LAT / AUTh

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

Detailed Report 7 - Cost -effectiveness of I/M

by TNO

Delft, April 1998

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

TNO report
98.RASID.1878.1/RR

Cost -effectiveness of I/M
A short Outline of the methodology used and the calculated results for the partner's countries

TNO Road-Vehicles
Research Institute

Schoemakerstraat 97
P.O.Box 6033
2600 JA Delft
The Netherlands

Phone + 31 15 269 69 00
Fax +31 15 262 07 66

Date
10 April 1998

Author(s)
Ir. R.C.Rijkeboer Eur Ing
Ing P. Hendriksen
A. Sjödin

Client/Sponsor
European Commission
EC Study Contracts:
B4-3040/95/000492/MAR/D3
B4-1031/95/002118
B2-7040/95/004055

This report is sub-report Nr. 7 to the main report:
The inspection of in-use cars in order to attain minimum emissions of pollutants and optimum energy efficiency.

ISO 9001 DNV CERTIFIED FIRM

The quality system of the TNO Road-Vehicles Research Institute conforms to ISO 9001.

Approved by
P.van Sloten
(Project Manager)

Approved by
C.J.T. van de Weijer
(Head of the department)

Project code
Project nr 731410609

Research period
week nr 24/1994 - 15/1/1998

Number of pages
30

Number of appendices
1

Number of figures

Number of tables

The TNO Road-Vehicles Research Institute carries out research and provides services in the field of road vehicles and their components.
The primary areas of attention are Vehicle Dynamics, Crash safety, Combustion Engines and Homologations.

Netherlands Organization for
Applied Scientific Research (TNO)

Abstract

This report is a subreport to the main report "The inspection of in-use cars in order to attain minimum emissions of pollutants and optimum energy efficiency" (LAT Report No. 9803). It deals with the cost-effectiveness of the various I/M systems considered in the project. Chapter 1 elaborates a methodology for the evaluation of cost-effectiveness. Chapter 2 gives a calculation example on the basis of the Dutch situation. Chapter 3 evaluates the outcome of the calculation, gives the results in a graphical representation and compares the outcome for the Netherlands (a typical north European country, with a large share of catalyst equipped cars already) with the calculation results for Greece (a typical south European country, with a continuing high share of non catalyst cars). Chapter 4 looks briefly into the question if OBD (on board diagnostics) may be expected to provide a more cost-effective way to monitor maintenance in the middle term. The Annex contains all the input and the calculated figures for the countries of the partners and associated partners of the project, i.e.:

- Austria
- France
- Germany
- Greece
- the Netherlands
- Sweden
- the United Kingdom

The main conclusions of this subreport are:

◊ For 1995 the current procedure according to 92/55/EEC proves to be a very cost-effective procedure.

◊ For countries with a continuing high share of non-catalyst cars this situation continues to be valid during the coming years.

◊ As soon as there is a high share of catalyst equipped cars in the fleet dynamic testing over a short driving cycle turns out to be much more cost-effective, provided that such testing can be organised in a system with centralised inspection stations with a high throughput per testing lane.

◊ For diesel cars the present test and a dynamic test do have approximately the same effectiveness. However, due to a high number of errors of commission (vehicles wrongly identified as faulty) the additional cost of unnecessary repair makes the present free acceleration method much more costly and therefore less cost-effective. This presupposes, however that the diesel cars can be tested on well occupied dynamic testing lanes, which would practically mean that the same lanes are also used for dynamic testing of otto engined cars.

◊ OBD is not likely to constitute a cost-effective alternative on the short or middle term, for the following reasons:

    * OBD will not be common for otto engines before 2005 and not be universal before 2010, with diesel engines trailing 5 years behind.
    * OBD does only monitor exceeding of the OBD thresholds, which may be considerably higher than the certification limits.

  - ∗ Under the present description OBD thresholds may start to slip after 80,000 km.
  - ∗ Under the present description OBD may be temporarily disabled under various circumstances.
- ◊ If remote sensing is used with a high cutpoint (detecting only very high emitters) and vehicle selection is done on the basis of multiple detection (the vehicle is detected on more than one pass), the effectiveness per vehicle detected can be high. Depending on the state of maintenance of the fleet, even the absolute effectiveness can be high.
- ◊ Using a low cutpoint, in order to detect all high polluters, may lead to lower cost-effectiveness by a factor of three, as well as an increased number of errors of commission.
- ◊ Detailed calculations of the cost-effectiveness are not yet possible, but a rough calculation seems to indicate that under the conditions mentioned above the cost-effectiveness may be of the same order of magnitude as that of a regular periodical inspection.

Contents

1 Methodology

1.1 General outline

This sub-report describes the methodology used to calculate the cost-effectiveness of the various inspection methods described in the main report. It further calculates the actual cost-effectiveness for the seven countries that are represented by the partners and associate partners of the project.

The methodology is outlined in the flowchart of Figure 1. The fixed input consists of the composition of a nation’s car fleet and its emission factors (top box column two), as well as the cost of maintenance per vehicle, which is dependant on the cost of labour in the country considered (top box column three). The variable input consists of the type of inspection programme chosen and the number of cars 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 as the results of this project and are reported in the relevant sub-report. For the present sub-report 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). This number includes the so-called errors of commission, i.e. the vehicles that the inspection method identifies as faulty, although they are actually o.k. Although the number of faulty vehicles in the fleet will partly depend on the general state of maintenance of the fleet considered, this influence was not varied per country in the calculation examples, since the available data were not sufficient to allow such variation. This means that the boxes ‘selectivity of the inspection programme’ and ‘number of faulty vehicles in the fleet’ were in actual fact treated as one box, which only varies for the type of vehicle (otto conventional, otto catalyst-equipped, diesel, etc.) and not for the nationality of the fleet. Therefore the actual number of vehicles detected as faulty is only a function of the composition of the fleet, and not of its state of maintenance. The number of vehicles detected as faulty, multiplied with the average effect of maintenance results in the total effect of maintenance in kton 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 (see section 1.4) 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 identified by the programme as being faulty (column three). 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 I/M programme is divided by the total effect of maintenance one obtains the cost per unit of effect (MECU / kton of pollutant avoided). This is the final result of the calculation (column two/three).

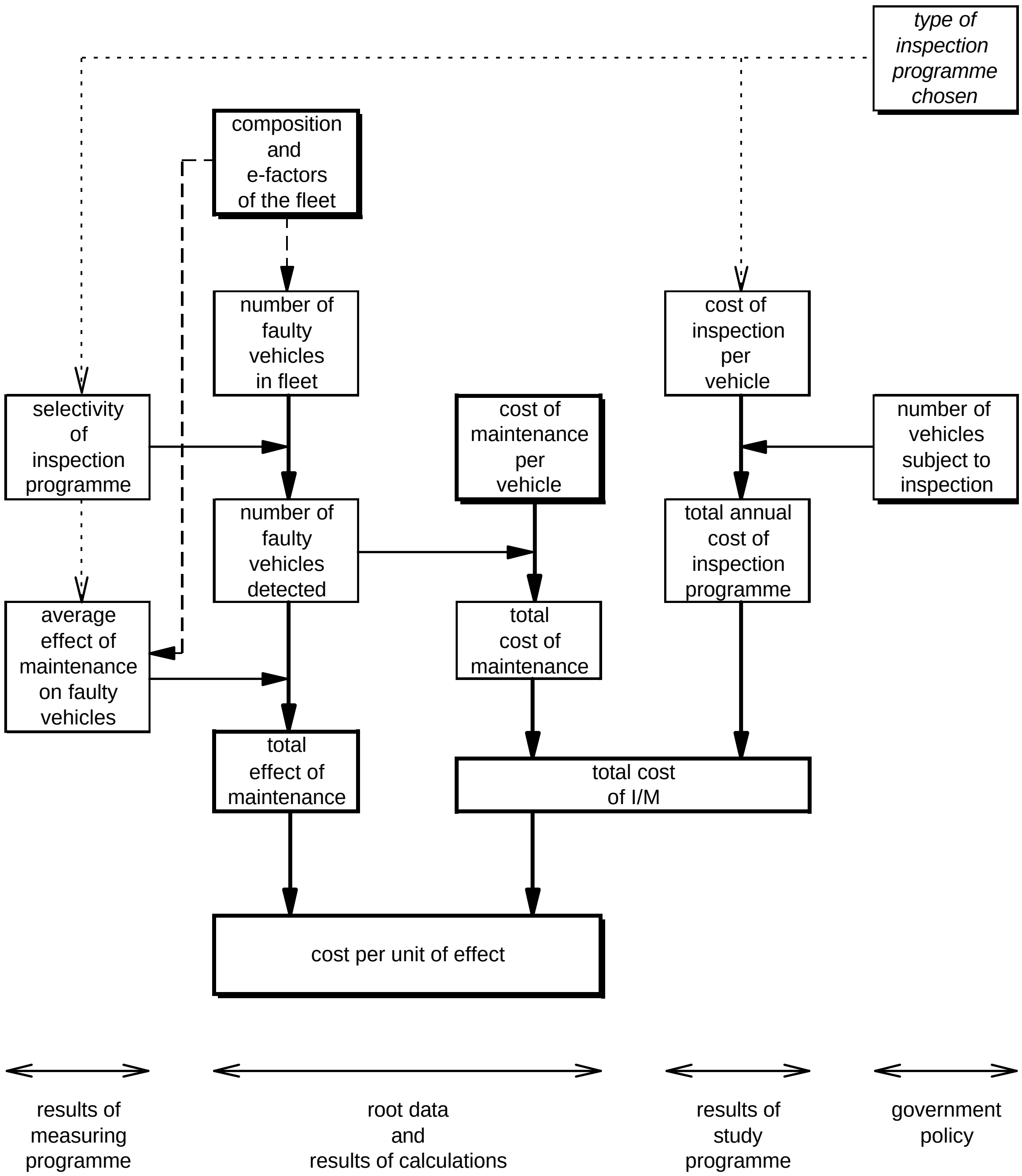

Figure 1: Flow chart of the cost-effectiveness calculation

1.2 Types of inspection programme considered

In this sub-report the following types of inspection programme are considered:

⇒ Unloaded test. For spark ignition (otto) engines this test usually consists of an idle test, possibly with the addition of a similar test at a raised idle speed. For compression ignition (diesel) engines it consists of a free acceleration test. In this study the test methodology of EC Directive 92/55/EEC has been used as a baseline for the evaluation of the other methods. In the calculation examples it has been assumed that such a system is based on a decentralised inspection programme (garages can test).

⇒ Static loaded test. This test consists of driving the vehicle on a non-adjustable chassis dynamometer. Within the project a fixed load of 7 kW at a fixed speed of 50 km/h was chosen. On the basis of practical considerations it was decided to calculate this option only for a centralised inspection system (separate inspection stations).

⇒ Dynamic loaded test. This test consists of a small driving cycle on a chassis dynamometer with limited adjustability. In the project two different driving cycles were evaluated: the TÜV-A cycle and the MODEM short cycle. Since the results of these two cycles were rather similar, they have been averaged for this evaluation. Two different options were evaluated:
  - Emission measurement by monitoring the raw average emission concentrations (‘ra’)
  - Emission measurement by monitoring the mass emissions through a sampling system (‘me’)

1.3 Selectivity of the programme and average emission reduction potential

The selectivity of the inspection programmes mentioned under 1.2 and the emission reduction rate potential (ERRP) have been determined by the Aristoteles University of Thessaloniki (see relevant sub-report). The ERRP is representative of the ideal effect of maintenance, occurring when all maintenance is successful. In practice the real effect may be less (see Table 9 in paragraph 2.3) . The vehicle samples of some participating partners contained a number of faulty vehicles chosen deliberately and not randomly, so as to test the capability of the short tests to detect faulty vehicles. This leads to an excessive percentage of faulty vehicles detected by the short test. The Aristoteles University therefore made a second evaluation of the selectivity, based on samples containing the randomly chosen vehicles only. In some cases this led to rather small samples for certain vehicle types, but this approach was still judged to be more representative of the situation in the field. These last mentioned figures have been used in the present evaluation. The ERRP has been determined relative to the certification cycle and relative to the MODEM cycle. The ERRPs relative to these two cycles do not differ greatly, but since the MODEM cycle was included in the programme because it did give a better representation of reality, the

ERRP relative to this cycle has been used in this evaluation. The selectivities of the inspection programmes are given in Table 1.

Table 1: The percentage of vehicles identified as faulty by the various inspection methods. In the case of diesel smoke only two methods are compared

inspection method	petrol/LPG w/o catalyst	petrol/LPG with catalyst	diesel smoke test
92/55/EEC	54	8.7	26
static	33	8.0	
dynamic ra	75	15	9
dynamic me	50	27	

In the case of diesel engines only the smoke measurement leads to any useful identification of faulty vehicles. The method according to 92/55/EEC is the free acceleration test. The ‘dynamic ra’ test measures the average smoke over a dynamic test. The sharing of the repair over minor maintenance, major maintenance and catalyst replacement has been determined on the basis of the experience with the present programme, combined with the experience with the Dutch in-use compliance programme. Variation of the sharing over minor and major repair shows that for the year 1995 this influence is only a few percent, due to the low share of major repair needed on non-catalyst vehicles (they are usually just maladjusted). For the year 2005, with a much higher share of catalyst equipped vehicles, for which a much higher share of major repair has been assumed (more replacement of faulty parts) the sensitivity for the assumption of the share of major repair does rise to 10-15% of the total cost of I/M. For diesel vehicles the sensitivity for the assumption of the share of major repair amounts to about 5% for the dynamic test or about 10% for the free acceleration test with its much higher number of errors of commission.

Table 2: Kind of repair assumed necessary

Class of repair	petrol/LPG w/o cat.	petrol/LPG with catalyst		diesel	
		pre Euro I	Euro I/II/III	pre Euro I	Euro I/II/III
minor	90%	80%	65%	90%	80%
major	10%	19%	34%	10%	20%
cat replace		1%	1%		

The ERRPs have been identified on the basis of the evaluation by the Aristoteles University of Thessaloniki as shown in Table 3. The ERRPs for Euro III have been calculated on the basis of the assumption that the wrong vehicles on average emit as much as the wrong vehicles of Euro I/II, but that the corrected vehicles have the same emissions as other correct vehicles of Euro III.

Table 3: The emission reduction rate potential of the various inspection methods

CO

FUEL	petrol/LPG				diesel	
technology	convent	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	16%	5%	5%	7%	0%	0%
static	15%	3%	3%	5%	0%	0%
dynamic ra	13%	16%	16%	20%	0%	0%
dynamic me	17%	16%	16%	20%	0%	0%

HC

FUEL	petrol/LPG				diesel	
technology	w/o cat	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	8%	5%	5%	12%	0%	0%
static	5%	6%	6%	14%	0%	0%
dynamic ra	5%	14%	14%	26%	0%	0%
dynamic me	5%	15%	15%	29%	0%	0%

NOx

FUEL	petrol/LPG				diesel	
technology	w/o cat	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	8%	5%	5%	10%	0%	0%
static	3%	10%	10%	14%	0%	0%
dynamic ra	3%	10%	10%	14%	0%	0%
dynamic me	5%	20%	20%	33%	0%	0%

PM

FUEL	petrol/LPG				diesel	
technology	convent	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	0%	0%	0%	0%	25%	33%
static	0%	0%	0%	0%		
dynamic ra	0%	0%	0%	0%	25%	31%
dynamic me	0%	0%	0%	0%		

The emission of NOx avoided is in most cases purely a come-along effect of a test that as such measures other pollutants and identifies high polluters on that basis. Only in the case of the ‘dynamic me’ has it been assumed that NOx analysers are present in the inspection station. NOx analysers are rather sophisticated equipment that is not available in garage type equipment. This explains the rather high ERRP for NOx in the ‘dynamic me’ test.

The effect of maintenance on fuel consumption has not been quantified in this subreport. The effect on fuel consumption of 3-way catalyst equipped vehicles is small, in the order of about 2 % maximum. This does seem to minute to calculate a cost-effectiveness. As such it is, of course, a small but advantageous come-along effect. For conventional cars the effect is somewhat bigger, in the order of about 5 % maximum. But even then the cost-effectiveness seems marginal if fuel consumption had to be the main driver.

1.4 Costs of inspection and maintenance

The costs of the inspection methods varies with the country, mainly on the basis of the hourly rates of the technicians involved. The costs of investment, amortisation, interest and housing have been kept constant. The amortisation period has been chosen as 7 years. The interest has been assumed as 10% over the average loan. By way of example the Dutch case is given in Table 4.

Table 4: Calculation of the cost in ECU/vehicle of an inspection in a centralised system

the NETHERLANDS	92/55/EEC	Static	Dynamic ra	Dynamic me
Investment ECU		30000	45000	50000
Amortisation/yr ECU		4286	6429	7143
Interest/yr ECU		1500	2250	2500
Housing/yr ECU		3000	3000	3000
Subtotal ECU		8786	11679	12643
vehicles/yr		10000	10000	8000
Fixed cost/vehicle		0.88	1.17	1.58
Labour/hr		50	50	50
Vehicle/hr		5	5	4
Labour/vehicle		10	10	12.5
Administrative/vehicle		3	3	3
Total/vehicle ECU	10.00	13.88	14.17	17.08

The cost of an inspection according to 92/55/EEC has been supplied by each of the partners of the project. Where necessary this cost has been corrected for the fact that a safety inspection is included. For the Netherlands the resulting cost would amount to 10 ECU per inspection in a decentralised system.

The cost of maintenance was supplied by the partners in the project for minor maintenance and major maintenance. Where necessary this was corrected for the additional cost of replacement parts. The cost of catalyst replacement was set at 500 ECU throughout. For the Netherlands this would come to the costs as set out in Table 5.

Table 5: Cost of maintenance

Minor repair	90 ECU
Major repair	190 ECU
Replacement of catalyst	500 ECU

In the case of catalyst replacement the cost of minor repair has to be added to the cost of the actual replacement catalyst. This brings the actual cost to 590 ECU.

So, if a programme indicates 27 % of the catalyst equipped vehicles (tax incentive) as faulty ('dynamic me', Table 1), the cost of maintenance is (see also Table 2):

minor repair	0.27 x 0.80 x 90 ECU	= 19.440	MECU/million vehicles
major repair	0.27 x 0.19 x 190 ECU	= 9.747	MECU/million vehicles
cat replacement	0.27 x 0.01 x 590 ECU	= 1.593	MECU/million vehicles
Subtotal cost		30.780	MECU/million vehicles

To this has to be added the cost of a second inspection on the repaired cars:

second inspect.	0.27 x 17.08 ECU	= 4.612	MECU/million vehicles
Total cost		35.392	MECU/million vehicles

2 Calculation example

2.1 The emission benefits

By way of example the calculation will be performed for the Dutch case. In 1995 the composition of the fleet and the emission factors were as follows:

Table 6: Composition of the Dutch car fleet and emission factors in 1995

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	PM g/km
Otto conv	1.710	9700	11.30	1.80	2.76	
cat tax inc	0.420	13600	2.80	0.30	0.58	
Euro I	2.680	13600	1.60	0.16	0.44	
diesel	0.420	25000	0.60	0.17	0.71	0.19
LPG	0.660	22500	1.30	0.39	0.95	
total	5.890					

The inspection set-up has been assumed as follows. Only cars of three years and older are subject to the inspection and the inspection is annually. That means that in 1995 approximately the following numbers would have been due to be inspected:

100 % of otto conventional (pre 1989) = 1.710 million
100 % of catalyst tax incentive (1989-1991) = 0.420 million
0 % of Euro 1 (1992-1995) = 0 million
approx 80 % of the LPG vehicles = 0.528 million
= 2.658 million otto vehicles
approx 80 % of the diesel vehicles = 0.336 million diesel vehicles
With diesel and LPG no account has been taken of the different legislation steps.

The ERRP for the various components in the various tests is given in Table 3. Applying these figures to e.g. the static test, the following potential reduction in CO can be calculated:

Number of cars x km/yr per car x emission g/km x ERRP = emission avoided/yr
1.710 x 9700 x 11.3 x 0.147 = 27.55 kton/yr otto conventional
0.420 x 13600 x 2.8 x 0.031 = 0.50 kton/yr cat tax incentive
0.528 x 22500 x 1.3 x 0.031 = 0.48 kton/yr LPG (cat assumed)
total = 28.53 kton/yr

In similar way it can be calculated that the total of emissions potentially avoided for all options is as indicated in Table 7.

Table 7: The potential emission avoided in kton of pollutant per year

	CO	HC	NOx	PM
92/55/EEC	30.6	2.66	4.40	0.40
static	28.5	2.43	3.15	
dynamic ra	29.7	2.24	2.20	0.40
dynamic me	36.0	2.48	5.02	

2.2 The costs

The cost of the inspection schemes is given in Table 4. The total cost of inspection for 2.658 million otto vehicles amounts to:

92/55/EEC	2.658 x 10.00 MECU = 26.58 MECU
static	2.658 x 13.88 MECU = 36.89 MECU
dynamic ra	2.658 x 14.17 MECU = 37.66 MECU
dynamic me	2.658 x 17.08 MECU = 45.40 MECU

For diesel vehicles it amounts to;

92/55/EEC	0.336 x 10.00 MECU = 3.36 MECU
dynamic ra	0.336 x 14.17 MECU = 4.76 MECU

The cost of repair was calculated for catalyst equipped vehicles in the dynamic me test as 35.392 MECU/million vehicles (section 1.5). In a similar way the cost for the total fleet composition (otto engines) can be calculated as:

92/55/EEC	112 MECU
static	75 MECU
dynamic ra	165 MECU
dynamic me	133 MECU

For the diesel engines it can be calculated as:

92/55/EEC	9.65 MECU
dynamic ra	3.34 MECU

The lower cost of the diesel dynamic test is a consequence of the fact that less vehicles are (erroneously) indicated as faulty (errors of commission), thereby leading to less unnecessary ‘repair’ cost.

This brings the total cost of the I/M system at the following costs:

92/55/EEC	138 MECU for otto and 13.01 MECU for diesel
static	111 MECU for otto
dynamic ra	203 MECU for otto and 8.10 MECU for diesel
dynamic me	178 MECU for otto

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 the different pollutants, since this would require a weighting of the importance of the different pollutants, which is not available. On

the other hand simply sharing the cost over the cumulative amount of ktonnes avoided, irrespective of 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. So in the tables the resulting figure represents the amount of MECU/kton that would apply if the measures were exclusively taken to avoid that particular pollutant, with the following condition: the cost-effectiveness of the abatement of CO, HC and NOx has been exclusively related to the costs of I/M for otto engined vehicles. The costs of the abatement of PM (particulate matter) has been exclusively related to the I/M costs of diesel engined vehicles. It should be noted, however, that the inspection cost of the diesel vehicle in the dynamic test is based on a high use of that test equipment (10 000 vehicles per year per lane). In practice that would mean that this cost is only realistic if the same equipment is also used for the inspection of otto engined cars! The resulting cost-effectiveness is given in Table 8.

Table 8: The results of the cost-effectiveness calculation for the Netherlands 1995.

the NETHERLANDS 1995	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	percent repaired
CO						
otto only	92/55/EEC	30.63	0.87	3.64	4.51	37.8%
	static	28.53	1.29	2.62	3.91	24.3%
	dyn. ra	29.74	1.27	5.55	6.81	53.7%
	dyn. me	35.99	1.26	3.70	4.96	41.6%
HC						
otto only	92/55/EEC	2.66	9.98	41.89	51.87	37.8%
	static	2.43	15.19	30.73	45.92	24.3%
	dyn. ra	2.24	16.78	73.50	90.28	53.7%
	dyn. me	2.48	18.27	53.54	71.81	41.6%
NOx						
otto only	92/55/EEC	4.40	6.04	25.37	31.41	37.8%
	static	3.15	11.70	23.67	35.37	24.3%
	dyn. ra	2.20	17.08	74.85	91.94	53.7%
	dyn. me	5.02	9.05	26.53	35.58	41.6%
PM						
diesel only	92/55/EEC	0.40	8.4	24.06	32.44	26.1%
	dyn. ra	0.40	11.8	8.26	20.03	8.7%

As stated above these figures relate to the potential effectiveness and therefore represent only a potential cost-effectiveness. In actual fact it should not be assumed that all vehicles are repaired to the point that their emissions represent the average of the non-identified cars. Some partners of the consortium had defect cars repaired at local garages, without special instructions. It may be assumed that the maintenance provided is typical for the standards in those countries. The relative real effectiveness of these repairs is given in Table 9, below:

Table 9: The actual effect of maintenance as a percentage of the potential effect

Type of inspection	CO %	HC %	NOx %
unloaded	94	92	36
static	93	91	56
dynamic ra	91	88	51
dynamic me	88	85	49

The following comments can be made. In the first place it may be noted that these percentages may differ for different countries. Some countries may have a higher standard of quality for garage maintenance than others. In the sample of Table 9 above the south-European countries are dominant. In the second place a second I/M test after the repair might have identified some of the vehicles insufficiently maintained as such. So in a real-life scheme the situation would presumably be somewhat better. This means that the real-life situation would tend to lie somewhere between the figures of Table 9 and 100%.

It can then be concluded that the actual emission reduction of CO and HC will most probably lie very close to the potential one. On the other hand the actual emission reduction for NOx may be as low as half the potential; only in the case of a short test that actually does measure NOx may the garage have an indication of the repair needed and would a possible check after the repair detect any shortcomings in the maintenance.

In the case of real effects below 100% the actual reductions would be the potential reductions multiplied by these figures and the cost-effectiveness would be the potential cost-effectiveness divided by these figures. In real-life cases Member States would have to determine the quality of the standards in their garages and, if necessary, improve these by separate actions.

3 Evaluation

3.1 The Dutch example

The amount of pollutants avoided per type of inspection system for the Netherlands in 1995 is shown in Figure 2 below. The number of vehicles identified as faulty, as a percentage of the total number of vehicles inspected, is shown in Figure 3.

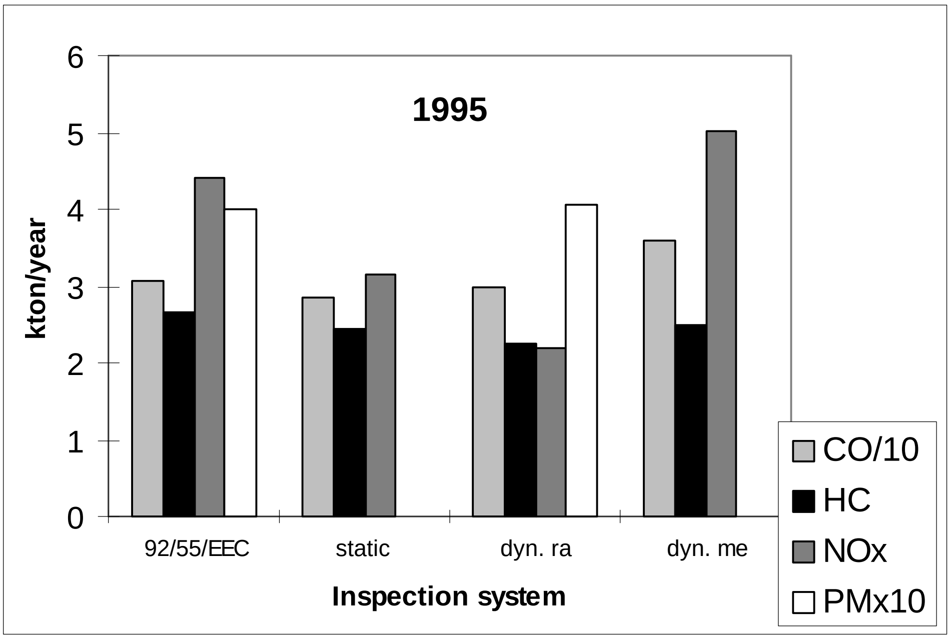

Figure 2: The amount of pollutants avoided for the various inspection systems; the Netherlands 1995

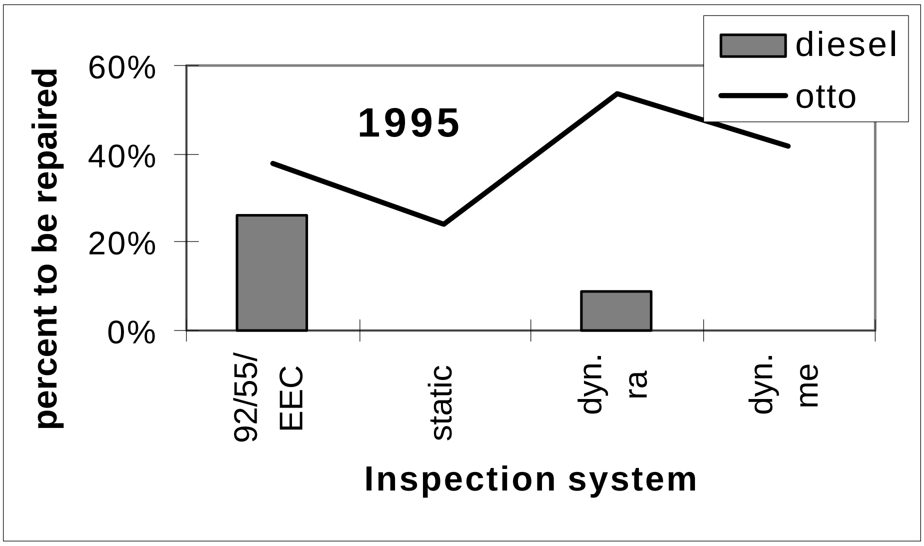

Figure 3: The percentage of vehicles identified as faulty

The costs of inspection and maintenance per kton of pollutant avoided are shown in Figure 4 below. The trend in the percentages identified as faulty and in the costs per million vehicles inspected is shown in Figure 5 below.

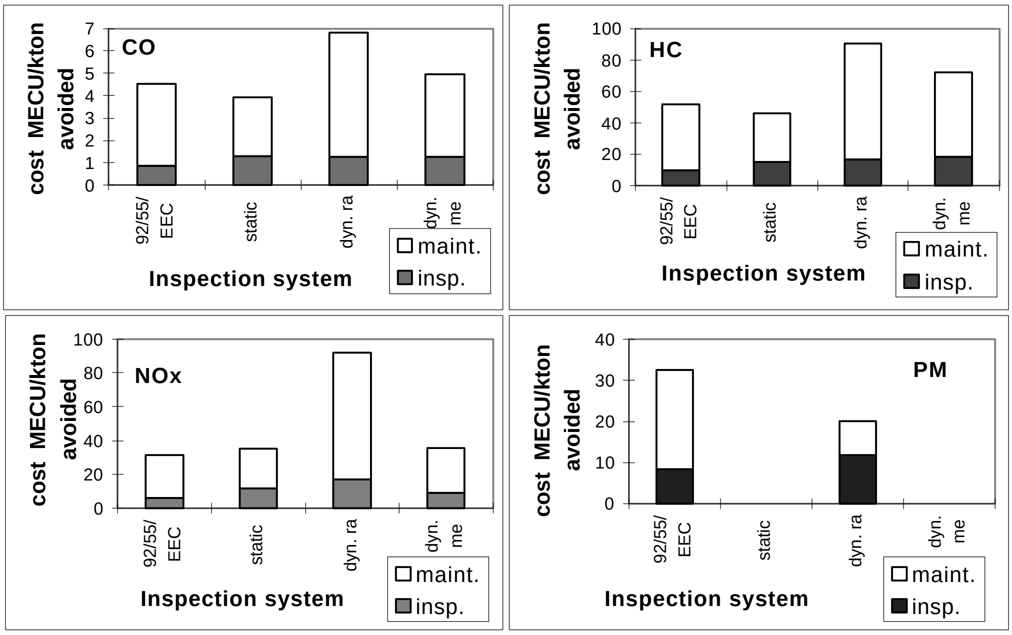

Figure 4: The cost-effectiveness of the various inspection systems; the Netherlands 1995

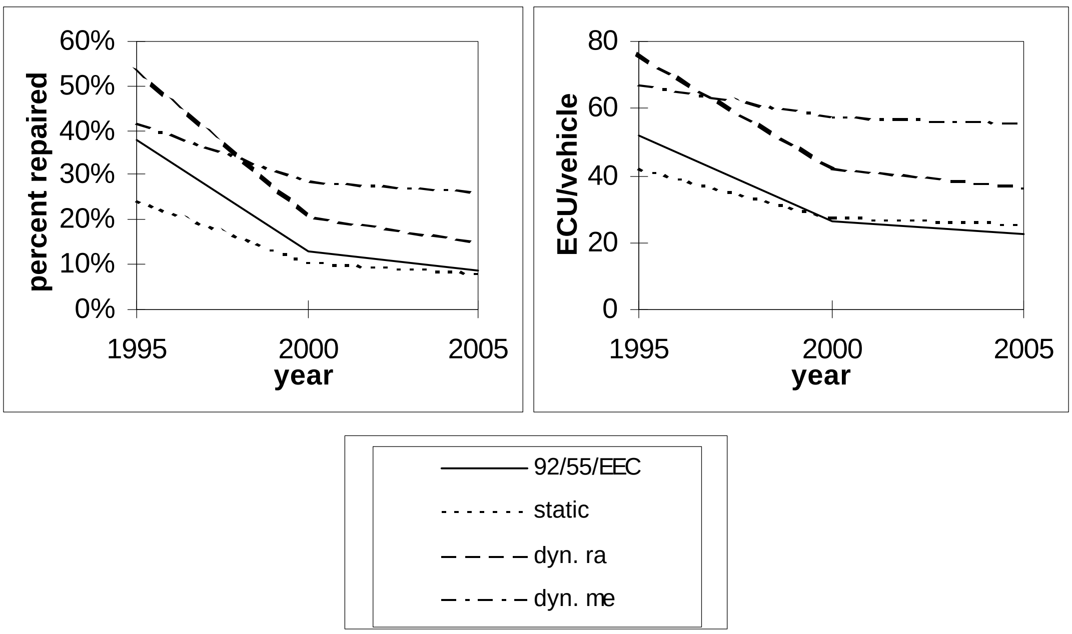

Figure 5: The trends in percentage identified as faulty and average cost of I/M per vehicle

The trends in the amount of pollutants avoided is shown in Figure 6 below.

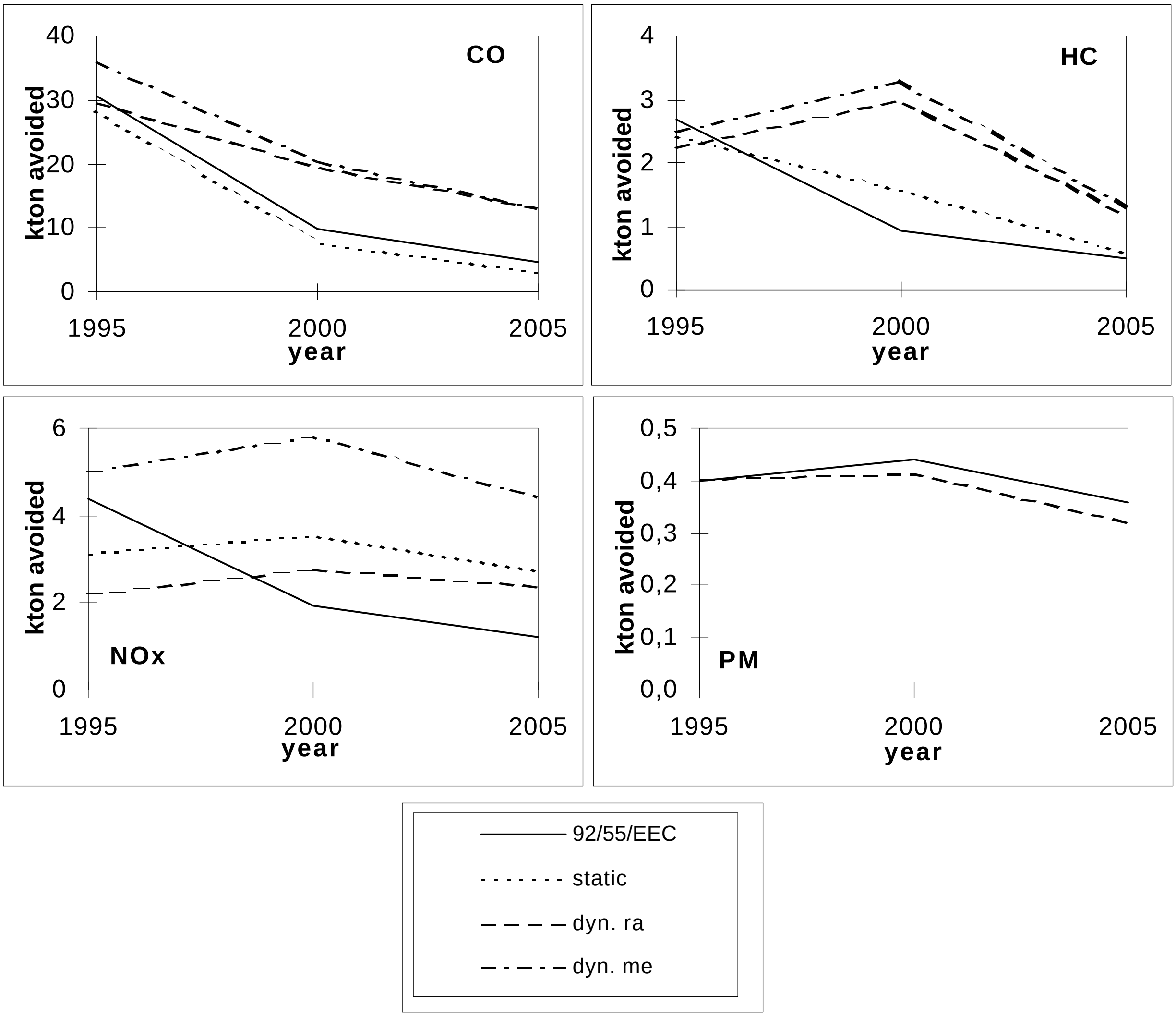

Figure 6: The trends in the amounts of pollutant avoided; the Netherlands

From Figure 2 it can be seen that there are generally no big differences between the effectiveness of the various inspection systems. In particular it is noteworthy that the procedure according to 92/55/EEC gives good results. Two things should be noted here, however. In the first place the results of this procedure for 1995 are very much influenced by the results from the non-catalyst vehicles. But the ERRPs from the non-catalyst vehicles are based on a relatively small sample, since the emphasis in the selection of cars lay on the catalyst equipped ones. So the ERRPs of the non-catalyst cars have a larger margin than those of the catalyst cars. In the second place, for the same reason the picture changes significantly when the share of catalyst cars rises in 2000 and 2005, as can be seen from Figure 6. Similarly Figure 3 seems to indicate that there is not much difference between the inspection systems in the percentage of otto vehicles identified as faulty, but again this picture changes significantly in future years (see Figure 6), especially for NOx.

The Figures 2 and 6 indicate a much higher amount of NOx avoided in the case of the ‘dynamic me’ test. This is a direct result from the fact that in that case NOx is actually measured in the short test, whereas in the other test it is simply a come-along effect.

Figure 3 shows a clear difference in the number of diesel engined cars indicated as faulty between the free acceleration test according to 92/55/EEC and the ‘dynamic ra’ test. This is a direct result of the large number of errors of commission (vehicles incorrectly identified as faulty). Figure 2 shows that indeed the amount of PM avoided does not actually increase with this high number of vehicles repaired. But Fig. 4 shows that the additional unnecessary cost of repair does actually make this an expensive option, even though the actual testing is cheap.

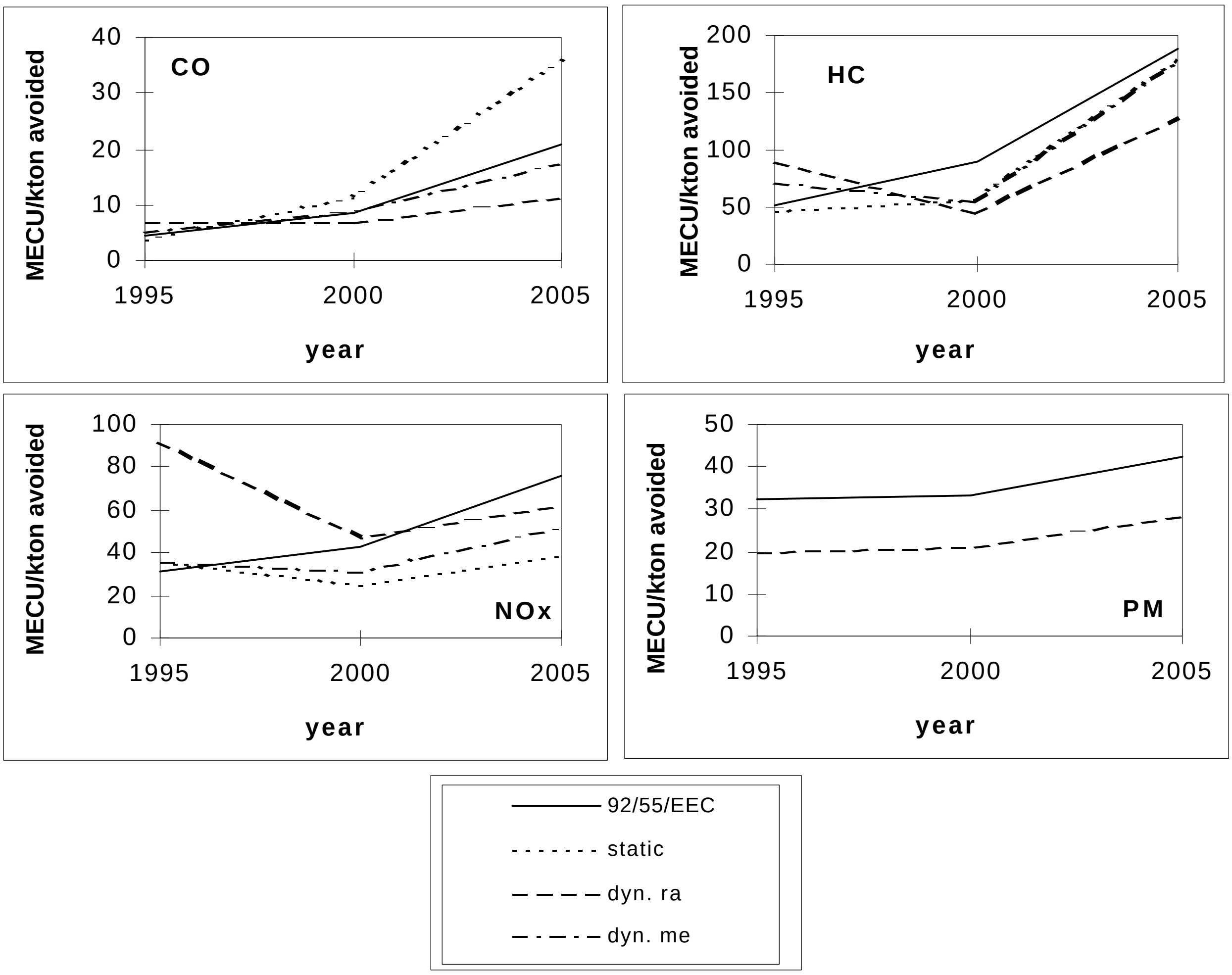

Figure 7: The trends in cost-effectiveness

In Figure 7 the trends in cost-effectiveness are given. As can be seen the dynamic tests show a much better cost-effectiveness in future years, when the share of catalyst equipped vehicles is higher than today. The cost-effectiveness of the dynamic tests also tends more towards a constant amount, notwithstanding the fact

that vehicles become cleaner. The present procedure tends to deteriorate the cost-effectiveness in coming years.

3.2 The Greek example

By way of comparison the cost-effectiveness is shown for a South-European country, in this case Greece. The cost-effectiveness over the years 1995, 2000 and 2005 is shown in Figure 8. As can be seen the procedure according to 92/55/EEC remains cost-effective for a much longer period, due to the continuing high number of non-catalyst vehicles in the Greek fleet.

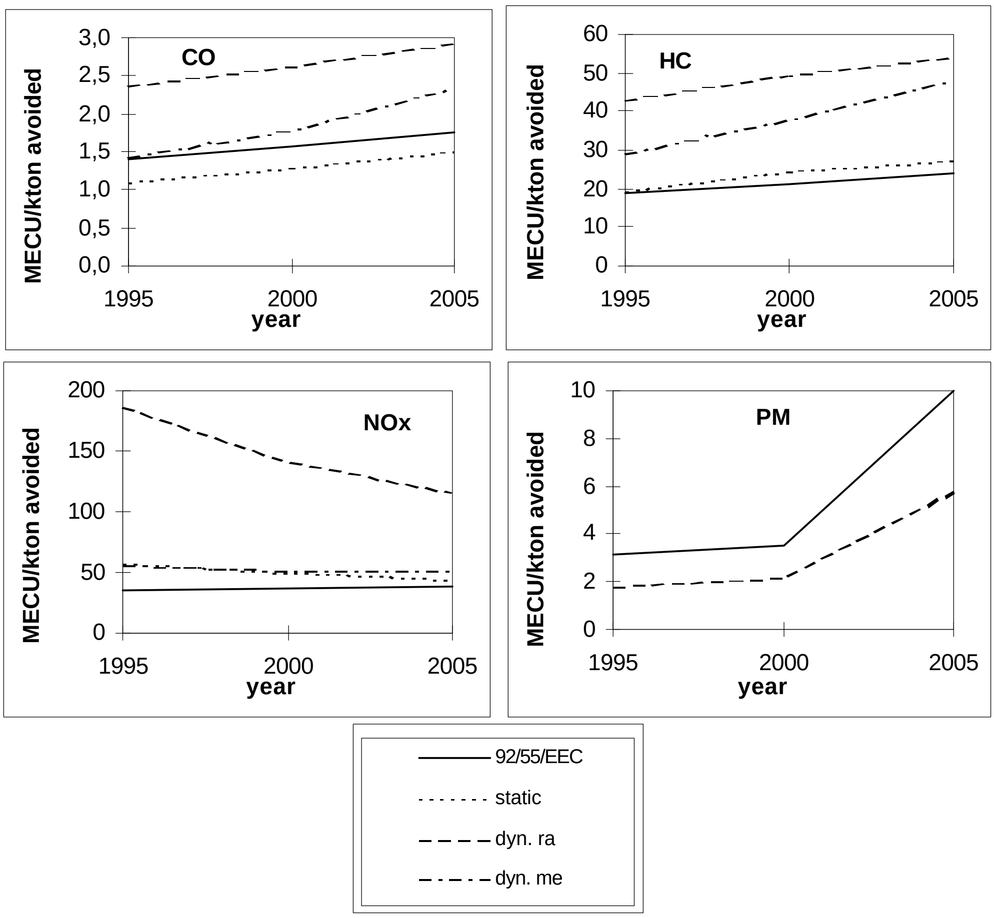

Figure 8: The trends in cost-effectiveness for Greece

4 Future outlook

In relation to the future the question needs to be considered if an I/M scheme still pays off in years after 2000, when OBD (on board diagnostics) begins to play an important role in new vehicles. The Common Position regarding the emission Directive stage III (2000 and beyond) specifies OBD for otto engined vehicles as from 01-01-2000 and for diesel engined vehicles as from 01-01-2005. According to the Common Position the OBD is subject to the following requirements and exemptions. Basically the OBD system is required to signal emission related defects that are likely to cause the emissions to exceed the so-called OBD threshold. This threshold lies considerably above the emission limit value for the type testing. The relevant values are shown in Table 9.

Table 9: Emission limit values for type testing and OBD thresholds

otto [g/km]	CO	HC	NOx
limit type test 2000	2,3	0,20	0,15
idem 2005 (indicative)	1,0	0,10	0,08
OBD threshold	3,2	0,40	0,60

diesel [g/km]	CO	HC+NOx	NOx	PM
limit type test 2000	0,64	0,56	0,50	0,050
idem 2005 (indicative)	0,50	0,30	0,25	0,025
OBD threshold	3,2	(HC:) 0,40	1,2	0,18

Furthermore the manufacturer has the right to temporarily disable the system under circumstances where he judges that reliable monitoring is not possible. This concerns cold starting below -7°C and heights above 2500 metres. Likewise, when the level in the fuel tank has dropped below 20% of the nominal capacity, if the manufacturer can show that this would lead to unreliable monitoring, the OBD may be temporarily disabled. Also the OBD basically monitors misfiring at a level where either exceeding of the OBD threshold values or permanent damage to the catalyst may be expected, but again this percentage may be increased if the manufacturer can show that reliable monitoring is not possible at lower percentages. The system is required to function properly over 80,000 km. At higher kilometrages it is still required to operate, but not necessarily in accordance with the original threshold values.

In summary it may be said that OBD has the potential to monitor the proper functioning of emission systems, but it will be some time before it will make I/M completely superfluous, especially for older cars:

- OBD will not be common for otto engines before 2005 and not be universal before 2010, with diesel engines trailing 5 years behind.
- OBD does only monitor exceeding of the OBD thresholds, which may be considerably higher than the certification limits.
- Under the present description OBD thresholds may start to slip after 80,000 km.
- Under the present description OBD may be temporarily disabled under various circumstances.

5 Estimation of the cost-effectiveness of remote sensing for I/M-purposes

5.1 General outline

In general, at present it is hard to ensure realistic cost-effectiveness estimates of remote sensing for I/M-purposes, mainly due to the fact that - in contrast to conventional I/M-schemes based on e.g. mandatory annual idle emission testing in a centralised network - there is a lack of experience of large scale uses of remote sensing for enforcement purposes, e.g.: what are the costs for routinely operating a remote sensor within an I/M-scheme (instrument amortisation and maintenance costs, staff operation costs, site installation and relocation costs, etc.); how many days a year and how many hours a day can a remote sensor be operated on average (this will certainly vary between countries); how many cars a day can be measured on average, etc.? In addition, although the data collected within the EU I/M-project give some indications, there are not yet very good statistics available to estimate the actual potential of the remote sensing technique to correctly detect high and low polluters. This potential is also likely to be site dependant.

Therefore, estimations of remote sensing cost-effectiveness have to rely on a fairly large number of assumptions, which all have an influence on the final outcome. To contribute further to the earlier calculations and discussions within the EU I/M working group on the matter, estimations are presented for the Swedish fleet based on the experiences from the work on remote sensing in Sweden. The approach is to present one pessimistic and one optimistic estimate, so as to give a range within which a likely cost-effectiveness would fall. Calculations are only made for catalyst cars, since so far there are too limited data to estimate the potential of remote sensing measurements to characterise the actual emission performance of non-catalyst cars.

The first step in this approach is to treat the very high polluters and the high polluters separately in the cost-effectiveness calculations. This was done because our experience shows that the Swedish catalyst car fleet might well be divided into the three polluter categories very high polluters, high polluters and low polluters, and that it is felt that a realistic scenario might be to use remote sensing complementary to a traditional I/M-scheme only to catch the very high polluters between regular inspections. Another realistic scenario would be to focus on all high polluters. Very high polluters are defined as cars emitting 20-30 times in excess of the CO standard and 10-15 times in excess of the HC standard, whereas high polluters are defined as any car exceeding the CO and HC standard.

Most of the calculations in this document are based on the work conducted 1995-97 at one remote sensing site outside Stockholm (Trollbäcken), the 1995 results of which are reported in: Sjödin, Å., Andréasson, K., Wallin, M., Lenner, M.,

Wilhelmsson, H. (1997) "Identification of High-Emitting Catalyst Cars on the Road by Means of Remote Sensing", *Int. J. Vehicle Design* **18**, 326-339.

5.2 Remote sensing cost-effectiveness for very high polluters only

5.2.1 Emission benefits per detected polluter

The fraction of the very high polluters within the Swedish catalyst car fleet, emitting on average 50 g CO and 2.5 g HC per km according to the FTP and 25 g CO and 1 g HC according to the HWFET, has been estimated to be 0.5% for both CO and HC in 1995 (Sjödin *et al*., 1997). It is assumed that the emission reduction potential for both CO and HC for the very high polluters on average is 90% (optimistic estimate, i.e. successful maintenance for any detected very high polluter) or 70% (pessimistic estimate, unsuccessful maintenance for one car out of four detected as very high polluters) according to both the FTP and HWFET.

Furthermore it is assumed that for an annual I/M-scheme the time left till the next inspection for a detected polluter is on average six months (optimistic estimate) or four months (pessimistic estimate). The optimistic estimate is based on the assumption that the probability for cars to become very high polluters between two annual inspections is normally distributed, i.e. for the average car independent of the time that has passed after the last inspection (with maintenance). The pessimistic estimate is an arbitrary estimate based on the assumption that the probability for cars to become very high polluters between two annual inspections increases with time after the last inspection (with maintenance). To date there are no data available to assess which of these two assumptions best reflects reality.

Finally it is assumed that the average yearly travel distance of a catalyst car in Sweden is 15000 km, distributed equally between city driving represented by the FTP, and rural or highway driving represented by HWFET.
The emissions avoided for each detected very high polluter then amounts to:

CO, optimistic estimate:	50*0.9*3750 + 25*0.9*3750 = 253 kg
CO, pessimistic estimate:	50*0.7*2500 + 25*0.7*2500 = 131 kg
HC, optimistic estimate:	2.5*0.9*3750 + 1*0.9*3750 = 11.8 kg
HC, pessimistic estimate:	2.5*0.7*2500 + 1*0.7*2500 = 6.1 kg

5.2.2 Identification rate and emission benefits per measurement campaign

If a cutpoint of 6% CO is taken on the remote sensor as an average of two consecutive readings, it is assumed that the error of commission is negligible(optimistic estimate), or 10% (pessimistic estimate) for both CO and HC, i.e. for the pessimistic case one car out of ten exceeding the 6% CO remote sensor cutpoint case has markedly lower FTP/HWFET emissions than those assumed for a very high polluter according to above (associated errors of omissions are assumed to be negligible

(optimistic) or 5% (pessimistic), however these EoO's are not used further in the cost-effectiveness calculations).

A further assumption is that for any given site a remote sensing measurement campaign comprises two full days of measurements, in order to achieve duplicate readings. For each campaign it is assumed that on average two valid CO readings are achieved on 2,000 (optimistic), or 1,000 TWC-cars (pessimistic).

The optimistic case assumes:

- high traffic density and commuter frequency sites, i.e. overall 5,000 cars daily
- 60% catalysts (today's situation)
- 2/3 commuting.

The pessimistic case assumes:

- moderate traffic density
- moderate commuter frequency

Of these, 10 cars are true very high polluters and none is a false very high polluter in the optimistic case. For the pessimistic case 4.5 cars are true very high polluters and 0.5 car is a false very high polluter (falsely sent to inspection).

The emission benefits resulting from each measurement campaign thus are:

CO, optimistic estimate:	10*253 = 2530 kg
CO, pessimistic estimate:	4.5*131 = 590 kg
HC, optimistic estimate:	10*11.8 = 118 kg
HC, pessimistic estimate:	4.5*6.1 = 27.5 kg

For the future emission benefits will generally be larger than the above along with an increased fraction of TWC-cars and an (assumed) increased fraction of very high polluting TWC-cars, due to emission deterioration of old TWC-cars. Addi-tional emission benefits could also be expected from capturing the worst polluting non-catalyst cars, as long as non-catalyst cars make up a significant portion of the fleet.

5.2.3 Costs

Estimated costs per two days measurement campaign (ECU):

	Optimistic	Pessimistic
Instrument costs[1]	300[2]	800[3]
Operating costs[4]	500[5]	1000[6]
Check in inspection station	200[7]	100[8]
Maintenance (labour + parts)	1000[9]	1350[10]
Total	2000	3250

1) including instalment, maintenance, occupation (number of days operated per year), etc.

2) remote sensor costs 75,000 ECU, amortisation in five years, in operation 100 days a year
3) remote sensor costs 100,000 ECU, amortisation in five years, in operation 50 days a year
4) including installation, surveillance, dismantling, license plate evaluation, administration
5) 1.5 work days, 1 for field work assuming self-contained remote sensor, 0.5 for evaluation and administration, assuming automatic license plate reader available
6) 3 work days, 2 for field work, 1 for evaluation and administration
7) 10 cars times 20 ECU
8) 5 cars times 20 ECU
9) 10 cars times 100 ECU
10) 4.5 cars times 300 ECU

5.2.4 Cost-effectiveness

Based on the calculated emission benefits and estimated costs the calculated cost-effectiveness becomes:

CO, optimistic estimate:	2000/2530	=	0.79 MECU/ktonnes
CO, pessimistic estimate:	3250/590	=	5.51 MECU/ktonnes
HC, optimistic estimate:	2000/118	=	16.9 MECU/ktonnes
HC, pessimistic estimate:	3250/27.5	=	118 MECU/ktonnes

5.3 Remote sensing cost-effectiveness for all high polluters

5.3.1 Emission benefits and identification rate

The fraction of catalyst cars in Sweden (in 1995) in excess of the FTP standards in 1995 is assumed to be 10% in the case of CO (above FTP 2.1 g/km) and 3% in the case of HC (above FTP 0.25 g/km). These correspond to cars with average remote sensor readings of 1% and 2% CO, respectively (i.e. for one particular site). Excluding the very high polluters and choosing a common cutpoint of 2% CO on the remote sensor (average of duplicate readings) to represent FTP excess emitters (for simplicity and in order to lower errors of commission), it is assumed that this category emit on average 5 g CO and 0.3 g HC per km according to the FTP and 2 g CO and 0.1 g HC per km according to the HWFET, and accounts for 2.5% of the fleet.
The average emission reduction potential for the high polluters, with the very high polluters excluded, is assumed to be less than for the very high polluters only, 50% as an optimistic estimate and 30% as a pessimistic estimate, for both CO and HC. Other assumptions to calculate the amount of emissions avoided per detected polluter are the same as for the very high polluters (cf. above).

The emissions avoided for each detected high polluter, excluding the very high polluters, then amounts to:

CO, optimistic estimate:	5*0.5*3750 + 2*0.5*3750 = 13.1 kg
CO, pessimistic estimate:	5*0.3*2500 + 2*0.3*2500 = 5.25 kg
HC, optimistic estimate:	0.3*0.5*3750 + 0.1*0.5*3750 = 0.75 kg
HC, pessimistic estimate:	0.3*0.3*2500 + 0.1*0.3*2500 = 0.30 kg

The errors of commission based on the 2% CO cutpoint as an average of two consecutive remote sensor readings, are assumed to be 10% as an optimistic estimate or 20% as a pessimistic estimate for both CO and HC.

Following the assumptions made for the detection of the very high polluters, a two days measurement campaign will result in the detection of 45 actual high polluters and 5 false detections in the optimistic case, and 20 actual high polluters and 5 false detections in the pessimistic case.

The emission benefits from the high polluters, excluding and including the very high polluters, resulting from each measurement campaign thus are:

	High polluters only	Incl. very high polluters
CO, optimistic:	45*13.1 = 590 kg	3120 kg
CO, pessimistic:	20*5.25 = 105 kg	695 kg
HC, optimistic:	45*0.75 = 33.8 kg	152 kg
HC, pessimistic:	20*0.30 = 6.0 kg	33.5 kg

5.3.2 Costs

Estimated costs (ECU) per two days measurement campaign, same assumptions as for the very high polluters above (figures within parenthesis represent costs when also the very high polluters are included):

	Optimistic	Pessimistic
Instrument costs	300	800
Operating costs	500	1000
Check in inspection station	1000 (1200)	500 (600)
Maintenance (labour + parts)	4500 (5500)	6000 (7500)
Total	6300 (7500)	8300 (9900)

5.3.3 Cost-effectiveness

Based on the calculated emission benefits and estimated costs, the calculated cost-effectiveness for remote sensing identification of all high polluters (including the very high polluters) becomes:

CO, optimistic estimate:	7500/3120 =	2.4 MECU/ktonnes
CO, pessimistic estimate:	9900/695 =	14.2 MECU/ktonnes
HC, optimistic estimate:	7500/152 =	49.3 MECU/ktonnes
HC, pessimistic estimate:	9900/33.5 =	295 MECU/ktonnes

5.4 Comments

Based on the above calculations it may be noted for instance that remote sensing identification of only the very high polluters is about 3 times more cost-effective compared to when all high polluters are detected. Moreover, the calculated cost-effectiveness for the conventional I/M-schemes for Sweden for 1995 (4.0-8.1 MECU/ktonnes CO and 65-156 MECU/ktonnes HC) falls within the range set by the optimistic and pessimistic estimates for the cost-effectiveness of remote sensing. Note that the emissions avoided by detection of the very high polluters account for the majority of the emissions avoided when all high polluters are detected, although it is likely that the average emissions and perhaps also the emission reduction potential of cars within the high polluter category (not including the very high polluters) are somewhat underestimated in our calculations. The fraction of the high polluter remote sensing identification costs of the overall costs range from 10% to more than 50%. Another question concerns the significance and impact of an additional emission test following the remote sensing detection, which - depending on the type of the test - will affect the final emission benefit and cost-effectiveness of the remote sensing program, if such a test will determine whether maintenance will be carried out or not, and what kind of maintenance will be carried out.

The possibility of including also remote sensing NO_x and opacity measurements needs also to be considered. Similar calculations of cost-effectiveness can be made for e.g. the use of remote sensing in roadside inspections.

Appendix A Input values and calculation results

A1. General

Table A1: The percentage of vehicles identified as faulty by the various inspection methods. In case of diesel smoke only two methods are compared

inspection method	petrol/LPG w/o catalyst	petrol/LPG with catalyst	diesel smoke test
92/55/EEC	54	8.7	26
static	33	8.0	
dynamic ra	75	15	9
dynamic me	50	27	

Table A2 : The emission reduction rate potential of the various inspection methods

CO

FUEL	petrol/LPG				diesel	
technology	convent	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	16%	5%	5%	7%	0%	0%
static	15%	3%	3%	5%	0%	0%
dynamic ra	13%	16%	16%	20%	0%	0%
dynamic me	17%	16%	16%	20%	0%	0%

HC

FUEL	petrol/LPG				diesel	
technology	w/o cat	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	8%	5%	5%	12%	0%	0%
static	5%	6%	6%	14%	0%	0%
dynamic ra	5%	14%	14%	26%	0%	0%
dynamic me	5%	15%	15%	29%	0%	0%

NOx

FUEL	petrol/LPG				diesel	
technology	w/o cat	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	8%	5%	5%	10%	0%	0%
static	3%	10%	10%	14%	0%	0%
dynamic ra	3%	10%	10%	14%	0%	0%
dynamic me	5%	20%	20%	33%	0%	0%

PM

FUEL	petrol/LPG				diesel	
technology	convent	cat tax inc.	Euro I/II	Euro III	< Euro III	Euro III
92/55/EEC	0%	0%	0%	0%	25%	33%
static	0%	0%	0%	0%		
dynamic ra	0%	0%	0%	0%	25%	31%
dynamic me	0%	0%	0%	0%		

Table A3: Level of repair assumed necessary

Class of repair	petrol/LPG w/o cat.	petrol/LPG with catalyst		diesel	
		pre Euro I	Euro I/II/III	pre Euro I	Euro I/II/III
minor	90%	80%	65%	90%	80%
major	10%	19%	34%	10%	20%
cat replace		1%	1%		

A2. Austria

Table Austria 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.043	14650	11.30	1.80	2.76	
cat tax inc	0					
Euro I	1.543	17500	1.60	0.16	0.44	
diesel	0.849	17500	0.60	0.17	0.71	0.19
LPG	0					
total	3.435					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.357	12000	11.30	1.80	2.76	
Euro I/II	2.252	15500	1.60	0.16	0.44	
Euro III	0					
diesel	1.265	17500	0.60	0.17	0.71	0.15
LPG	0					
total	3.874					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.056	9500	11.30	1.80	2.76	
Euro I/II	1.552	15500	1.60	0.16	0.44	
Euro III	1.06	17500	1.30	0.09	0.26	
diesel	1.603	17500	0.60	0.17	0.71	0.07
LPG	0					
total	4.271					

Table Austria 2: The cost of inspection and maintenance

AUSTRIA	92/55/EEC	Static	Dynamic ra	Dynamic me	cost of repair	
Investment		30000	45000	50000	minor	110
					major	240
Amortisation/yr		4286	6429	7143	replace cat	500
Interest/yr		1500	2250	2500		
Housing/yr		3000	3000	3000		
Subtotal		8786	11679	12643		
vehicles/yr		10000	10000	8000		
Fixed cost/vehicle		0.88	1.17	1.58		
Labour/hr		65	65	65		
Vehicle/hr		5	5	4		
Labour/vehicle		13	13	16.25		
Administrative/vehicle		3	3	3		
Total/vehicle	10.00	16.88	17.17	20.83		

Table Austria 3: The calculation results for 1995

AUSTRIA	I/M system	kton/yr	MECU/kton	MECU/kton	MECU/kton	number
1995		avoided	inspection	maintenance	insp.+ maint.	repaired
CO						
S.I. only	unload.	26.8	0.39	2.31	2.70	54%
	static	25.4	0.69	1.60	2.29	33%
	dyn. ra	22.8	0.79	4.02	4.81	75%
	dyn. me	28.7	0.76	2.20	2.96	50%
HC						
S.I. only	unload.	2.15	4.9	28.8	33.7	54%
	static	1.72	10.2	23.6	33.8	33%
	dyn. ra	1.27	14.2	72.4	86.6	75%
	dyn. me	1.40	15.5	44.9	60.4	50%
NOx						
S.I. only	unload.	3.42	3.1	18.1	21.1	54%
	static	1.31	13.5	31.1	44.5	33%
	dyn. ra	0.74	24.1	123.5	147.6	75%
	dyn. me	1.97	11.0	32.0	43.0	50%
PM						
diesel only	unload.	0.57	12.0	34.4	46.3	26%
	static					
	dyn. ra	0.57	20.4	12.1	32.5	9%
	dyn. me					

Table Austria 4: The calculation results for 2000

AUSTRIA	I/M system	kton/yr	MECU/kton	MECU/kton	MECU/kton	number
2000		avoided	inspection	maintenance	insp.+ maint.	repaired
CO						
S.I. only	unload.	9.8	1.52	3.57	5.09	20%
	static	8.5	2.94	3.18	6.13	14%
	dyn. ra	13.5	1.89	4.19	6.07	30%
	dyn. me	15.0	2.06	4.43	6.49	32%
HC						
S.I. only	unload.	0.84	17.7	41.6	59.3	20%
	static	0.94	26.5	28.6	55.2	14%
	dyn. ra	1.50	16.9	37.6	54.5	30%
	dyn. me	1.66	18.6	39.8	58.4	32%
NOx						
S.I. only	unload.	1.54	9.6	22.6	32.3	20%
	static	1.82	13.7	14.8	28.5	14%
	dyn. ra	1.39	18.4	40.8	59.2	30%
	dyn. me	2.97	10.4	22.3	32.7	32%
PM						
diesel only	unload.	0.88	11.5	36.1	47.6	26%
	static					
	dyn. ra	0.83	21.0	13.5	34.5	9%
	dyn. me					

Table Austria 5: The calculation results for 2005

AUSTRIA	I/M system	kton/yr	MECU/kton	MECU/kton	MECU/kton	number
2005		avoided	inspection	maintenance	insp.+ maint.	repaired
CO						
S.I. only	unload.	3.5	2.94	7.71	10.65	10%
	static	2.5	6.92	9.92	16.84	9%
	dyn. ra	8.9	2.02	5.53	7.55	17%
	dyn. me	8.9	2.43	9.16	11.60	27%
HC						
S.I. only	unload.	0.36	29.3	76.8	106.1	10%
	static	0.39	45.1	64.6	109.7	9%
	dyn. ra	0.75	23.9	65.6	89.5	17%
	dyn. me	0.83	26.2	98.8	125.1	27%
NOx						
S.I. only	unload.	0.82	12.8	33.5	46.3	10%
	static	1.70	10.3	14.8	25.2	9%
	dyn. ra	1.42	12.6	34.6	47.2	17%
	dyn. me	2.80	7.8	29.2	37.0	27%
PM						
diesel only	unload.	0.71	9.5	56.3	65.8	26%
	static					
	dyn. ra	0.64	18.2	22.1	40.3	9%
	dyn. me					

A3. France

Table France 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	13.497	11500	18.70	2.74	2.00	
cat tax inc	0					
Euro I	5.338	12000	3.00	0.26	0.42	
diesel	6.188	21000	0.72	0.18	0.70	0.3
LPG	0					
total	25.023					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	6.09	10000	11.30	1.80	2.76	
Euro I/II	11.605	12000	1.60	0.16	0.44	
Euro III	0					
diesel	8.633	21000	0.60	0.17	0.71	0.15
LPG	0		1.30	0.16	0.44	
total	26.328					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.327	10000	11.30	1.80	2.76	
Euro I/II	9.035	11500	1.60	0.16	0.44	
Euro III	6.562	12000	1.30	0.09	0.26	
diesel	10.293	21000	0.60	0.17	0.71	0.07
LPG	0		1.30	0.09	0.26	
total	27.217					

Table France 2: cost of inspection and maintenance

FRANCE	92/55/EEC otto/diesel	Static	Dynamic ra	Dynamic me	cost of repair	
Investment		30000	45000	50000	minor	115
					major	250
Amortisation/yr		4286	6429	7143	replace cat	500
Interest/yr		1500	2250	2500		
Housing/yr		3000	3000	3000		
Subtotal		8786	11679	12643		
vehicles/yr		10000	10000	8000		
Fixed cost/vehicle		0.88	1.17	1.58		
Labour/hr		70	70	70		
Vehicle/hr		5	5	4		
Labour/vehicle		14	14	17.5		
Administrative/vehicle		3	3	3		
Total/vehicle	17.00/20.00	17.88	18.17	22.08		

Table France 3: The calculation results for 1995

FRANCE 1995	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	449.9	0.51	2.35	2.86	54%
	static	426.7	0.57	1.54	2.11	33%
	dyn. ra	383.1	0.64	3.88	4.52	75%
	dyn. me	481.8	0.62	2.11	2.73	50%
HC						
S.I. only	unload.	33.17	6.9	31.9	38.8	54%
	static	23.44	10.3	28.1	38.4	33%
	dyn. ra	19.56	12.5	75.9	88.4	75%
	dyn. me	21.69	13.7	46.9	60.6	50%
NOx						
S.I. only	unload.	25.14	9.1	42.1	51.2	54%
	static	9.62	25.1	68.4	93.5	33%
	dyn. ra	5.46	44.9	271.7	316.6	75%
	dyn. me	14.50	20.6	70.1	90.7	50%
PM						
diesel only	unload.	7.83	10.7	24.0	34.7	26%
	static					
	dyn. ra	7.90	11.4	8.0	19.4	9%
	dyn. me					

Table France 4: The calculation results for 2000

FRANCE 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	115.6	1.75	4.93	6.68	32%
	static	106.7	1.99	3.58	5.58	21%
	dyn. ra	119.2	1.81	6.99	8.80	46%
	dyn. me	141.9	1.85	5.27	7.12	39%
HC						
S.I. only	unload.	9.49	21.3	60.0	81.3	32%
	static	8.78	24.2	43.6	67.8	21%
	dyn. ra	7.68	28.1	108.5	136.7	46%
	dyn. me	8.51	30.9	87.8	118.7	39%
NOx						
S.I. only	unload.	15.93	12.7	35.8	48.5	32%
	static	11.03	19.3	34.7	54.0	21%
	dyn. ra	7.65	28.2	108.9	137.1	46%
	dyn. me	17.51	15.0	42.7	57.7	39%
PM						
diesel only	unload.	10.49	11.2	27.3	38.5	26%
	static					
	dyn. ra	9.43	13.3	10.2	23.5	9%
	dyn. me					

Table France 5: The calculation results for 2005

FRANCE 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	34.5	6.66	8.42	15.08	13%
	static	29.2	8.27	8.09	16.36	11%
	dyn. ra	54.6	4.49	8.69	13.18	21%
	dyn. me	59.0	5.05	11.54	16.59	29%
HC						
S.I. only	unload.	3.07	74.7	94.5	169.2	13%
	static	2.72	88.8	86.9	175.6	11%
	dyn. ra	4.13	59.4	114.9	174.3	21%
	dyn. me	4.57	65.2	149.0	214.2	29%
NOx						
S.I. only	unload.	5.96	38.5	48.7	87.2	13%
	static	8.26	29.2	28.6	57.8	11%
	dyn. ra	6.64	37.0	71.4	108.4	21%
	dyn. me	13.46	22.1	50.6	72.7	29%
PM						
diesel only	unload.	7.07	11.9	48.3	60.2	26%
	static	7.07	12.5	0.0	12.5	0%
	dyn. ra	6.45	14.0	17.8	31.7	9%
	dyn. me	6.45	17.0	0.00	16.96	0.0%

A4. Germany

Table Germany 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	10	11600	12.02	1.79	2.09	
cat tax inc	4.5	19500	3.30	0.20	0.58	
Euro I	14.8	22600	1.89	0.10	0.44	
diesel	4.5	20400	0.43	0.07	0.60	0.13
LPG	0					
total	33.8					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	4.4	10500	11.30	1.80	2.76	
Euro I/II	27.5	21000	1.60	0.16	0.44	
Euro III	0					
diesel	4.9	20400	0.60	0.17	0.71	0.15
LPG	0		1.30	0.16	0.44	
total	36.8					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.6	9000	11.30	1.80	2.76	
Euro I/II	20.3	11600	1.60	0.16	0.44	
Euro III	12.8	21000	1.30	0.09	0.26	
diesel	5.2	20400	0.60	0.17	0.71	0.07
LPG	0					
total	38.9					

Table Germany 2:The cost of inspection and maintenance

GERMANY	92/55/EEC	Static	Dynamic ra	Dynamic me	cost of repair	
	no-cat/cat					
Investment		30000	45000	50000	minor	110
					major	250
Amortisation/yr		4286	6429	7143	replace cat	500
Interest/yr		1500	2250	2500		
Housing/yr		3000	3000	3000		
Subtotal		8786	11679	12643		
vehicles/yr		10000	10000	8000		
Fixed cost/vehicle		0.88	1.17	1.58		
Labour/hr		75	75	75		
Vehicle/hr		5	5	4		
Labour/vehicle		15	15	18.75		
Administrative/vehicle		3	3	3		
Total/vehicle	25.00/40.00	18.88	19.17	23.33		

Table Germany 3:The calculation results for 1995

GERMANY	I/M system	kton/yr	MECU/kton	MECU/kton	MECU/kton	number
1995		avoided	inspection	maintenance	insp.+ maint.	repaired
CO						
S.I. only	unload.	230.7	1.86	3.79	5.65	40%
	static	213.9	1.28	2.50	3.78	25%
	dyn. ra	230.1	1.21	5.15	6.35	56%
	dyn. me	276.4	1.22	3.38	4.60	43%
HC						
S.I. only	unload.	17.12	25.1	51.0	76.1	40%
	static	14.20	19.3	37.6	56.9	25%
	dyn. ra	11.96	23.2	99.0	122.3	56%
	dyn. me	13.25	25.5	70.4	96.0	43%
NOx						
S.I. only	unload.	22.04	19.5	39.6	59.2	40%
	static	13.56	20.2	39.4	59.6	25%
	dyn. ra	9.14	30.4	129.5	159.9	56%
	dyn. me	21.35	15.8	43.7	59.6	43%
PM						
diesel only	unload.	2.40	37.5	58.4	95.9	26%
	static					
	dyn. ra	2.42	28.5	18.5	47.1	9%
	dyn. me					

Table Germany 4: The calculation results for 2000

GERMANY 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	118.1	5.59	5.05	10.64	20%
	static	99.7	3.44	4.11	7.54	14%
	dyn. ra	186.5	1.87	4.58	6.45	30%
	dyn. me	201.4	2.10	4.97	7.08	32%
HC						
S.I. only	unload.	10.38	63.6	57.4	121.0	20%
	static	10.29	33.3	39.8	73.1	14%
	dyn. ra	16.49	21.1	51.8	72.9	30%
	dyn. me	18.23	23.2	55.0	78.2	32%
NOx						
S.I. only	unload.	19.92	33.1	29.9	63.1	20%
	static	28.08	12.2	14.6	26.8	14%
	dyn. ra	21.72	16.0	39.3	55.4	30%
	dyn. me	46.02	9.2	21.8	31.0	32%
PM						
diesel only	unload.	3.97	24.7	42.0	66.7	26%
	static					
	dyn. ra	3.74	20.1	14.3	34.4	9%
	dyn. me					

Table Germany 5: The calculation results for 2005

GERMANY 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	28.4	15.14	17.52	32.66	10%
	static	20.6	13.26	19.26	32.51	9%
	dyn. ra	68.0	4.09	11.34	15.42	17%
	dyn. me	68.6	4.93	18.90	23.83	27%
HC						
S.I. only	unload.	2.74	156.7	181.4	338.1	10%
	static	2.93	93.3	135.5	228.8	9%
	dyn. ra	5.62	49.5	137.2	186.6	17%
	dyn. me	6.21	54.5	208.9	263.4	27%
NOx						
S.I. only	unload.	6.10	70.5	81.6	152.1	10%
	static	12.76	21.5	31.2	52.6	9%
	dyn. ra	10.19	27.3	75.7	102.9	17%
	dyn. me	21.12	16.0	61.4	77.4	27%
PM						
diesel only	unload.	3.22	27.9	54.9	82.8	26%
	static					
	dyn. ra	2.89	23.8	19.7	43.5	9%
	dyn. me					

A5. Greece

Table Greece 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.333	13000	25.42	3.69	1.93	
cat tax inc	0.052	13000	10.50	2.33	1.31	
Euro I	0.587	13000	4.04	0.42	0.40	
diesel	0.032	100000	1.01	0.29	0.80	0.5
LPG	0.006	100000	7.06	1.86	1.85	
total	2.010					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.213	13000	25.42	3.69	1.93	
Euro I/II	1.085	13000	1.30	0.16	0.26	
Euro III	0.000					
diesel	0.037	100000	0.80	0.23	0.71	0.25
LPG	0.007	100000	2.8	0.42	0.44	
total	2.342					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.968	13000	25.42	3.69	1.93	
Euro I/II	1.024	13000	1.60	0.16	0.44	
Euro III	0.614	13000	1.30	0.09	0.26	
diesel	0.042	100000	0.60	0.17	0.71	0.07
LPG	0.008	100000	1.30	0.09	0.26	
total	2.656					

Table Greece 2: The cost of inspection and maintenance

GREECE	92/55/EEC	Static	Dynamic ra	Dynamic me	cost of repair	
Investment		30000	45000	50000	minor	100
					major	210
Amortisation/yr		4286	6429	7143	replace cat	500
Interest/yr		1500	2250	2500		
Housing/yr		3000	3000	3000		
Subtotal		8786	11679	12643		
vehicles/yr		10000	10000	8000		
Fixed cost/vehicle		0.88	1.17	1.58		
Labour/hr		40	40	40		
Vehicle/hr		5	5	4		
Labour/vehicle		8	8	10		
Administrative/vehicle		3	3	3		
Total/vehicle	8.00	11.88	12.17	14.58		

Table Greece 3: The calculation results for 1995

GREECE 1995	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	68.8	0.16	1.25	1.41	52%
	static	65.1	0.25	0.85	1.10	32%
	dyn. ra	59.8	0.28	2.08	2.36	73%
	dyn. me	74.8	0.27	1.15	1.42	49%
HC						
S.I. only	unload.	5.12	2.2	16.8	19.0	52%
	static	3.74	4.4	14.8	19.2	32%
	dyn. ra	3.28	5.2	37.9	43.1	73%
	dyn. me	3.64	5.6	23.6	29.2	49%
NOx						
S.I. only	unload.	2.79	4.0	30.8	34.8	52%
	static	1.25	13.2	44.3	57.5	32%
	dyn. ra	0.76	22.3	163.9	186.2	73%
	dyn. me	1.91	10.6	44.9	55.5	49%
PM						
diesel only	unload.	0.32	0.6	2.5	3.1	26%
	static					
	dyn. ra	0.32	1.0	0.8	1.8	9%
	dyn. me					

Table Greece 4: The calculation results for 2000

GREECE 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	63.1	0.22	1.35	1.57	40%
	static	59.5	0.35	0.95	1.30	25%
	dyn. ra	56.0	0.38	2.23	2.61	56%
	dyn. me	69.6	0.37	1.42	1.79	43%
HC						
S.I. only	unload.	4.65	3.0	18.3	21.3	40%
	static	3.19	6.6	17.7	24.2	25%
	dyn. ra	2.96	7.2	42.3	49.5	56%
	dyn. me	3.28	7.8	30.2	38.0	43%
NOx						
S.I. only	unload.	2.71	5.2	31.3	36.5	40%
	static	1.56	13.4	36.1	49.5	25%
	dyn. ra	1.03	20.7	120.8	141.5	56%
	dyn. me	2.45	10.5	40.4	50.9	43%
PM						
diesel only	unload.	0.36	0.7	2.8	3.5	26%
	static					
	dyn. ra	0.32	1.1	1.1	2.2	9%
	dyn. me					

Table Greece 5: The calculation results for 2005

GREECE 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	51.0	0.22	1.54	1.76	28%
	static	47.9	0.34	1.16	1.50	19%
	dyn. ra	46.6	0.36	2.57	2.93	41%
	dyn. me	57.4	0.35	1.98	2.34	37%
HC						
S.I. only	unload.	3.77	2.9	20.9	23.8	28%
	static	2.63	6.3	21.1	27.4	19%
	dyn. ra	2.52	6.7	47.5	54.2	41%
	dyn. me	2.79	7.3	40.8	48.1	37%
NOx						
S.I. only	unload.	2.34	4.7	33.6	38.4	28%
	static	1.65	10.0	33.6	43.5	19%
	dyn. ra	1.18	14.3	101.3	115.6	41%
	dyn. me	2.61	7.7	43.5	51.3	37%
PM						
diesel only	unload.	0.13	1.5	8.4	10.0	26%
	static					
	dyn. ra	0.12	2.6	3.2	5.8	9%
	dyn. me					

A6. the Netherlands

Table the Netherlands 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.71	9700	11.30	1.80	2.76	
cat tax inc	0.42	13600	2.80	0.30	0.58	
Euro I	2.68	13600	1.60	0.16	0.44	
diesel	0.42	25000	0.60	0.17	0.71	0.19
LPG	0.66	22500	1.3	0.39	0.95	
total	5.89					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.292	9700	11.30	1.80	2.76	
Euro I/II	4.643	13600	1.60	0.16	0.44	
Euro III	0	13600	1.30	0.09	0.26	
diesel	0.444	25000	0.60	0.17	0.71	0.15
LPG	0.693	22500	1.30	0.16	0.44	
total	6.072					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.009	3200	11.30	1.80	2.76	
Euro I/II	2.523	9700	1.60	0.16	0.44	
Euro III	2.583	13600	1.30	0.09	0.26	
diesel	0.459	25000	0.60	0.17	0.71	0.07
LPG	0.717	22500	1.30	0.09	0.26	
total	6.291					

Table the Netherlands 2: The cost of inspection and maintenance

the NETHERLANDS	92/55/EEC	Static	Dynamic ra	Dynamic me
Investment ECU		30000	45000	50000
Amortisation/yr ECU		4286	6429	7143
Interest/yr ECU		1500	2250	2500
Housing/yr ECU		3000	3000	3000
Subtotal ECU		8786	11679	12643
vehicles/yr		10000	10000	8000
Fixed cost/vehicle		0.88	1.17	1.58
Labour/hr		50	50	50
Vehicle/hr		5	5	4
Labour/vehicle		10	10	12.5
Administrative/vehicle		3	3	3
Total/vehicle ECU	10.00	13.88	14.17	17.08

cost of repair	
minor	90
major	190
replace cat	500

Table the Netherlands 3: The calculation results for 1995

the NETHERLANDS 1995	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	percent repaired
CO						
otto only	92/55/EEC	30.6	0.87	3.64	4.51	38%
	static	28.5	1.29	2.62	3.91	24%
	dyn. ra	29.7	1.27	5.55	6.81	54%
	dyn. me	36.0	1.26	3.70	4.96	42%
HC						
otto only	92/55/EEC	2.66	10.0	41.9	51.9	38%
	static	2.43	15.2	30.7	45.9	24%
	dyn. ra	2.24	16.8	73.5	90.3	54%
	dyn. me	2.48	18.3	53.5	71.8	42%
NOx						
otto only	92/55/EEC	4.40	6.0	25.4	31.4	38%
	static	3.15	11.7	23.7	35.4	24%
	dyn. ra	2.20	17.1	74.9	91.9	54%
	dyn. me	5.02	9.1	26.5	35.6	42%
PM						
diesel only	92/55/EEC	0.40	8.4	24.1	32.4	26%
	dyn. ra	0.40	11.8	8.3	20.0	9%

Table the Netherlands 4: The calculation results for 2000

the NETHERLANDS 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	9.8	3.22	5.30	8.52	13%
	static	7.7	5.70	5.70	11.40	10%
	dyn. ra	19.7	2.28	4.47	6.76	21%
	dyn. me	20.4	2.66	6.30	8.96	29%
HC						
S.I. only	unload.	0.93	34.1	56.2	90.3	13%
	static	1.56	28.3	28.3	56.5	10%
	dyn. ra	2.98	15.0	29.5	44.5	21%
	dyn. me	3.29	16.4	39.0	55.4	29%
NOx						
S.I. only	unload.	1.94	16.3	26.9	43.2	13%
	static	3.53	12.4	12.4	24.9	10%
	dyn. ra	2.79	16.1	31.5	47.6	21%
	dyn. me	5.83	9.3	22.0	31.3	29%
PM						
diesel only	unload.	0.44	8.1	25.2	33.3	26%
	static					
	dyn. ra	0.42	12.1	9.2	21.4	9%
	dyn. me					

Table the Netherlands 5: The calculation results for 2005

the NETHERLANDS 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	4.4	9.34	11.44	20.78	9%
	static	2.9	19.59	16.21	35.80	8%
	dyn. ra	13.3	4.42	6.87	11.29	15%
	dyn. me	13.1	5.38	12.21	17.59	27%
HC						
S.I. only	unload.	0.49	84.6	103.5	188.0	9%
	static	0.59	98.1	81.2	179.3	8%
	dyn. ra	1.17	50.2	78.1	128.3	15%
	dyn. me	1.30	54.5	123.7	178.3	27%
NOx						
S.I. only	unload.	1.22	34.0	41.6	75.5	9%
	static	2.71	21.2	17.5	38.7	8%
	dyn. ra	2.39	24.5	38.1	62.7	15%
	dyn. me	4.43	16.0	36.2	52.2	27%
PM						
diesel only	unload.	0.36	10.3	32.1	42.4	26%
	static					
	dyn. ra	0.32	16.2	12.3	28.5	9%
	dyn. me					

A7. Sweden

Table Sweden 1: Characteristicse of the car fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	1.893	13900	12.02	1.79	2.09	
cat tax inc	0.472	13900	3.30	0.20	0.58	
Euro I	1.368	21950	1.89	0.10	0.44	
diesel	0.1	20540	0.43	0.07	0.60	0.13
LPG	0					
total	3.833					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.866	10000	11.3	1.8	2.76	
Euro I/II	3.2	18700	1.6	0.16	0.44	
Euro III	0	21950	1.3	0.09	0.26	
diesel	0.109	20540	0.6	0.17	0.71	0.15
LPG	0					
total	4.175					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.25	10000	11.30	1.80	2.76	
Euro I/II	2.43	14050	1.60	0.16	0.44	
Euro III	1.668	21950	1.30	0.09	0.26	
diesel	0.117	20540	0.60	0.17	0.71	0.07
LPG	0					
total	4.465					

Table Sweden 2: The cost of inspection and maintenance

SWEDEN	92/55/EEC	Static	Dynamic ra	Dynamic me
Investment		30000	45000	50000
Amortisation/yr		4286	6429	7143
Interest/yr		1500	2250	2500
Housing/yr		3000	3000	3000
Subtotal		8786	11679	12643
vehicles/yr		10000	10000	8000
Fixed cost/vehicle		0.88	1.17	1.58
Labour/hr		70	70	70
Vehicle/hr		5	5	4
Labour/vehicle		14	14	17.5
Administrative/vehicle		3	3	3
Total/vehicle	10.00	17.88	18.17	22.08

cost of repair	
minor	180
major	350
replace cat	500

Table Sweden 3: The calculation results for 1995

SWEDEN	I/M system	kton/yr	MECU/kton	MECU/kton	MECU/kton	number
1995		avoided	inspection	maintenance	insp.+ maint.	repaired
CO						
S.I. only	unload.	50.1	0.47	4.40	4.87	45%
	static	47.2	0.90	3.06	3.96	28%
	dyn. ra	45.2	0.95	7.14	8.09	63%
	dyn. me	55.9	0.93	4.25	5.18	45%
HC						
S.I. only	unload.	3.74	6.3	58.9	65.2	45%
	static	2.75	15.3	52.4	67.8	28%
	dyn. ra	2.35	18.3	137.4	155.7	63%
	dyn. me	2.60	20.1	91.2	111.3	45%
NOx						
S.I. only	unload.	4.63	5.1	47.6	52.7	45%
	static	2.16	19.6	67.0	86.6	28%
	dyn. ra	1.33	32.2	242.0	274.3	63%
	dyn. me	3.32	15.7	71.5	87.3	45%
PM						
diesel only	unload.	0.05	14.9	80.5	95.5	26%
	static					
	dyn. ra	0.05	26.9	27.7	54.5	9%
	dyn. me					

Table Sweden 4: The calculation results for 2000

SWEDEN 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	19.0	1.30	6.93	8.23	25%
	static	16.8	2.63	5.69	8.32	17%
	dyn. ra	25.1	1.78	8.11	9.89	36%
	dyn. me	31.4	1.73	6.59	8.33	35%
HC						
S.I. only	unload.	1.62	15.2	81.4	96.6	25%
	static	1.43	30.8	66.7	97.5	17%
	dyn. ra	2.03	22.1	100.4	122.5	36%
	dyn. me	2.24	24.3	92.4	116.7	35%
NOx						
S.I. only	unload.	2.93	8.4	45.0	53.4	25%
	static	3.24	13.6	29.4	43.0	17%
	dyn. ra	2.44	18.4	83.5	101.9	36%
	dyn. me	5.27	10.3	39.3	49.7	35%
PM						
diesel only	unload.	0.09	9.8	57.3	67.2	26%
	static					
	dyn. ra	0.08	18.9	21.0	39.9	9%
	dyn. me					

Table Sweden 5: The calculation results for 2005

SWEDEN 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	8.5	2.80	11.38	14.17	12%
	static	6.8	6.25	12.19	18.43	10%
	dyn. ra	16.3	2.64	10.07	12.70	20%
	dyn. me	17.0	3.07	14.37	17.43	28%
HC						
S.I. only	unload.	0.79	29.8	121.3	151.2	12%
	static	0.77	54.9	107.0	161.9	10%
	dyn. ra	1.30	33.0	125.7	158.7	20%
	dyn. me	1.44	36.2	169.5	205.7	28%
NOx						
S.I. only	unload.	1.66	14.3	58.1	72.4	12%
	static	2.79	15.2	29.6	44.7	10%
	dyn. ra	2.31	18.6	71.0	89.6	20%
	dyn. me	4.56	11.5	53.7	65.2	28%
PM						
diesel only	unload.	0.06	13.9	95.2	109.1	26%
	static					
	dyn. ra	0.05	28.0	36.5	64.5	9%
	dyn. me					

A8. the United Kingdom

Table UK 1: Characteristics of the vehicle fleet

1995	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	13.559	16500	18.70	2.74	2.76	
cat tax inc	0					
Euro I	6.997	20000	3.00	0.26	0.42	
diesel	2.322	28500	0.72	0.18	0.70	0.3
LPG	0					
total	22.878					

2000	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	4.874	13500	11.30	1.80	2.76	
Euro I/II	15.429	19500	1.60	0.16	0.44	
Euro III	0					
diesel	4.868	28500	0.60	0.17	0.71	0.15
LPG	0					
total	25.171					

2005	number millions	km/yr	CO g/km	HC g/km	NOx g/km	Partic g/km
Otto conv	0.559	9700	11.30	1.80	2.76	
Euro I/II	10.354	13500	1.60	0.16	0.44	
Euro III	9.782	19500	1.30	0.09	0.26	
diesel	6.614	28500	0.60	0.17	0.71	0.07
LPG	0					
total	27.309					

Table UK 2: The cost of inspection and maintenance

UNITED KINGDOM	92/55/EEC	Static	Dynamic ra	Dynamic me	cost of repair	
Investment		30000	45000	50000	minor	125
					major	240
Amortisation/yr		4286	6429	7143	replace cat	500
Interest/yr		1500	2250	2500		
Housing/yr		3000	3000	3000		
Subtotal		8786	11679	12643		
vehicles/yr		10000	10000	8000		
Fixed cost/vehicle		0.88	1.17	1.58		
Labour/hr		60	60	60		
Vehicle/hr		5	5	4		
Labour/vehicle		12	12	15		
Administrative/vehicle		3	3	3		
Total/vehicle	12.00	15.88	16.17	19.58		

Table UK 3: The calculation results for 1995

UK 1995	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	648.5	0.25	1.67	1.92	36%
	static	615.0	0.35	1.12	1.47	22%
	dyn. ra	552.2	0.40	2.81	3.21	49%
	dyn. me	694.5	0.38	1.52	1.91	33%
HC						
S.I. only	unload.	47.81	3.4	22.7	26.1	36%
	static	34.58	6.2	19.9	26.1	22%
	dyn. ra	28.20	7.8	55.1	62.8	49%
	dyn. me	31.26	8.5	33.8	42.3	33%
NOx						
S.I. only	unload.	50.02	3.3	21.7	24.9	36%
	static	19.14	11.2	36.0	47.2	22%
	dyn. ra	10.87	20.2	142.9	163.0	49%
	dyn. me	28.84	9.2	36.7	45.9	33%
PM						
diesel only	unload.	3.99	5.6	18.0	23.6	26%
	static					
	dyn. ra	4.02	7.5	6.1	13.6	9%
	dyn. me					

Table UK 4: The calculation results for 2000

UK 2000	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	134.6	1.12	3.80	4.92	16%
	static	121.2	1.65	2.98	4.63	11%
	dyn. ra	159.4	1.28	4.87	6.15	24%
	dyn. me	183.2	1.35	4.18	5.53	22%
HC						
S.I. only	unload.	11.27	13.4	45.4	58.8	16%
	static	9.48	21.1	38.1	59.2	11%
	dyn. ra	8.29	24.5	93.6	118.2	24%
	dyn. me	9.19	26.8	83.3	110.1	22%
NOx						
S.I. only	unload.	19.71	7.7	26.0	33.6	16%
	static	18.20	11.0	19.9	30.9	11%
	dyn. ra	13.34	15.3	58.2	73.5	24%
	dyn. me	29.35	8.4	26.1	34.5	22%
PM						
diesel only	unload.	8.03	5.8	20.3	26.1	26%
	static					
	dyn. ra	7.22	8.7	7.7	16.4	9%
	dyn. me					

Table UK 5: The calculation results for 2005

UK 2005	I/M system	kton/yr avoided	MECU/kton inspection	MECU/kton maintenance	MECU/kton insp.+ maint.	number repaired
CO						
S.I. only	unload.	27.7	5.88	9.77	15.64	7%
	static	20.7	10.38	11.55	21.92	6%
	dyn. ra	63.8	3.44	7.34	10.77	13%
	dyn. me	65.0	4.08	11.64	15.72	20%
HC						
S.I. only	unload.	2.74	59.3	98.5	157.9	7%
	static	2.90	74.1	82.5	156.6	6%
	dyn. ra	5.33	41.2	87.9	129.1	13%
	dyn. me	5.90	45.0	128.3	173.2	20%
NOx						
S.I. only	unload.	6.14	26.5	44.0	70.5	7%
	static	11.89	18.1	20.1	38.3	6%
	dyn. ra	10.06	21.8	46.5	68.3	13%
	dyn. me	19.45	13.6	38.9	52.6	20%
PM						
diesel only	unload.	5.41	4.1	40.8	44.9	26%
	static					
	dyn. ra	4.93	6.1	15.3	21.4	9%
	dyn. me					