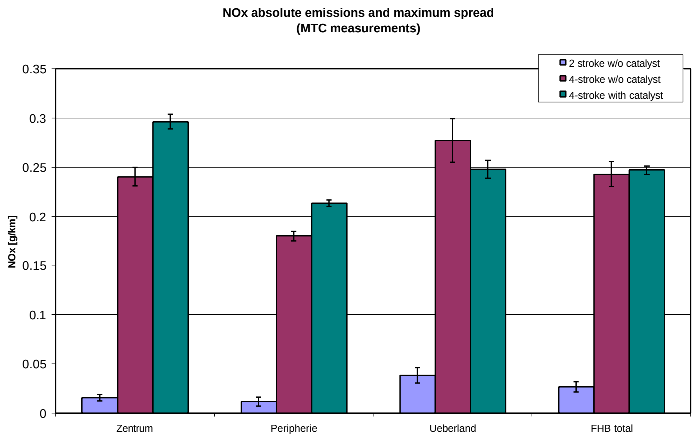
Außen ∅ - *external diameter* : 120

L Repeatability of exhaust gas emission measurements

Repeatability results of the consecutive measurements executed on the FHB driving cycles at the MTC laboratory measuring one 2-stroke motorcycle without catalyst, one 4-stroke without catalytic converter and one 4-stroke motorcycle equipped with a catalytic converter. The maximum spread is indicated by the black error bars (I).







Repeatability results of the consecutive measurements executed at the TÜV Nord laboratory. The repeatability is analysed using the on-line emission data. The emissions of the 4 subcycles of the Type Approval driving cycles were calculated and analysed. The average emission results has been calculated and the minimum and maximum values were selected in order to calculate the spread in the emission values. In some cases it can be concluded that the engine was not yet on operating temperature, causing a wide spread in the emission results. For the components CO, HC and NO_x, the maximum spread is indicated by the black error bars (I)