

Annex 5

Cost effectiveness analysis

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A5.1 Introduction

This cost effectiveness analysis builds on those described in the reports on Phases 1 and 2 of this project^{1,2}. The methodology used in these previous iterations was reviewed as part of Phase 2 to check

- the consistency of approach and data used in this analysis with that used to calculate the NAEI, and
- the consistency of approach used in this analysis with that used by the Cleaner Vehicle Task Force (CVTF).

It was concluded that the methodology used in the two previous phases were appropriate, and consistent with the data used to compute the NAEI. Further, the DfT economist concluded that in this project **annual** costs and emission savings should be calculated (rather than costs or savings over vehicles' lifetimes). Therefore the methodology used in this project (to assess the cost effectiveness of an annual in-service emissions test) differs significantly from the CVTF calculations which were principally aimed at calculating the cost effectiveness of abatement devices fitted to specific vehicle types.

Principal conclusions reached by the review meeting that define the scope of this iteration of the cost effectiveness analysis are as follows:

Timescales

- 1) The cost effectiveness should be calculated on an annual basis, i.e. using annual emission savings for each year and annual cost (rather than over the vehicle or test equipment lifetime). This was to be done for representative years, e.g. 2000, 2005, 2010 and 2015.

Calculation of savings

- 1) Estimates of annual savings of pollutants should be based on
 - a) NAEI forecasts
 - b) an analysis of possible failure modes, their effect on emissions and their frequency.
- 2) Estimates of annual savings of pollutants should be broken down
 - a) into the 4 vehicle types (passenger cars, light-duty vans, HGVs and PSVs) noting particularly the proportion of the annual savings for the fractions of the fleet lighter and heavier than 3.5 tonnes,
 - b) by emission control technology for each vehicle type.
- 3) The fraction of the "savings potential" that would be realised from the estimated effectiveness of proposed I&M test programmes should be calculated.

Calculation of costs

- 1) Annual costs should be calculated (rather than costs over fleet lifetime).
- 2) Capital and setting up costs should be amortised over the period specified by VOSA.
- 3) The discount rate to be used is currently 3.5% (standard DfT/VOSA figure).
- 4) Vehicle testing time should be costed (as £/minute) at a rate to be obtained from VOSA.
- 5) Cost of repair to be calculated, but kept as a separate cost component.
- 6) The costs calculated should be those **incremental** to the current test programme.
- 7) Costs presented are in current year costs.

¹ Reference to report from Phase 1

² Reference to report from Phase 2

A5.1.1 SCOPE OF THIS ANALYSIS

The scope of the cost effectiveness analysis undertaken in Phase 2 was as below.

1. A range of possible test procedures were considered, ranging from continuing with the current unloaded procedure to using a loaded test on a dynamometer.
2. A number of possible vehicle technology scenarios were considered. Specifically, the alternatives that heavy-duty Euro 4 vehicle would either use traps, or would involve incremental changes to the current evolving technology to comply with lower PM emissions standards.
3. The analysis presumed that changes to the in-service emissions test would apply to all vehicles presented for testing.

Following the completion of Phase 2, discussions with VOSA and DfT concluded that for the testing of all vehicles (both light-duty and heavy-duty) only unloaded test procedures should be considered. This was because cost-effectiveness and practical considerations showed that on-the-road driving or loaded testing on a dynamometer, whilst having some advantages, were overall not viable options.

The number of vehicle scenarios considered in this analysis is reduced in-line with the latest views from OEMs regarding the technologies to be used to meet future emissions standards. In particular, this means that the technology assumed for PM abatement will be incremental changes to existing technology rather than the widespread fitting of particulate traps or filters.

The recent amendment to the EU directive on roadworthiness testing (Directive 2003/27/EC) introduces changes to pass/fail limits for FAS testing of Euro 4 vehicles, and those which meet later emissions standards. Consideration was given by the Commission to applying the tighter pass/fail limits to older vehicles, but negotiations concluded that retrospective application of limits should not occur. This is an important precedent that has been adopted across the European Community. Its implications within this project are that any changes to the in-service emissions test would **only apply to Euro 4, and later, vehicles.**

The impact of this change is not immediately apparent from the Tables in Appendix 5 of the Phase 2 report because the emissions listed, and the emissions savings potential derived from these, are not sub-divided by Euro standard. By way of illustration, the relative PM emissions from HGVs (rigids and artics) are given below in Table A5.1.

Table A5.1 Relative PM emissions from heavy-goods vehicles

Year	PM emissions from pre-Euro 4 vehicles	PM emissions from Euro 4, and later, vehicles
2005	6.08 ktonnes	0.00 ktonnes
2010	2.43 ktonnes	0.60 ktonnes
2015	0.47 ktonnes	1.13 ktonnes

These data highlight the large reduction in PM emissions predicted from Euro 4 and later vehicles, which is primarily a consequence of the five-fold reduction in the PM standards between Euro 3 and Euro 4 HDVs. Thus the PM emissions that might be saved from an improved emissions test that applies to Euro 4 and later vehicles only are correspondingly less than if an improved test were applied to the whole fleet.

A5.2 Scenarios considered

Tasks 2, 3 and 4 generated a list of technical options. Their cost effectiveness will be evaluated in this iteration of the cost effectiveness analysis.

For the in-service testing of PM emissions from light-duty vehicles the options identified were:

- Option PL1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.
- Option PL2: Further stepwise decrease in pass/fail limit that applies to all Euro 4 and later vehicles.
- Option PL3: Introduce vehicle specific pass/fail limits for each type of vehicle.
- Option PL4: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.
- Option PL5: Change from smoke meter to a more sensitive meter in conjunction with lower pass/fail limits.

For the in-service testing of PM emissions from heavy-duty vehicles the options identified were:

- Option PH1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.
- Option PH2: Cease emissions testing at the annual roadworthiness test.
- Option PH3: Further stepwise decrease in pass/fail limit that applies to all Euro 4 and later vehicles.
- Option PH4: Introduce vehicle specific pass/fail limits for each type of vehicle.
- Option PH5: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.
- Option PH6: Change from smoke meter to a more sensitive meter in conjunction with lower pass/fail limits.

For the in-service testing of NO_x emissions from light-duty vehicles the options identified were:

- Option N1: Change nothing – i.e. continue to test for smoke using the current free acceleration test with its pass/fail limits.
- Option N2: Adapt the current roadworthiness smoke test, as described in Option PL2 in Annex4 for PM testing of light-duty vehicles. Do not introduce an additional test procedure.
- Option N3: Introduce a new procedure, using 4-gas analysers and a 2 speed idle test that is the same for all vehicles fitted with EGR.
- Option N4: Using 4-gas analysers, introduce new procedures, based on a 2 speed idle test, that are vehicle type specific for all vehicle types fitted with EGR.
- Option N5: Using 4-gas analysers, introduce new procedures based on a changes at idle only, that are vehicle type specific and apply to most vehicle types fitted with EGR.

A5.3 Cost analysis

A5.3.1 GENERIC COST ANALYSIS

The costs involved with implementing the possible unloaded test regimes given in Section 2 of this appendix can be itemised to include³:

- 1a Setting up costs at test centres
 - 1.1 Purchase of the meters that meet the specification
 - 1.2 Cost of training the testers on the use of new meters and undertaking a new procedure.
- 1b Setting up costs incurred centrally by DfT and VOSA
 - 1.3 Organising, and obtaining agreement for, the setting of vehicle specific pass fail limits.
 - 1.4 Communicating the manufacturer defined vehicle specific pass/fail limits to test centres, incorporating these new limits into testing software.

These one-off costs should be depreciated over an appropriate term, enabling an annual cost of interest on capital expenditure and depreciation to be calculated.

- 2a Annual costs incurred by test centres
 - 2.1 Servicing of the meters
 - 2.2 Cost of refresher training for the testers.
 - 2.3 Insurance costs.
- 2b Annual costs incurred centrally by DfT and VOSA
 - 2.4 Revising the vehicle specific pass fail limits.
 - 2.5 Communicating the revised manufacturer defined vehicle specific pass/fail limits to test centres, incorporating these new limits into testing software.
- 3 Costs per test (all incurred by test centres)
 - 3.1 Time taken by tester to examine vehicle and report findings
 - 3.2 Cost of repair of failed vehicles by owners.

Tables A5.2 to A5.4 indicate the significant cost categories for the various options for PM testing of light-duty vehicles (Table A5.2), and heavy-duty vehicles (Table A5.3) and NO_x testing of light-duty vehicles (Table A5.4) relative to the current in-service test regime. Because the costs calculated are those incremental to the current test programme costs, the cost of items for Option 1 "Change nothing", are always zero. In the tables a "√" denotes that this cost category will be considered further in Sections A5.3.3 to A5.3.5, whereas a "X" denotes that incremental costs are believed to be zero or insignificant.

The letters TC after an item indicate that this cost will be incurred by the test centre, whereas the letter C indicates it will be borne centrally.

³ This list is a revised version of that used in the cost effectiveness analysis given in the Phase 2 report because options that involved the introduction of dynamometers are not included in this iteration.

Table A5.2 The significant generic cost categories for the incremental cost of various technical testing options for PM from light-duty vehicles

	Option PL1	Option PL2	Option PL3	Option PL4	Option PL5
1.1 Purchase of meters (TC)	X	X	X	X	√
1.2 Cost of training (TC)	X	X	X	X	√
1.3 Initial organising/agreeing system for setting of pass/fail limits (C)	X	√	√	√	X
1.4 Initial implementation of vehicle specific pass/fail limits at test centres (C)	X	√	√	√	X
2.1 Servicing of meters (TC)	X	X	X	X	√
2.2 Refresher training for testers (TC)	X	X	√	√	√
2.3 Insurance costs (TC)	X	X	X	X	√
2.4 Annual revision of pass/fail limits (C)	X	X	√	√	X
2.5 Annually updating test centres with revised pass/fail limits (C)	X	X	√	√	X
3.1 Time taken to do test (TC)	X	X	√	√	X
3.2 Cost of repair of failed vehicle	X	√	√	√	X

Table A5.3 The significance of generic cost categories on the incremental cost of various technical testing options for PM from heavy-duty cycles

	Option PH1	Option PH2	Option PH3	Option PH4	Option PH5	Option PH6
1.1 Purchase of meters (TC)	X	X	X	X	X	√
1.2 Cost of training (TC)	X	X	X	X	X	√
1.3 Initial organising/agreeing system for setting of pass/fail limits (C)	X	X	√	√	√	X
1.4 Initial implementation of vehicle specific pass/fail limits at test centres (C)	X	X	√	√	√	X
2.1 Servicing of meters (TC)	X	X	X	X	X	√
2.2 Refresher training for testers (TC)	X	X	X	√	√	√
2.3 Insurance costs (TC)	X	X	X	X	X	√
2.4 Annual revision of pass/fail limits (C)	X	X	X	√	√	X
2.5 Annually updating test centres with revised pass/fail limits (C)	X	X	X	√	√	X
3.1 Time taken to do test (TC)	X	√	X	√	√	X
3.2 Cost of repair of failed vehicle	X	√	√	√	√	X

Table A5.4 The significance of generic cost categories on the incremental cost of various technical testing options for NO_x light-duty vehicles

	Option N1	Option N2	Option N3	Option N4	Option N5
1.1 Purchase or adaptation of meters (TC)	X	X	√	√	√
1.2 Cost of training (TC)	X	X	√	√	√
1.3 Initial organising/agreeing system for setting of pass/fail limits (C)	X	(√)	√	√	√
1.4 Initial implementation of vehicle specific pass/fail limits at test centres (C)	X	(√)	X	√	√
2.1 Servicing of meters (TC)	X	X	X	X	X
2.2 Refresher training for testers (TC)	X	X	√	√	√
2.3 Insurance costs (TC)	X	X	X	X	X
2.4 Annual revision of pass/fail limits (C)	X	X	X	√	√
2.5 Annually updating test centres with revised pass/fail limits (C)	X	X	X	√	√
3.1 Time taken to do test (TC)	X	X	√	√	√
3.2 Cost of repair of failed vehicle	X	√	√	√	√

(√) denotes a significant incremental cost for this option **but** these are accounted for in the cost effectiveness calculations for PM, the pollutant principally reduced.

A5.3.2 ASSUMPTIONS USED IN CALCULATING COSTS

Some costs of changing a test programme are dependant on the number of test centres (and test lanes) whilst others depend on the number of vehicles tested. The values used in this cost effectiveness analysis for these parameters are as follows:

Parameter	Value	Source
Number of centres that can test light-duty diesel vehicles	15,000	VOSA ⁴
Number of VOSA test centres that can test heavy-duty diesel vehicles	91	VOSA ⁴
Average number of lanes per VOSA test centres	2.5	VOSA ⁴
Number of designated premises that test either HGVs and/or PSVs	355	VOSA ⁴
Average number of lanes per designated premises	1.0	VOSA ⁴
Number of vehicles in the fleet, sub-divided by Euro standard and vehicle type	see Tables A5.5 and A5.6	NAEI ⁵
Number of tests, sub-divided by Euro standard and vehicle type	see Tables A5.5 and A5.6	see text

⁴ Private communication with VOSA Testing Standards Policy and Strategy staff, November 2004

⁵ NAEI – the vehicle stock figures used here were taken from those within the NAEI database which were used to calculate the 2003 inventory, and the projections associated with this iteration of the NAEI calculation.

Time taken to test light-duty vehicle using FAS test	7 minutes	VOSA ⁴
Time taken to test heavy-duty vehicle using FAS test	4 minutes	VOSA ⁴
Time taken to test light-duty vehicle using catalyst emissions test	10 minutes	VOSA ⁴

Price of testing (fully overheaded) for centralised and de-centralised test stations and designated premises	£1.00 / minute	VOSA ⁴
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The vehicle stock numbers used for all vehicle classes were taken from the database used to calculate the NAEI for 2003 for DEFRA⁵. These are listed in Tables A5.5 and A5.6.

Table A5.5 Vehicle numbers and number of tests for light-duty vehicles

Vehicle numbers		2005	2010	2015
Passenger cars	pre-Euro 4	5,330,177	3,688,929	1,741,167
	Euro 4 and later	0	4,997,688	10,162,871
Light-duty vans	pre-Euro 4	2,422,769	1,531,819	603,786
	Euro 4 and later	0	1,283,768	2,456,216
TOTAL LDVs	pre-Euro 4	7,752,946	5,220,748	2,344,953
	Euro 4 and later	0	6,281,456	12,619,086
Total LD vehicles	all standards	7,752,946	11,502,204	14,964,039
Number of tests		2005	2010	2015
Passenger cars	pre-Euro 4	4,797,159	4,426,714	2,089,400
	Euro 4 and later	0	2,998,613	8,130,296
Light-duty vans	pre-Euro 4	2,180,492	1,838,183	724,543
	Euro 4 and later	0	770,261	1,964,972
TOTAL LDVs	pre-Euro 4	6,977,651	6,264,898	2,813,943
	Euro 4 and later	0	3,768,874	10,095,269
Total LD vehicles	all standards	6,977,651	10,033,772	12,909,212

Table A5.6 Vehicle numbers and number of tests for heavy-duty vehicles

Vehicle numbers		2005	2010	2015
Rigid HGVs	pre-Euro 4	303,920	176,436	57,723
	Euro 4 and later	0	114,282	220,245
Articulated HGVs	pre-Euro 4	123,040	63,363	14,428
	Euro 4 and later	0	64,105	115,086
Buses	pre-Euro 4	101,579	81,739	56,516
	Euro 4 and later	0	34,951	75,892
TOTAL HDVs	pre-Euro 4	528,538	321,538	128,667
	Euro 4 and later	0	213,337	411,223
Total HD vehicles	all standards	528,538	534,875	589,890
Number of tests		2005	2010	2015
Rigid HGVs	pre-Euro 4	319,116	185,257	60,609
	Euro 4 and later	0	119,996	231,257
Articulated HGVs	pre-Euro 4	129,192	66,531	15,149
	Euro 4 and later	0	67,311	120,841
Buses	pre-Euro 4	106,658	85,826	59,342
	Euro 4 and later	0	36,698	79,687
TOTAL HDVs	pre-Euro 4	554,965	337,615	135,100
	Euro 4 and later	0	224,004	431,784
Total HD vehicles	all standards	554,965	561,619	566,885

In the lower half of Tables 5 and 6 the number of tests associated with the different categories of vehicles are calculated.

When the NAO undertook an audit in 1998 they reported the number of light-duty diesel tests in the year⁶. This was 0.96 times the number of light-duty diesel vehicles. This number is less than the number of vehicles in the fleet because in-service testing only applies to vehicles that are at least 3 years old. However, the number of tests is greater than the number of vehicles that are at least 3 years old because some vehicles fail and have to be retested. Also, some vehicles less than 3 years old are tested, and some vehicles are tested more than once a year (for example, local authorities may require taxis to be tested more than once a year).

Since 1997 the growth in the number of diesel passenger cars sold has increased as a proportion of the total number of passenger cars sold. This increased penetration of diesel vehicles is predicted to continue and is therefore reflected in the significantly higher estimates for the number of diesel light-duty vehicles predicted to be in the fleet (from national forecasts) used in this work (Table A5.5) relative to those used in the previous iteration (see Table A5.1 on page 4 of Appendix 5 of the Phase 2 report). This growth in the diesel fleet has also led to a reduction in the average age of the diesel fleet and a reduction in the number of tests per vehicle.

Also, the number of vehicles failing the MOT emissions test has fallen as vehicles have become cleaner but the pass/fail limit for the FAS test has remained unchanged. This too has led to a reduction in the number of tests per vehicle.

Hence whilst the NAO data, as a ratio of the number of diesel vehicles in the fleet, gave a factor of 96% for the relative number of tests to the number of vehicles, the projections used here are for factors of 90% in 2005, 87% in 2010 and 86% in 2015.

The estimates for the numbers of tests for each Euro standard also takes into account the implementation date of the Euro 4 standard of 1/1/05 (for light-duty vehicles), such that in 2005 no Euro 4 vehicles are tested, whereas by the end of 2010 the oldest vehicles registered after 1/1/05 would be reaching 6 years old.

For heavy-duty vehicles the vehicle stock numbers used here were taken from the database used to calculate the NAEI for 2003 for DEFRA (i.e. were those current in November 2004). Vehicle test numbers are taken as 105% of vehicle stock numbers, the same figure that was used in the previous iterations of the cost effectiveness analysis^(1,2). It reflects the testing of heavy-duty vehicles annually from new, and the need to retest some vehicles which fail the annual roadworthiness (MOT) test.

A5.3.3 COSTS FOR INDIVIDUAL TECHNICAL OPTIONS FOR PM TESTING OF LIGHT-DUTY VEHICLES

Option PL1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.

The incremental cost for this option is nil because it is the current test regime.

⁶ See Figure 14 of "Vehicle emissions testing", NAO May 1999

The actual cost projected for 2005, 2010, and 2015 is primarily dependant on the number of vehicles to be tested and the cost per test (this ignores depreciation costs for the meters and some other minor costs). From the data in Section 3.2 the test costs are calculated to be (for all vehicles):

2005	2010	2015
£48,843,557	£70,236,397	£90,364,484

For Euro 4 (and later vehicles) only the test costs are calculated to be:

2005	2010	2015
£0	£5,653,311	£15,142,904

Option PL2: Further stepwise decrease in pass/fail limit that applies to all vehicles.

From Table A5.2 it is seen that the significant incremental costs occur for items 1.3 and 1.4 –the one-off costs incurred centrally by DfT/VOSA in setting the new lower limits and then implementing them. This is the activity that has been undertaken relatively recently with the adoption of European Directive 2003/27/EC, where the FAS limit has been reduced to 1.5 m⁻¹ for Euro 4 and later specification vehicles.

It is assumed that this change does not alter the time required to undertake each test relative to the current test programme. Consequently, there is no incremental cost directly associated with each test for this option.

The other incremental cost will be the consequence of failing more vehicles, namely an increased cost of repair by owners.

Option PL3: Introduce vehicle specific pass/fail limits for each type of vehicle.

As for Option PL2 it is anticipated that DfT/VOSA would incur significant costs in setting vehicle type specific pass/fail limits. These costs will be many times the equivalent ones for Option PL2 because this option will have to include:

- agreeing a methodology with OEMs for setting vehicle type specific pass/fail limits
- obtaining values for the pass/fail limit from OEMs for all vehicle types, and
- creating the associated data base for the meters used at the 15,000 decentralised diesel test stations.

Moreover, unlike option PL2 which would incur a one-off cost, this option would require each new vehicle type to have an associated pass/fail limit. Consequently, the database of pass/fail limits would need to be updated periodically, e.g. annually, and this too would lead to annual incremental costs.

The cost incurred would be that for staff time. If it is estimated that the implementation of Option PL3 requires 3 man years effort of VOSA and DfT staff across a range of grades (a figure that is believed to be a generous estimate) then this cost could be around £200,000. If this were amortised over 5 years it would be equivalent to £44,296 p.a. These figures are small in comparison with the costs of testing, see Option PL1. However, what is more likely to be a serious challenge would be finding the appropriate resources for undertaking this work.

In addition to these centrally borne costs, each test centre will need to have its testers appropriately trained. However, the precedent for vehicle type specific limits has already been set at the decentralised test stations for the testing of petrol fuelled vehicles fitted

with three-way catalysts. Consequently, the implementation of vehicle type specific limits is not anticipated to generate an insurmountable barrier with regard to the testers.

The time taken for each test is anticipated to be increased for this option because the tester would need to identify and enter the vehicle type to define the pass/fail limits appropriate. It is predicted that this will increase the test time by 1½ minutes per test. Consequently the **incremental** costs for this option are:

Year	2005	2010	2015
No of tests	0	3,768,874	10,095,269
Incremental cost	£0	£5,653,311	£15,142,904

Option PL4: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.

This option can be viewed as being somewhere between options PL2 and PL3. It is anticipated that the revised generic limits would be applicable to at least 75% of vehicle types. Consequently, only up to 25% of the vehicle types, rather than all types as for Option PL3, would need to be characterised, and hence the centrally incurred cost of introducing this option is anticipated to lie between that for Options PL2 and PL3.

For this option it is anticipated that the smoke meter will contain a database containing pass/fail limits for each vehicle type, as for Option PL3, but with the majority of pass/fail limits being the default values. However, this would, like Option PL3, require identifying the type of each vehicle presented for test, and entering the vehicle type into the meter. Consequently, it is assumed that this option too requires an additional 1½ minutes per test. This leads to incremental costs, per test, as for Option PL3, namely:

Year	2005	2010	2015
No of tests	0	3,768,874	10,095,269
Incremental cost	£0	£5,653,311	£15,142,904

Option PL5: Change from smoke meter to a more sensitive meter.

A further technical option would be to use a more sensitive meter in conjunction with lower pass/fail limits. (It would not be necessary to specify a more sensitive meter with the current 3.0 m⁻¹ and coming 1.5 m⁻¹ pass/fail limits because the current meters are appropriate for the measurement of these smoke densities.)

The significant generic cost categories listed in Table A5.2 are **for changing the meter alone**. It is assumed that the cost of an improved meter is in the £3,000 to £4,000 range, and that the cost of purchasing meters, having testers trained, servicing and insurance for the meters totals to £5,000, and is to be depreciated over 5 years. Hence the amortised cost for this option is taken as £1,107.4 /year. It is also assumed that each of the 15,000 decentralised diesel vehicle test stations would buy **one** meter.

Because it has been argued that testing to tighter limits will not start until 2008 it is presumed that the new meters are bought in 2008 and replaced in 2012. Consequently, the figures from Table A5.5 for the number of tests in 2010 and 2015 are taken as a reasonable mean for the number of tests that will occur over the meters' lifetimes.

The above assumptions lead to the following costs -

Year	2005	2010	2015
Amortised cost of meters per year	£0	£16,611,000	£16,611,000
No of tests / year	0	3,768,874	10,095,269
Incremental cost /test	£0	£4.41	£1.65

A5.3.4 COSTS FOR INDIVIDUAL TECHNICAL OPTIONS FOR PM TESTING OF HEAVY-DUTY VEHICLES

Many of the comments made regarding the testing options for light-duty vehicles apply equally to heavy-duty vehicles. Consequently this section is considerably briefer than the preceding section, and should be read in conjunction with it.

Option PH1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.

The incremental cost for this option is nil because it is the current test regime.

The actual cost projected for 2005, 2010, and 2015 is primarily dependant on the number of vehicles to be tested and the cost per test. From the data in Section 3.2 the test costs are calculated to be:

Year	2005	2010	2015
For all vehicles	£2,219,861	£2,246,476	£2,267,538
For Euro 4 (and later) vehicles	£0	£896,016	£1,727,136

Option PH2: Cease emissions testing at the annual roadworthiness test.

This option has a negative incremental cost, i.e. it costs less than the current scheme, by the amounts tabulated above, i.e.

Year	2005	2010	2015
For all vehicles	-£2,219,861	-£2,246,476	-£2,267,538
For Euro 4 (and later) vehicles	£0	-£896,016	-£1,727,136

A variant on this option would be not to test Euro 4 and later specification vehicles. For this option the savings would be:

Year	2005	2010	2015
No of tests	0	224,004	431,784
Incremental cost	£0	£896,016	£1,727,136

Option PH3: Further stepwise decrease in pass/fail limit that applies to all vehicles.

This option is the heavy-duty vehicle analogy to Option PL2. As for that option it is expected that it would be applied only to vehicles built to Euro 4 and later emissions standards, it would incur some costs within DfT/VOSA but that the actual test will cost no more than the current test programme. Consequently, there is no incremental cost directly associated with each test for this option.

If it is assumed that more vehicles fail the more stringent test that results from this option, then there will be an incremental cost of repair for owners.

Option PH4: Introduce vehicle specific pass/fail limits for each type of vehicle.

As for Option PL3 it is anticipated that this option would require the largest central setting up investment of all the six options proposed. However, it is anticipated that the size of this will be much less than for light-duty vehicles because:

- there are fewer “types” of heavy-duty vehicles relative to light-duty vehicles,
- the implementation would involve a much smaller number of test stations.

As for option PL3, whilst resourcing the implementation of this option may be a challenge, the actual cost when amortised over 5 years is small in the context of the overall costs of the emissions test for HDVs.

In addition to the cost of setting up the emissions limit database, it would require updating and maintaining. This would necessitate, for example, an annual cost to the central bodies.

The use of vehicle specific limits will also require an increased test time because of the need to identify the vehicle’s type and enter this into the test equipment. It is assumed that the increase in test time is 1½ minutes per test – the same as that required for the analogous change to the testing of light-duty vehicles. Consequently the incremental cost for each test should this option be adopted is:

Year	2005	2010	2015
No of tests	0	224,004	431,784
Incremental cost	£0	£336,006	£647,676

Option PH5: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.

This option is in between options PH3 and PH4. As for the equivalent light-duty option it is assumed that the generic limits apply to at least 75% of vehicles presented for testing. The comments made for Option PL4 apply here, and similarly the incremental cost, per test, that was calculated for the previous option also applies, i.e.

Year	2005	2010	2015
No of tests	0	224,004	431,784
Incremental cost	£0	£336,006	£647,676

Option PH6: Change from smoke meter to a more sensitive meter.

As was the case for Option PL5 only **incremental costs of changing the meter** are calculated here. Also, as for Option PL5, it is assumed:

- that the cost of purchasing, servicing and insuring meter, and the associated training of testers is £5,000 amortised over 5 years, and
- that the number of test for vehicles meeting Euro 4 and later emissions standards in 2010 and 2015 are a reasonable mean for the number of tests that will occur over the meter’s lifetime.

It is also assumed that **one** meter will be required for each lane at the 91 VOSA test centres and **one** meter for each of the 355 designated premises, making a total of 583 meters.

The above assumptions lead to the following costs:

Year	2005	2010	2015
Amortised cost of meters per year	£0	£645,614	£645,614
No of tests / year	0	224,004	431,784
Incremental cost /test	£0	£2.88	£1.50

A5.3.5 COSTS FOR INDIVIDUAL TECHNICAL OPTIONS FOR NO_x TESTING OF LIGHT-DUTY VEHICLES

Option N1: Change nothing – i.e. continue to test for smoke using the current free acceleration test with its pass/fail limits.

This option assumes no specific NO_x test is introduced. Instead some faulty EGR units are identified by the increase in smoke emissions from a FAS test.

Consequently, this option has no associated incremental cost, and no separate cost.

Option N2: Adapt the current roadworthiness smoke test, as described in Option PL2 in the Annex 4 for PM testing of light-duty vehicles. Do not introduce an additional test procedure.

In this option it is assumed that a tightening of the pass/fail limits for the FAS test occurs (as in Options PL2, PL3 or PL4) but no additional new test is introduced. The incremental costs are identical to those given for Options PL2, PL3 and PL4. As far as the testers are concerned the fact that the change in smoke limit delivers some NO_x benefit has no effect on the way they undertake the test (i.e. the NO_x benefit is secondary to the main driver for changing the test). Consequently, this test option leads to no incremental costs in its own right.

Option N3: Introduce a new procedure, using 4-gas analysers and a 2 speed idle test that is the same for all vehicles fitted with EGR.

In this and the three following options a new procedure is introduced. These will need defining, pass/fail limits will need to be defined, and the testers will need to be trained. The above are setting up costs that will be incurred centrally by DfT/VOSA.

In this and the following options it is assumed that the vehicles tested using the technical options are restricted to those built to Euro 4 or later emission standards. Hence the number of vehicles tested is the same as those used for options PL2, PL3, PL4 and PL5. (This assumption is the outcome of discussions between the contractor, DfT and VOSA at a project meeting.)

For this and the next two options the current 4-gas analyser will also need to be adapted. A discussion was held with the Applications Director of a large, well established MOT equipment manufacturer. This covered:

- the practicality of the proposed test procedures in terms of meters’ functionality,
- the changes that would need to be made to the hardware of current meters,
- the changes that would need to be made to the controlling software of the current meters,
- the costs involved with the above hardware and software changes,
- the costs involved with an annual upgrade of the vehicle type pass/fail limits and/or procedure, and for consumables.

The first important conclusion reached by these discussions was that **there is no fundamental technical barrier to implementing the ideas** proposed. From these discussions the following indicative costs have been derived:

- The initial cost of upgrading the current exhaust gas analyser units is £500 /meter (for hardware and software) which is amortised over 5 years.
- The annual costs of consumables (e.g. replacing additional filters) and of software upgrades, is £20 p.a.
- The sum of the above two items is £130.74 /meter/year

The two speed idle test is assumed to be similar to the current two speed emissions test currently used at the roadworthiness test for petrol fuelled vehicles fitted with three-way catalysts. Data from an audit undertaken by VOSA⁷ indicate the time taken for this test at the decentralised test centres is 10 minutes. This contains the following components:

- | | |
|---------------------------------|-------|
| • exhaust system leak check | 11.6% |
| • connect speed and oil senders | 7.9% |
| • raise oil temperature | 17.4% |
| • conduct tests | 39.4% |
| • remove and store meter | 3.6% |
| • set up/close down computer | 20.1% |

If the NO_x test outlined in this option was introduced in addition to, and immediately following the FAS test, then the exhaust system leak check and the raise oil temperature components would have already been counted/done, and the duration of activities under set up/close down computer will be significantly reduced. These changes are estimated, using VOSA’s data, to reduce the test time to 6½ minutes per test.

The above assumptions lead to the following costs -

Year	2005	2010	2015
<i>Costs associated with meter</i>			
Amortised cost of meters per year, plus annual running costs (£130.74 /meter)	£0	£1,961,100	£1,961,100

Costs associated with doing test

⁷ Private communication with VOSA, November 2004

No of tests / year	0	3,768,874	10,095,269
Incremental cost of testing £/year	£0	£24,497,681	£65,619,249
Total cost of this option	£0	£26,458,781	£67,580,349
Incremental cost /test	£0	£7.02	£6.69

Option N4: Using 4-gas analysers, introduce new procedures, based on a 2 speed idle test, that are vehicle type specific for all vehicle types fitted with EGR.

This option is an extension to Option N3 in that instead of having a test that is the same for all vehicles fitted with EGR there are variations for different vehicle types, e.g. in the engine speed used for the testing, and/or the gas concentrations used to distinguish between EGR units that are operating correctly and are defective. For this option it is assumed as below.

- The one off costs associated with the use of 4-gas EGAs are taken as the same as for Option N3.
- The annual costs associated with the use of these meters is increased to £100/meter for the annual upgrading of the vehicle type specific database.
- The time required per test is increased by 1½ minutes /test (as for Options PL3, PL4, PH4 and PH5 where the vehicle type needs to be entered into the test equipment too). Hence the time required per test is now 8 minutes /test.

These assumptions lead to the following costs:

Year	2005	2010	2015
<i>Costs associated with meter</i>			
Amortised cost of meters per year, plus annual running costs (£210.74 /meter)	£0	£3,161,100	£3,161,100
<i>Costs associated with doing test</i>			
No of tests / year	0	3,768,874	10,095,269
Incremental cost of testing £/year	£0	£30,150,992	£80,762,152
Total cost of this option	£0	£33,312,092	£83,923,252
Incremental cost /test	£0	£8.84	£8.31

In addition to these costs to the test stations, there would be some centrally borne costs associated with setting up the testing regime, see the three dot points under Option PL3.

Option N5: Using 4-gas analysers, introduce new procedures based on changes at idle only, that are vehicle type specific and apply to most vehicle types fitted with EGR.

This option is similar to Options N3 and N4 in that it requires the adaptation of the current 4-gas analysers. However, the test procedure is quite different, relying on an idle test rather than a two-speed unloaded test as for the preceding two options.

The cost associated with equipment are taken as identical to those for Option N4 because, as for that option, this option requires vehicle type specific information.

The time taken for the test is estimated to be 5 minutes – comprising 1½ minutes to identify the vehicle type and to enter this into the measurement equipment, and 3½ minutes completing the test. This is significantly less than the 6½ minutes found by VOSA for the two speed idle test used to test SI vehicles because of the simplicity of the test, and that it is only at normal idle.

Given these assumptions the costs for this option are:

Year	2005	2010	2015
<i>Costs associated with meter</i>			
Amortised cost of meters per year, plus annual running costs (£210.74 /meter)	£0	£3,161,100	£3,161,100
<i>Costs associated with doing test</i>			
No of tests / year	0	3,768,874	10,095,269
Incremental cost of testing £/year	£0	£18,844,370	£50,476,345
Total cost of this option	£0	£22,005,470	£53,637,445
Incremental cost /test	£0	£5.84	£5.31

A5.4 Effectiveness analysis

The key quantity to be identified is: What are the emissions savings delivered by, or expected from, a current, or proposed, test regime.

The strategy for answering this is as follows:

- Firstly, to calculate the excess emissions savings that a “perfect” test would deliver. This is known as the emissions savings potential.
- Secondly, to calculate the fraction of this “emissions savings potential” that various test regimes would be expected to deliver.

One advantage of this approach is that if it were found that the assumptions involved in making forecasts changed, then this could lead to a change in the emissions savings potential which feeds through to all testing options. Hence, whilst the absolute quantities of emissions saved does change, the relative merits of the various options remains broadly unaltered.

A5.4.1 CALCULATION OF EMISSION SAVINGS POTENTIALS FOR PM

A5.4.1.1 General methodology

Figure 1 gives a flow diagram for the inputs and steps involved in computing the emissions savings potential for PM.

The NAEI calculation assumes a 20% increase in PM emissions for each 80,000 km driven (referred to as the PM degradation rate) for vehicles built to Euro 3 and later emission standards. This takes into account the increasing PM emissions of an aging fleet when vehicles do receive appropriate maintenance and repair.

For vehicles that are not appropriately maintained and repaired **further** degradation occurs which is reversed when the vehicle is repaired and/or maintained. It is difficult to quantify this. The figure assumed in the cost effectiveness analyses undertaken in Phases 1 and 2 is that the quantity of these additional PM emissions is the same as the “accepted” rates of degradation, i.e. in the absence of repair and maintenance PM emissions increase twice as fast as actually occurs, when averaged over the whole fleet.

The next figure to be estimated is how much of this additional degradation is uncorrected at the time of the annual MOT test, i.e. what reduction in PM emissions would a “perfect” test generate? Discussions with OEMs and service and repair centres indicate that many faults that lead to excessive emissions have only a small effect on driveability. A vehicle with a serious fault that prevents it from being driven does not generate excess emissions.

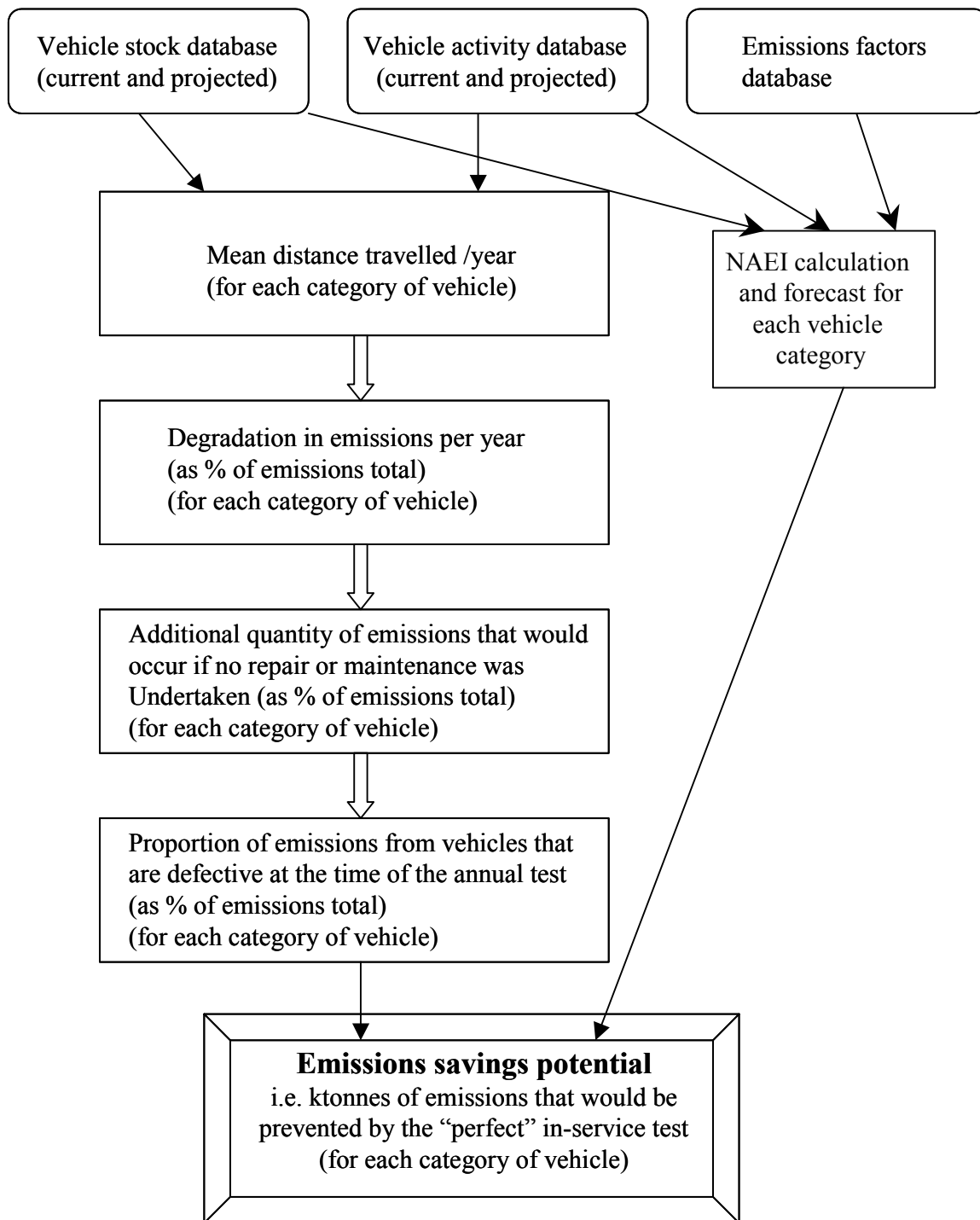


Figure 5.1 Flow diagram for the inputs and steps involved in estimating emissions savings potential for PM

The majority of light-duty vehicles are serviced just once a year. Some vehicles travelling higher than average mileages are serviced more frequently, and some owners neglect to have their vehicles serviced even annually. Servicing occurs at a mixture of OEM franchised garages and non-franchised, or independent, garages with a small proportion being undertaken by the vehicles’ owners or by “friends”. Hence it is estimated that at the time of the annual MOT test half of the group of vehicles that will develop faults in the year are faulty, generating excess emissions. Hence a perfect MOT

test would save 50% if the additional quantity of PM emissions that would occur in a year if no repair and maintenance occurred.

The situation is distinctly different for heavy-duty vehicles. Firstly, the majority, and it is an increasing majority, of inspection, servicing and repair of heavy-duty vehicles is undertaken by OEM franchised service and repair centres. Whilst there is virtually no "DIY" maintenance, some fleets do have their own in-house servicing and repair facilities. Secondly, heavy-duty vehicle owners require an operators licence, with the majority of vehicles being checked every six to eight weeks for safety related aspects. These inspections are additional to routine services, although they may occur during the same visit to the service and repair centres. However, discussions with some franchised service and repair centres showed that they routinely undertake a FAS test even at these inspections. Consequently, it is estimated that at the annual MOT test only 10% of the vehicles in the fleet that will develop faults in the year are faulty. Hence a perfect MOT test would save 10% of the additional quantity of PM emissions that would occur in a year if no repair and maintenance occurred.

A5.4.1.2 Quantification of emissions savings potential for PM

The NAEI forecasting calculation sub-divides diesel vehicles into 5 categories, listed in Tables A5.5 and A5.6. It has databases containing estimates of the numbers of vehicles in each category (further sub-divided by Euro class) and containing the number of vehicle kilometres driven. From these the average distance travelled by Euro 4 and later specification vehicles can be forecast for 2010 and 2015 for each of the five categories. These are listed in Table A5.7. From the average mileages data the degradation factor can be calculated, assuming 80,000 km leads to 20% degradation for all categories of vehicle. The far right hand column of Table A5.7 gives the rounded degradation values (based on the mean of the 2010 and 2015 figures). These are the values used to compute the emissions savings potential in this cost effectiveness analysis. (From Table A5.5 and A5.6 it is seen that no Euro 4 standard vehicles appear in the NAEI for 2005. Hence no data are provided for this year.)

It has been argued earlier that the additional quantity of emissions that would occur if no repair or maintenance was undertaken is equal to the "unavoidable" degradation, i.e. the values is the right hand column of Table A5.7.

Table A5.8 lists the PM emissions predicted from the NAEI calculation for 2005, 2010 and 2015 sub-divided into pre-Euro 4 and Euro 4 and later vehicles.

The proportion of these emissions that arise from vehicles that are defective at the time of the annual test, has been taken as 50% for light-duty vehicles and 10% for heavy-duty vehicles, respectively. Table A5.9 lists the PM emissions forecast by the NAEI for the

Table A5.7 Average mileages and corresponding PM emissions degradation for Euro 4 and later vehicles

	2005	2010		2015		Mean degradation factor
	average km/year	average km/year	degradation factor	average km/year	Degradation factor	
Passenger cars	0	13,781 km	3.45%	12,838 km	3.21%	3.50%
Light-duty vans	0	24,180 km	6.04%	24,879	6.22%	6.5%
Rigid HDVs	0	65,450 km	15.86%	58,244	14.56%	15.0%
Articulated HDVs	0	138,047 km	34.51%	140,217	35.05%	35.0%
Buses	0	48,590 km	12.15%	44,408	11.10%	12.0%

Table A5.8 PM Emissions predicted from NAEI calculation for some future years, sub-divided by vehicle type and emissions standard

	2005		2010		2015	
	pre-Euro 4 vehicles	Euro 4 and post-Euro 4 vehicles	pre-Euro 4 vehicles	Euro 4 and post-Euro 4 vehicles	pre-Euro 4 vehicles	Euro 4 and post-Euro 4 vehicles
Passenger cars	5.535 ktonnes	0.000 ktonnes	2.826 ktonnes	1.790 ktonnes	0.912 ktonnes	3.526 ktonnes
Light-duty vans	11.117 ktonnes	0.000 ktonnes	5.441 ktonnes	2.777 ktonnes	1.411 ktonnes	5.054 ktonnes
Rigid HDVs	1.988 ktonnes	0.000 ktonnes	0.817 ktonnes	0.146 ktonnes	0.191 ktonnes	0.285 ktonnes
Articulated HDVs	4.097 ktonnes	0.000 ktonnes	1.615 ktonnes	0.456 ktonnes	0.282 ktonnes	0.842 ktonnes
Buses	1.058 ktonnes	0.001 ktonnes	0.433 ktonnes	0.075 ktonnes	0.165 ktonnes	0.142 ktonnes
Total LDVs	16.652 ktonnes	0.000 ktonnes	8.267 ktonnes	4.568 ktonnes	2.323 ktonnes	8.580 ktonnes
Total HDVs	7.143 ktonnes	0.001 ktonnes	2.865 ktonnes	0.677 ktonnes	0.637 ktonnes	1.269 ktonnes
TOTAL	23.795 ktonnes	0.001 ktonnes	11.131 ktonnes	5.244 ktonnes	2.960 ktonnes	9.849 ktonnes

Table A5.9 PM emissions forecast by NAEI and resulting emissions savings potential for Euro 4 and later vehicles

	2010				2015			
	NAEI forecast (ktonnes)	Mean degradation factor	Proportion faulty at MOT test	Emissions savings potential (ktonnes)	NAEI forecast (ktonnes)	Mean degradation factor	Proportion faulty at MOT test	Emissions savings potential (ktonnes)
Passenger cars	1.790	3.5%	50%	0.0313	3.526	3.5%	50%	0.0617
Light-duty vans	2.777	6.5%	50%	0.0903	5.054	6.5%	50%	0.1643
Rigid HDVs	0.146	15%	10%	0.0022	0.285	15%	10%	0.0043
Articulated HDVs	0.456	35%	10%	0.0160	0.842	35%	10%	0.0295
Buses	0.075	12%	10%	0.0009	0.142	12%	10%	0.0017
Total LDVs				0.1216				0.2260
Total HDVs				0.0190				0.0355
TOTAL				0.141				0.261

various vehicle categories for vehicles built to meet Euro 4 or later emissions standards. The annual degradation factors and proportion of vehicles that are defective at the time of test are also tabulated, along with the resulting emissions savings potential, in ktonnes per year.

The emissions savings potential for light-duty vehicles in 2015 is similar to that calculated in the Phase 2 cost effectiveness calculation⁸, however, for 2010 the figure calculated in this iteration is much smaller because the Phase 2 value included contributions from the pre-Euro 4 vehicles. For heavy-duty vehicles the emissions savings potential calculated in this iteration is also less than that cited in the Phase 2 report, both because of the exclusion of pre-Euro 4 emissions and because of the lower proportion of vehicles that are predicted to be faulty at the time of test.

A5.4.2 CALCULATION OF PM EMISSIONS SAVED BY VARIOUS TESTING OPTIONS FOR LD VEHICLES

One generic issue is the relationship between the number of vehicles failed by a test and the proportion of all the emissions that these vehicles contribute. The Low Emission Diesels Project has not contained any modelling of emissions. Further, whilst the JCS survey⁹ contained graphs of % of total emissions/emissions rate (in g/km) and cumulative distributions against cumulative vehicle number for spark ignition vehicles fitted with three way catalysts, no comparable data was presented for PM emissions from diesel vehicles. However, borrowing knowledge from the parallel Spark Ignition in-service project, a log normal distribution is assumed for the PM distribution profile over the Type 1 drive cycle. Further it is assumed that the excess emissions come from the dirtiest 25% of the vehicles. This is taken as a distribution somewhere between the low variability found for CO₂, where 50% of the cumulative emissions are produced from 40% of the vehicles, and the high variability found for CO, where 50% of the cumulative emissions are produced from only 5% of the vehicles. This gives a distribution profile for the excess emissions as given in the table below:

Table A5.10 Relationship between cumulative vehicle number and PM emissions for LD vehicles

Cumulative vehicle number	0.25 %	1%	2.5%	5%	7.5%	10%	15%	20%	25%
Cumulative PM emissions	3.6%	10.5 %	20%	34%	46%	56%	74%	90%	100%

Whilst it is accepted that the correlation between the PM emissions over the loaded Type 1 test and the peak smoke density from the FAS test is very poor the data in Table A5.10 does show an important feature: detecting only the highest emitting 0.25% or 1.0% of vehicles leads to disproportionately higher savings, specifically 3.6% or 10.5% of the excess emissions.

⁸ See Table on page 21 of Appendix 5 of Phase 2 report

⁹ See figures 13 to 15 of the Joint Commission Study (A study on inspection of in-use cars by the EC DGs for Environment (DG XI) Transport (DG VII) and Energy (DG XVII), May 1998

Option PL1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.

Emissions savings generated by this option – Question directed to MOT testing stations, and our experience from this project, reported in Annex 4, indicate that the number of light-duty vehicles that fail the current MOT test is small. However, no quantitative assessment of this number was included in the work programme for this project for light-duty vehicles. The figure assumed is an average of 1.5% for pre-Euro 4 vehicles and 0.2% for Euro 4 and later specification vehicles. Interpolation of the data in Table A5.10 this will lead to a predicted emissions saving of 14.4% for pre-Euro 4 vehicles and 1.5% for later vehicles.

Table A5.11 lists the values assumed for:

- the mean degradation factors,
- the proportion of vehicles that are faulty at the time they are presented for testing,
- the fraction of these that are detected by the current test, and
- the resulting fraction of the excess emissions that are saved by the repair and maintenance of the vehicles identified.

From these assumptions, and the predictions from the NAEI calculations for PM emissions from the different classes of vehicles (by Euro standard) the emissions saved by the current test can be estimated. These are given in the three right-hand columns for 2005, 2010 and 2015 respectively.

It is against this baseline of detecting excess emitters that the efficacy of other testing options are compared.

It is anticipated that the advance warning of the lowering of the pass/fail limit as specified in Directive 2003/27/EC, which will be implemented from 2008 for Euro 4 and later specification vehicles, will mean that the lower limits will not cause a significant increase in the number of new vehicles that will fail the FAS test.

Errors of commission – Because of the relatively high pass/fail limits in use, and to be introduced for Euro 4 vehicles, for this option it is presumed that **no** vehicles fail the current test whilst their emissions remain below the standard for the Type 1 test, i.e. the number of errors of commission is 0%.

Option PL2: Further stepwise decrease in pass/fail limit that applies to all Euro 4 and later vehicles.

Emissions savings generated by this option – In this option it is assumed that the pass/fail limit is set at a low value so the (Euro 4) vehicle failure rate rises from 0.20% to 8.5%. This increases the emissions saved from 3.0% to 50% of that possible. From Table A5.9 this is 0.0608 ktonnes in 2010 and 0.1130 ktonnes in 2015 from Euro 4 and later emissions specification vehicles.

Errors of commission – The data in Figure A4.10 of Annex 4 of this report shows the correlation between PM emissions over a drive cycle and the peak smoke emissions during a FAS test. It shows how some vehicles in their well maintained state have FAS values very significantly above the mean. Consequently it is inevitable that a lowering of the FAS pass/fail limit that applies to all vehicles, that identifies more genuine excess emitters, will also identify vehicles whose PM emissions over the Type 1 cycle are acceptable.

Table A5.11 PM Emissions saved by current FAS test procedure from predicted from NAEI PM emissions, sub-divided by vehicle type and emissions standard

Vehicle type	Emissions standard	Mean degradation factor	Proportion faulty at MOT test	Fraction of faulty vehicles detected	Excess emissions from detected faulty vehicles	2005	2010	2015
Passenger cars	Euro 4 and later	3.5%	50%	0.2%	3.0%	0.0000	0.0005	0.0009
	Euro 2 & 3	3.5%	50%	1.5%	14.4%	0.0092	0.0007	0.0002
	pre-Euro 2	10.5%	50%	1.5%	14.4%	0.0141	0.0001	0.0000
Light-duty vans	Euro 4 and later	6.5%	50%	0.2%	3.0%	0.0000	0.0014	0.0025
	Euro 2 & 3	6.5%	50%	1.5%	14.4%	0.0393	0.0235	0.0065
	pre-Euro 2	19.5%	50%	1.5%	14.4%	0.0382	0.0001	0.0000
Total LDVs	Euro 4 and later					0.0000	0.0018	0.0034
	Euro 2 & 3					0.0485	0.0242	0.0067
	pre-Euro 2					0.0524	0.0002	0.0000
	All LDVs					0.1009	0.0262	0.0101
Rigid HDVs	Euro 4 and later	15%	10%	0.1%	6.2%	0.0000	0.0001	0.0003
	Euro 2 & 3	15%	10%	0.49%	20%	0.0046	0.0024	0.0006
	pre-Euro 2	45%	10%	3.46%	80%	0.0160	0.0006	0.0000
Articulated HDVs	Euro 4 and later	35%	10%	0.1%	6.2%	0.0000	0.0010	0.0018
	Euro 2 & 3	35%	10%	0.49%	20%	0.0259	0.0112	0.0020
	pre-Euro 2	105%	10%	3.46%	80%	0.0330	0.0017	0.0000
Buses	Euro 4 and later	12%	10%	0.1%	6.2%	0.0000	0.0001	0.0001
	Euro 2 & 3	12%	10%	0.49%	20%	0.0025	0.0007	0.0004
	pre-Euro 2	36%	10%	3.46%	80%	0.0174	0.0037	0.0004
Total HDVs	Euro 4 and later					0.0000	0.0012	0.0022
	Euro 2 & 3					0.0331	0.0143	0.0029
	pre-Euro 2					0.0664	0.0060	0.0004
	All HDVs					0.0995	0.0215	0.0055
TOTAL	all vehicles					0.2004	0.0477	0.0156

It is estimated that the number of errors of commission would be at least 1.5%, i.e. around 18% of the vehicles "identified" as requiring repair or maintenance actually do not.

Further, the data from Figure A4.10 of Annex 4, and from other experience, indicates that the 1.5% errors of commission will be predominantly for a relatively small number of models.

Option PL3: Introduce vehicle-type specific pass/fail limits for each type of vehicle.

The objective of using vehicle type specific pass/fail limits is to tailor the test to deliver greater emissions savings and not to incorrectly fail vehicles whose emissions are satisfactory.

Emissions savings generated by this option – It is presumed that the pass/fail limits for this option are set so that 10% of the fleet (as modelled) fail the test, i.e. 40% of all the "excess emitters". From Table A5.10 this will save 56% of the emissions savings potential. From Table A5.9 this is 0.0681 ktonnes PM in 2010 and 0.1265 ktonnes PM in 2015.

Errors of commission – It is presumed that the use of vehicle type specific pass/fail limits for the FAS test means that the likelihood of a vehicle failing the FAS test is approximately constant for all vehicle types. Consequently, despite this option generating higher a emissions reduction than Option PL2, the number of errors of commission is greatly reduced to around 0.1% of vehicles tested. This is 1% of the vehicles that fail the test.

Option PL4: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.

The objective of this option is to circumvent the necessity of generating pass/fail limits for all vehicle types. It would be the responsibility of manufacturers whose vehicles would repeatedly fail a universally applied lower pass/fail limit to declare higher, non-default values. Hence this option lies between Options PL2 and PL3.

Emissions savings generated by this option – It is presumed that the number of vehicles that fail the test, and the emissions saved by their repair and maintenance is that of option PL2, namely 8.5% of vehicles fail the test, and this will save 50% of the emissions savings potential (from Table A5.10). As for Option PL2, Table A5.9 indicates this is 0.0608 ktonnes of PM in 2010 and 0.1130 ktonnes in 2015.

Errors of commission – The opportunity for the manufacturers of vehicles whose FAS limits lie above the default value, even when new, to declare higher limits for these vehicle types is presumed to reduce the number of errors of commission to the value predicted for Option PL3, i.e. 0.1% of vehicles tested. For this option 0.1% represents 1.2% of the failing vehicles.

Option PL5: Change from smoke meter to a more sensitive meter.

Emissions savings generated by this option – This option differs from the previous three in that changing the smoke meter to a more sensitive one is not predicted, by itself, to

change the emissions saved. If implemented with Option PL2, 3, or 4 the incremental emissions savings discussed above would be realised.

Errors of commission – The benefit of improving the sensitivity of the meter is to improve both the accuracy and precision of the smoke measurement from the FAS test. Whilst this does not change the number of vehicles failed it does reduce the number of errors of commission for Options PL3 and PL4. This is because for vehicles that are close to, but really below, the pass/fail limit, the likelihood of the meter’s precision classing it as being above the limit, i.e. a fail, is reduced with improved sensitivity.

However, the above change does not reduce the overall number of vehicles that fail the test because the vehicles that are now classed as passes with the more sensitive meter are replaced by vehicles which were close to, but really above, the pass/fail limit and had previously been classed as a pass. With the improved meter precision these would now be correctly identified as a fail.

If the FAS pass/fail limit were in the range 0.25 – 1.5 m⁻¹, it is estimated that the reduction in the number of errors of commission could be as high as 25% of those indicated¹⁰. For Options PL3 and PL4, where the number of errors of commission had been estimated to be 0.1% of the vehicles tested this would reduce it to potentially 0.075% of the vehicles tested.

A5.4.3 CALCULATION OF PM EMISSIONS SAVED BY VARIOUS TESTING OPTIONS FOR HD VEHICLES

The generic issue of the relationship between the number of vehicles failed by various test options and the proportion of all the emissions that these vehicles contribute, which was considered at the start of Section A5.4.2, also requires addressing here too. For light-duty vehicles it was assumed that the excess emissions arose from the dirtiest 25% of vehicles. It was also explained why the proportion of “excess emissions” (i.e. those avoidable by I&M) arising from vehicles defective at the time of test was 50% for light-duty vehicles and 10% for heavy-duty vehicles. In keeping with this approach, for heavy-duty vehicles it is assumed that.

- the excess emissions due to vehicles defective at the time of testing arise from 5% of all heavy-duty vehicles presented for testing, and
- the relationship between the cumulative vehicle number and PM emissions for this 5% follows the same log form as for light-duty vehicles, with the relationship being tabulated in Table A5.12.

Table A5.12 Relationship between cumulative vehicle number and PM emissions for HD vehicles.

Cumulative vehicle number	0.05 %	0.2%	0.5%	1%	1.5%	2%	3%	4%	5%
Cumulative PM emissions	3.6%	10.5 %	20%	34%	46%	56%	74%	90%	100%

¹⁰ Based on +/- 0.07 m⁻¹ for three calibration filter readings, see Accuracy requirement specified in Annex 9 of the VOSA Smoke meter specification.

Option PH1: Change nothing – i.e. continue to test for smoke using the current free acceleration test, equipment and pass/fail limits, including the new lower limits to be introduced as described in EU Directive 2003/27/EC.

In contrast to the “change nothing” option for light-duty vehicles, Option PL1, a quantitative assessment of the pass/fail rates for the current test was undertaken in this work. This found failure rates as follows:

Pre Euro 1	Euro 1	Euro 2	Euro 3	All vehicles
5.39%	1.61%	0.72%	0.00%	1.38%

The weighted mean for the failure rate for pre-Euro 2 vehicles from the above is 3.46%, and the weighted mean for Euro 2 + Euro 3 vehicles was 0.49%. These are the values used in Table 11.

No Euro 3 vehicles failed the FAS test.

The type approval PM emissions standards are Euro 4 are a factor of 5 less than for Euro 3 (Directive 99/96/EC) whilst the pass/fail limit in the roadworthiness directive reduces by a factor of 2 (Directive 2003/23/EC). On the foundation of these facts, the failure rate for Euro 4 vehicles using the current, and agreed future, limits is taken as 0.1%.

The relationship between the number of vehicles which fail the FAS test and their excess PM emissions during on-the-road driving is taken from Table A5.12, and is transferred to Table A5.11.

The total HDV line of this detailed analysis in Table A5.11 quantifies the subjective opinion that the effectiveness of the current test diminishes for later technologies. (This is in addition to the reduction in the emissions savings potential caused by vehicles’ PM emissions reducing with later emissions standards.) Notwithstanding, the current test is, in 2004, still detecting some excess emitters, although this is predominantly vehicles using older technology.

To enable direct comparison with later options, the savings from the current test for Euro 4 and later vehicles is 0.0012 ktonnes PM in 2010 and 0.0022 ktonnes PM in 2015. However, it is noted that this data are based directly on the assumption that the future failure rate will be 0.1%, or 1 in 1,000 Euro 4 vehicles. If it fell to half this the above figures would be halved.

Errors of commission – Because of the relatively high pass/fail limited used, and proposed, for this option it is presumed that **no** vehicles fail the current test whilst their emissions remain below the type approval standard, i.e. the number of errors of commission is 0%.

Option PH2: Cease emissions testing at the annual roadworthiness test.

If this option were implemented then the emissions savings calculated above would cease to be realised.

Option PH3: Further stepwise decrease in pass/fail limit that applies to all vehicles.

The emissions savings and risks, in terms of errors of commission, are directly comparable to Option PL2 for the reasons given in Section A5.3.4

Emissions savings generated by this option – It is presumed that the revised pass/fail limits result in a vehicle failure rate of 1.7%, with the emissions saved rising to 50% of the emissions savings potential. From Table A5.9 this is 0.0095 ktonnes PM in 2010 and 0.0177 ktonnes PM in 2015.

Errors of commission – Following the arguments presented for Option PL2 it is estimated that the number of errors of commission would be around 1% of the vehicles tested in addition to the 1.7% genuine failure rate. This represents around 37% of the vehicles identified as “requiring” repair or maintenance. Data has also indicated that, as for the light-duty equivalent, these errors of commission will be predominantly from a relatively small number of vehicle make-model combinations.

Option PH4: Introduce vehicle specific pass/fail limits for each type of vehicle.

The objective of using vehicle type specific pass/fail limits is to tailor the test to deliver greater emissions savings and to not incorrectly fail vehicles whose emissions are satisfactory. The emissions saved and risks (errors of commission) for this option are directly comparable to Option PL3 for the reasons given in Section 3.4

Emissions savings generated by this option – It is presumed that the pass/fail limits for this option are set so that 2% of the fleet fail the test, i.e. 40% of the “excess emitters” and this will save 56% of the emissions savings potential. From Table A5.9 this is 0.0107 ktonnes PM in 2010 and 0.0199 ktonnes PM in 2015.

Errors of commission – As for Option PL3 i. It is presumed that the likelihood of a vehicle failing the FAS test is approximately constant for all vehicle types. Similarly, the number of errors of commission is predicted to fall from 1% to 0.04% of the vehicles tested. (This is calculated as 0.015% being due to vehicle-vehicle variability and 0.025% being due to imprecision from the meter.

Option PH5: Further stepwise decrease in generic pass/fail limit plus option that manufacturers can declare a higher value for vehicles that meet the type approval emissions specification in all other respects.

The objective of this option is to circumvent the necessity of generating pass/fail limits for all vehicle types by moving the onus on the declaration of vehicle types to those manufacturers whose vehicles would repeatedly fail a universally applied lower pass/fail limit. Hence this option lies between Options PH3 and PH4.

Emissions savings generated by this option – It was argued that the emissions savings for the analogous Option PL4 were the same as for Option PL2. Using an analogous argument it is presumed that the emissions savings for this option are the same as for Option PH3, namely 0.0095 ktonnes PM in 2010 and 0.0177 ktonnes PM in 2015.

Errors of commission – It was argued that the errors of commission for Option PL4 were the same as for Option PL3. By an analogous argument it is presumed that errors of

commission for Option PH5 will be the same as for Option PH4, namely it is predicted to fall from 1% to 0.04% of the vehicles tested.

Option PH6: Change from smoke meter to a more sensitive meter.

Emissions savings generated by this option – As for Option PL5, this option by itself is not predicted to change the emissions saved. If implemented with Option PH3, PH4 or PH5 the incremental emissions savings discussed above would be realised.

Errors of commission – It was argued regarding Option PL5 that if the FAS pass/fail limit were in the range 0.25 to 1.5 m⁻¹, the reduction in the errors of commissions could be as high as 0.025% of the vehicles tested, reducing the errors of commission for Options PL3 and PL4 from 0.10% to 0.075%. By the same argument increasing the smoke meters sensitivity could also reduce the error of commission for heavy-duty vehicles by 0.025% to 0.015%.

A5.4.4 CALCULATION OF EMISSION SAVINGS POTENTIALS FOR NO_x

Figure A5.2 shows the flow diagram used to compute the emissions savings potential for NO_x emissions from light-duty vehicles fitted with EGR units.

The number of new registrations of diesel cars and light-commercial vehicles (under 2000 kg) in 2002 was obtained from the SMMT. This gave a breakdown by make and model. From our knowledge of models, augmented by information obtained by contacting manufacturers it was established whether or not EGR units were fitted to specific models. The data from this survey are given in Table A5.13. This shows that >99.5% of vehicles were surveyed, of which only 0.06% (around 1 in 2,000 vehicles) was not fitted with EGR. Therefore, it was assumed that 100% of vehicles are fitted with EGR units in this cost effectiveness calculation. (The small error introduced by ignoring the vehicles not fitted with EGR is insignificant in the context of other assumptions made here.)

Table A5.13 Survey of fitting of EGR units to vehicles sold in 2002

	Fitted	not-fitted	Unknown	Sample size
Passenger cars	99.49%	0.04%	0.47%	602,623
Light-commercial vehicles	99.58%	0.18%	0.24%	71,010
TOTAL	99.50%	0.06%	0.45%	673,633

At the same time as manufacturers were contacted to establish the extent of use of EGR units amongst their models, their views were also sought on the reliability of these units in an attempt to quantify their rate of failure. The general comment from the majority of main dealer workshops contacted was "EGR systems are reliable and are one of the less common systems that they repair". One figure provided was that they comprise under 10% of all engine sensor faults.

Faults are mainly exhaust admittance valves sticking, caused by exhaust deposits being baked onto the operating mechanisms by the high exhaust temperatures. Occasional instances of failed electro-vacuum control valves (these enable signals from the ECU to

control the vacuum that is used to operate the exhaust admittance valve) are reported. Some model specific faults, e.g. the supply pipe bellows fracturing and water leaks with some cooled EGR systems were reported.

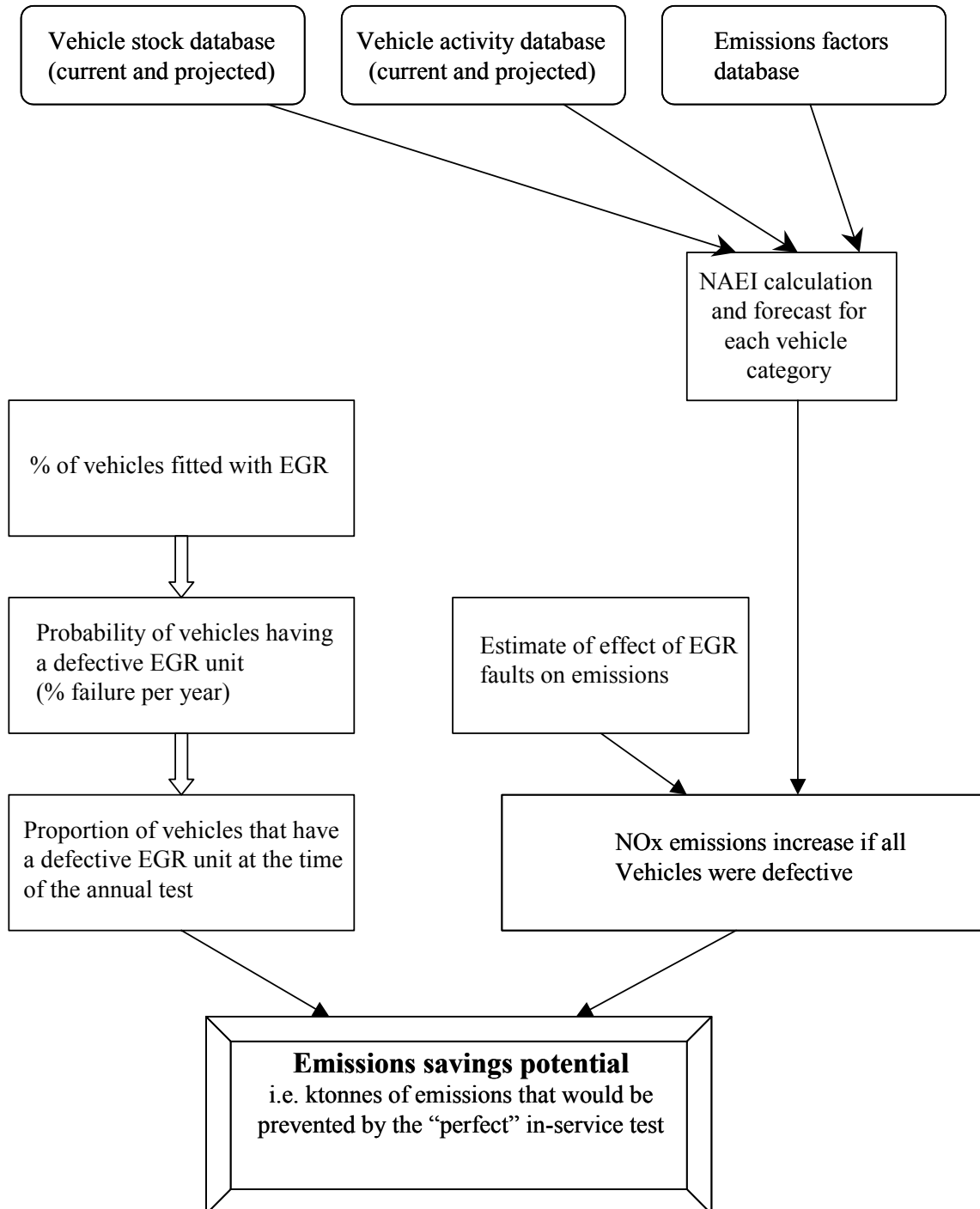


Figure A5.2 Flow diagram for the inputs and steps involved in estimating emissions savings potential for PM

Presuming the information that we were given was correct, and was not systematically distorted to protect commercial interests, there are a number of reasons as to why the true situation is extremely difficult to gauge.

- Routine servicing and maintenance does not check if the EGR system is working correctly: it is usually only investigated if it is believed to be faulty. Some vehicles are fitted with engine diagnostic systems which check some components of the EGR system, but some of these would not detect the most common fault of a sticking valve.
- Owners' tolerance – EGR faults do not generally lead to a major or rapid change in vehicle driveability characteristics. One vehicle seen during this project was severely lacking in power. However, the owner had not noticed the gradual deterioration in performance over time, and since he did not drive other vehicles, he did not have anything to compare its performance against.
- Owners I&M habits – when asking about whether EGR units were fitted to 2002 models we predominantly contacted main dealer workshops. The inspection and maintenance of vehicles under five years old, i.e. the younger vehicles in the fleet is predominantly undertaken by such workshops. However, older vehicles are often no longer owned by their original owner, and their inspection and maintenance is increasingly, with advancing age, undertaken by independent workshops.
- Motorist rescue services tend to be called out only to "no start" situations. However, they report being called out to some vehicles where the fault is diagnosed to a defective EGR unit, usually stuck wide open.
- So far the EGR system has been treated as a homogenous entity. In practice this is not the case because technology has evolved significantly over the past ten years. The newest engines use cooled EGR, incorporating a heat exchanger around the exhaust transfer pipe and using engine coolant to lower the temperature of the exhaust gas admitted to the inlet manifold. Thus the exhaust is cooled before it passes through the exhaust admittance valve, and so these units are anticipated to suffer less from sticking because of the lower operating temperatures. Also, newer engines are tending to use electrical rather than vacuum operated exhaust admittance valves. These are under the direct control of the ECU and tend to be continually moved (fluttering) with the quantity of EGR being varied by the overall time the valve is in the open position. Cooled EGR, besides being more effective for NO_x control, also reduces the thermal stress on these electrically controlled units. Further, because they are directly electrically controlled the ECU can better monitor their operation.

The cumulative effect of the factors listed above is that despite the contacts and discussions held, a reliable figure for the rate of failure of EGR units remains elusive. The assumptions used in this iteration of the cost effectiveness are:

- 1 in 4 diesel cars develops an EGR fault at sometime during its life, presumed to be 12.5 years. This gives a failure rate of 1 in 50 vehicle years, i.e. 2% per year.
- The average fault is undetected for a year, i.e. 2% of vehicles are defective at the time of testing.

The other important factor required to estimate the emissions savings potential for NO_x abatement from detecting faulty EGR units is the effect of the failure of an EGR system on the NO_x emissions for on-the-road driving. From Section 3.4 of Task 1 it was found that disabling the EGR unit in the shut position caused between 34% and 138% increase in NO_x emissions over the Type 1 test. The mean of the data collected was an 87% increase, and this is the figure used in this cost effectiveness analysis.

The EGR system can fail with the critical control valve in one of three states: fully open, fully closed or in some intermediate position. The excess emissions from these states

ranges from 0% to 87%. The relationship between these, and the fraction of the 2% failure rate that is apportioned to each of the three states are listed in Table A5.14.

Table A5.14 The excess NO_x emissions and fraction of fleet in the three EGR fault states

	Excess NO _x emissions	Fraction of fleet in this state	Excess NO _x emissions relative to whole fleet for this fault	Effect of fault on smoke emissions
EGR valve stuck fully open	0%	0.5%	0.00%	Large increase
EGR valve stuck fully closed	87%	0.5%	0.435%	No effect
EGR valve stuck fully open	intermediate ¹¹	1.0%	0.435%	intermediate increase
All vehicles with defective EGR		2.0%	0.87%	

Using these assumptions the excess NO_x emissions from all faulty vehicles can be calculated.

¹¹ Scales as X², where X = fraction open. Hence if a FAS test, detects 30% of the intermediate vehicles, selectively identifying those whose EGR units are the most open, rectification of this 30% would produce 9% (i.e. 30%²) of the excess emissions produced from all vehicles whose EGR units are stuck in an intermediate position.

Table A5.15 NAEI NO_x emissions forecasts and the resulting emissions savings potential for representative years

		2005		2010		2015	
		NAEI NO _x emissions forecast (ktonnes)	Resulting emissions savings potential (ktonnes)	NAEI NO _x emissions forecast (ktonnes)	Resulting emissions savings potential (ktonnes)	NAEI NO _x emissions forecast (ktonnes)	Resulting emissions savings potential (ktonnes)
Diesel cars	Pre-Euro 4	55.2	0.480	31.3	0.272	12.9	0.112
	Euro 4 and later	0.0	0.000	31.8	0.277	59.8	0.520
Light-goods vehicles	Pre-Euro 4	55.4	0.482	25.6	0.223	6.9	0.060
	Euro 4 and later	0.0	0.000	16.9	0.147	28.9	0.251
All vehicles	Pre-Euro 4	110.6	0.962	56.8	0.495	19.8	0.172
	Euro 4 and later	0.0	0.000	48.7	0.424	88.7	0.771
	All standards	110.6	0.962	105.6	0.918	108.4	0.943

A5.4.5 CALCULATION OF NO_x EMISSIONS SAVED BY VARIOUS TESTING OPTIONS FOR LD VEHICLES

In the preceding section the reduction in NO_x emissions that would arise from rectifying **all** vehicles with defective EGR units was calculated within the framework of the assumptions stated. In this section the fraction of this emissions savings potential that would be realised by the various test options will be calculated. **These calculations are based on the further assumption that it is only Euro 4 and vehicles with later emissions standards that are tested.**

Option N1: Change nothing – i.e. continue to test for smoke using the current free acceleration test with its pass/fail limits.

For this option it is assumed that the profile of all vehicles with faulty EGR units that are detected by the FAS test is as below.

	% faulty units identified	% of ESP saved
Vehicles with EGR units stuck fully open	100%	(0%)
Vehicles with EGR units stuck fully closed	0%	(0%)
Vehicles with EGR units stuck in an intermediate position	20%	(2%)
Total of all 3 above fault groups		(2%)

The bracketed figures on the far right-hand side are the percentage of the emissions savings potential that are saved by rectifying the identified malfunctioning vehicles.

Emissions saved by this option - Whilst all vehicles with their EGR units stuck fully open are identified, unfortunately with respect to NO_x emissions, their rectification does not reduce NO_x emissions. Identification of the 20% of vehicles with EGR units stuck nearly open only saves (20%)², i.e. 4%, of the emissions from this group. Because this group contribute 50% of the overall excess emissions, see Table A5.14, their rectification only saves 2% of all the excess emissions.

The emissions saved by this option are therefore estimated to be: 0.0085 ktonnes in 2010 and 0.0154 ktonnes in 2015.

Errors of commission – Because the FAS test is primarily designed to detect excess PM emitters, the fact that it generates some NO_x savings too does not change the number of errors of commission. Hence these NO_x savings are generated with there being **no** additional errors of commission.

Option N2: Adapt the current roadworthiness smoke test, as described in Option PL2 in Annex 4 for PM testing of light-duty vehicles. Do not introduce an additional test procedure.

Emissions saved by this option - For this option it is assumed that the lower pass/fail limit for the FAS test leads to 80% of vehicles whose EGR units are stuck in an intermediate position being identified. Again it is further assumed that these are vehicles whose EGR units are the more open. This leads to the assumed vehicle detection profile, and the resulting NO_x savings following rectification as given below.

	% faulty units identified	% of ESP saved
Vehicles with EGR units stuck fully open	100%	(0%)
Vehicles with EGR units stuck fully closed	0%	(0%)
Vehicles with EGR units stuck in an intermediate position	80%	(32%)
Total of all 3 above fault groups		(32%)

The emissions saved by this option are therefore estimated to be 16 times that from the previous option, namely: 0.136 ktonnes in 2010 and 0.247 ktonnes in 2015.

Errors of commission – As for Option N1, because the NO_x savings are in addition to the FAS tests primarily objective of detecting excess PM emitters, these NO_x savings are generated with there being **no** additional errors of commission.

Option N3: Introduce a new procedure, using 4-gas analysers and a 2 speed idle test that is the same for all vehicles fitted with EGR.

The 4-gas analyser diagnostic test proposed identifies the large majority of vehicles whose EGR units are stuck. Unlike the FAS test, research indicates that this approach would identify similar proportions of defective vehicles irrespective of the position their EGR unit is siezed in. One consequence of this is that for vehicles whose EGR units are stuck in an intermediate position the 95% detection rate is **randomly** distributed, i.e. not biased towards either end of the NO_x emission range. This would lead to the percentage of the emissions savings potential that is realised being 95%, rather than the square of this value as for Options N1 and N2.

Emissions saved by this option – Given the comments above, the detection profile for the different fault groups, and the resulting NO_x savings that would result from rectifying defective vehicles, are given below.

	% faulty units identified	% of ESP saved
Vehicles with EGR units stuck fully open	95%	(0%)
Vehicles with EGR units stuck fully closed	95%	(47.5%)
Vehicles with EGR units stuck in an intermediate position	95%	(47.5%)
Total of all 3 above fault groups		(95.0%)

In terms of the mass of NO_x saved, this is calculated from the data in Table A5.15 to be: 0.403 ktonnes in 2010 and 0.733 ktonnes in 2015.

Errors of commission – The principal drawback of the approach in this option is the relatively high number of vehicles that might incorrectly be labelled as faulty. The exact number would depend on the details of the test, but a figure of 1% of all vehicles tested appears to be a reasonable estimate consistent with identifying 95% of the failing vehicles. However, if the failing vehicles comprise 2% of the fleet then this would mean 1 in 3 failures would be an error of commission.

Option N4: Using 4-gas analysers, introduce new procedures, based on a 2 speed idle test, that are vehicle type specific for all vehicle types fitted with EGR.

This option involves combining a 4-gas diagnostic test with pass/fail limits that are set for each vehicle type.

Emissions saved by this option – The use of vehicle specific pass/fail limits would enable the better identification of faulty units. It is presumed this increases from 95% for the previous option to 98% for all fault groups for this option. This would lead to a predicted 98% of the emissions savings potential being realised, see below.

	% faulty units identified	% of ESP saved
Vehicles with EGR units stuck fully open	98%	(0%)
Vehicles with EGR units stuck fully closed	98%	(49.0%)
Vehicles with EGR units stuck in an intermediate position	98%	(49.0%)
Total of all 3 above fault groups		(98.0%)

In terms of the mass of NO_x saved, this is calculated from the data in Table A5.15 to be: 0.415 ktonnes in 2010 and 0.756 ktonnes in 2015.

Errors of commission – The use of vehicle specific pass/fail limits not only causes a modest improvement in the probability of detecting a faulty vehicle, but also a significant reduction in the number of vehicles incorrectly failed. It is presumed this number could be reduced to a quarter of that for the previous option, i.e. 0.5%.

Option N5: Using 4-gas analysers, introduce new procedures based on changes at idle only, that are vehicle type specific and apply to most vehicle types fitted with EGR.

This option is based on using a 4-gas analyser in conjunction with a simplified idle test rather than a two-speed idle test. It is presumed that this test successfully identifies 85% of all faulty vehicles, no matter what position the EGR is stuck in. The reason for the 85% detection rate is not because the detection rate is poor, this is presumed to be around 100%, but because this test approach is not applicable to all vehicles.

Emissions saved by this option – Given the assumptions above the savings are around 85% of the maximum possible, comprised as below:

	% faulty units identified	% of ESP saved
Vehicles with EGR units stuck fully open	85%	(0%)
Vehicles with EGR units stuck fully closed	85%	(42.5%)
Vehicles with EGR units stuck in an intermediate position	85%	(42.5%)
Total of all 3 above fault groups		(85.0%)

In terms of the mass of NO_x saved, this is calculated from the data in Table A5.15 to be: 0.360 ktonnes in 2010 and 0.656 ktonnes in 2015.

Errors of commission – The practical experience reported in Annex 1 showed that this procedure was both simple, and gave a good signal/noise ratio when the EGR turned on and off. Consequently, it is anticipated that this procedure gives the lowest number of errors of commission for Options N3, N4 and N5, estimated to be in the region 0.1 to 0.2%.

A5.5 Cost effectiveness calculations

This section involves collecting together the costs, as calculated in Section A5.3, and the effectiveness, as calculated in Section 4, for each of the options considered, and to divide one by the other. This gives the £ that need to be spent for each kg saved. (In this context smaller numbers are the more desirable.) The data are given in the following 3 tables for the cost effectiveness of PM savings from light-duty (Table A5.16) and heavy-duty (Table A5.17) vehicles and NO_x savings from light-duty vehicles (Table A5.18).

As discussed in the context of the effectiveness of various test options, in addition to the cost effectiveness the number of errors of commission are another key parameter in deciding the relative merits of test options. Therefore these figures are also included in the summarising tables.

A5.5.1 CONCLUSIONS REGARDING PM COST EFFECTIVENESS

Conclusion 1

The current test continues to provide some benefit for both heavy-duty and light-duty vehicles.

The cost effectiveness in 2005 for the “do nothing options” demonstrate how the current test continues to provide some benefit. For light-duty vehicles (Table A5.16) the figure is £484 /kg, whilst for heavy-duty vehicles (Table A5.17) the figure is £22.32 /kg.

Conclusion 2

The cost effectiveness of the current test is predicted to fall markedly in the future.

The cost effectiveness in 2015 for the “do nothing options”, however, shows a large deterioration in performance. This is calculated to be around £9,000 /kg for light-duty vehicles (Option PL1 in 2015 from Table A5.16) and around £415 /kg for heavy-duty vehicles (from Table A5.17) despite the lowering of the FAS pass/fail limit to 1.5 m⁻¹ for Euro 4 (and later) vehicles tested from 2008. Further, greater than 60% of the emissions saved in 2015 are forecast to come from the few remaining pre-Euro 4 vehicles. The cost effectiveness for Euro 4 (and later) vehicles is estimated to be around £21,000 /kg for light-duty vehicles and £800 /kg for heavy-duty vehicles.

On the positive side, the 3.0 and 1.5 m⁻¹ pass/fail limits are predicted not to fail any vehicles incorrectly.

Conclusion 3

Lowering pass/fail limits would improve cost effectiveness **but** at the risk of increasing the proportion of incorrectly failed vehicles by an amount which depends on the approach adopted.

Table A5.16 Cost effectiveness calculations for PM emissions from light-duty vehicles

Option	Vehicles tested	Costs	Savings (ktonnes)	Cost effectiveness £ / kg	Errors of commission
PM emissions from light-duty vehicles in 2005					
PL1 – change nothing	All vehicles	£48,843,557	0.1009	£484	0.0%
	Euro 4 only	£0	0.0	N/A	
	Incremental costs	N/A as this is the baseline case			
PM emissions from light-duty vehicles in 2010					
PL1 – change nothing	All vehicles	£70,236,397	0.0262	£2,684	0.0%
	Euro 4 only	£26,382,118	0.0018	£14,464	0.0%
	Incremental costs	N/A as this is the baseline case			
PL2 – Lower limit for all vehicles	Euro 4 only	£26,382,118	0.0608	£434	1.5%
	Incremental costs	£0	0.0590	N/A	1.5%
PL3 – Vehicle specific limits	Euro 4 only	£32,035,429	0.0681	£470	0.1%
	Incremental costs	£5,653,311	0.0663	£85.31	0.1%
PL4 – Lower default + Vehicle specific exemptions	Euro 4 only	£32,035,429	0.0608	£527	0.1%
	Incremental costs	£5,653,311	0.0590	£95.86	0.1%
PL5 – better meter + Option PL3	Euro 4 only	£48,646,429	0.0681	£714	0.075%
	Incremental costs	£16,611,000	0.0000	N/A	0.075%
PM emissions from light-duty vehicles in 2015					
PL1 – change nothing	All vehicles	£90,364,484	0.0101	£8,937	0.0%
	Euro 4 only	£70,666,883	0.0034	£20,850	0.0%
	Incremental costs	N/A as this is the baseline case			
PL2 – Lower limit for all vehicles	Euro 4 only	£70,666,883	0.1130	£625	1.5%
	Incremental costs	£0	0.1096	N/A	1.5%
PL3 – Vehicle specific limits	Euro 4 only	£85,809,787	0.1265	£678	0.1%
	Incremental costs	£15,142,904	0.1231	£123	0.1%
PL4 – Lower default + Vehicle specific exemptions	Euro 4 only	£85,809,787	0.1130	£760	0.1%
	Incremental costs	£15,142,904	0.1096	£138	0.1%
PL5 – better meter + Option PL3	Euro 4 only	£102,420,786	0.1265	£809	0.075%
	Incremental costs	£16,611,000	0.1231	N/A	0.075%

Table A5.17 Cost effectiveness calculations for PM emissions from heavy-duty vehicles

Option	Vehicles tested	Costs	Savings (ktonnes)	Cost effectiveness £ / kg	Errors of commission
PM emissions from heavy vehicles in 2005					
PH1- change nothing	All vehicles	£2,219,861	0.0994	£22.32	0.0%
	Euro 4 only	£0	0.0	N/A	
	Incremental costs	N/A as this is the baseline case			
PM emissions from heavy vehicles in2010					
PH1 - change nothing	All vehicles	£2,246,476	0.0215	£104.40	0.0%
	Euro 4 only	£896,016	0.0012	£758.90	0.0%
	Incremental costs	N/A as this is the baseline case			
PH2 - Cease testing Euro 4 vehicles	Euro 4 only	£0	0.0000	£434	0.0%
	Incremental costs	-£896,016	-0.0012	N/A	0.0%
PH3 - Lower limit for all vehicles	Euro 4 only	£896,016	0.0095	£94.10	1.0%
	Incremental costs	£0	0.0083	N/A	1.0%
PH4 - Vehicle specific limits	Euro 4 only	£1,232,022	0.0107	£115.53	0.04%
	Incremental costs	£336,006	0.0095	£35.43	0.04
PH5 - Lower default + Vehicle specific exemptions	Euro 4 only	£1,232,022	0.0095	£129.39	0.04%
	Incremental costs	£336,006	0.0083	£40.28	0.04
PH6 - better meter + Option PH4	Euro 4 only	£1,877,636	0.0107	£176.07	0.015%
	Incremental costs	£645,614	0.0000	N/A	0.015%
PM emissions from heavy vehicles in2015					
PH1 - change nothing	All vehicles	£2,267,538	0.0055	£412.73	0.0%
	Euro 4 only	£1,727,136	0.0022	£785.49	0.0%
	Incremental costs	N/A as this is the baseline case			
PH2 - Cease testing Euro 4 vehicles	Euro 4 only	£0	0.0000	£434	0.0%
	Incremental costs	-£1,727,136	-0.0022	N/A	0.0%
PH3 - Lower limit for all vehicles	Euro 4 only	£1,727,136	0.0177	£97.40	1.0%
	Incremental costs	£0	0.0155	N/A	1.0%
PH4 - Vehicle specific limits	Euro 4 only	£2,374,812	0.0199	£119.58	0.04%
	Incremental costs	£647,676	0.0177	£36.67	0.04
PH5 - Lower default + Vehicle specific exemptions	Euro 4 only	£2,374,812	0.0177	£133.93	0.04%
	Incremental costs	£647,676	0.0155	£41.70	0.04
PH6 - better meter + Option PH4	Euro 4 only	£3,020,426	0.0199	£152.09	0.015%
	Incremental costs	£645,614	0.0000	N/A	0.015%

Table A5.18 Cost effectiveness calculations for NO_x emissions from light-duty vehicles

Option	Vehicles tested	Costs	Savings (ktonnes)	Cost effectiveness £ / kg	Errors of commission
NO_x emissions from light-duty vehicles in 2005					
N1 – change nothing	All vehicles	£0	0.0192	N/A	N/A
	Euro 4 only	£0	0.0	N/A	N/A
	Incremental costs	N/A as this is the baseline case			
NO_x emissions from light-duty vehicles in 2010					
N1 – change nothing	All vehicles	£0	0.0184	N/A	N/A
	Euro 4 only	£0	0.0085	N/A	N/A
	Incremental costs	N/A as this is the baseline case			
N2 – Lower FAS limit	Euro 4 only	£0	0.1356	N/A	N/A
	Incremental costs	£0	0.1271	N/A	N/A
N3 – 4-gas analysers, 1 test for all	Euro 4 only	£26,458,781	0.4026	£65.72	2%
	Incremental costs	£26,458,781	0.3941	£67.13	2%
N4 – 4-gas analysers, vehicle specific procedure and limits	Euro 4 only	£33,312,092	0.4153	£80.20	0.5%
	Incremental costs	£33,312,092	0.4069	£81.08	0.5%
N5 – 4-gas analyser + low idle test	Euro 4 only	£22,005,470	0.3602	£61.09	0.15%
	Incremental costs	£22,005,470	0.3518	£62.56	0.15%
NO_x emissions from light-duty vehicles in 2015					
N1 – change nothing	All vehicles	£0	0.0189	N/A	N/A
	Euro 4 only	£0	0.0154	N/A	N/A
	Incremental costs	N/A as this is the baseline case			
N2 – Lower FAS limit	Euro 4 only	£0	0.2469	N/A	N/A
	Incremental costs	£0	0.2314	N/A	N/A
N3 – 4-gas analysers, 1 test for all	Euro 4 only	£67,580,348	0.7329	£92.21	2%
	Incremental costs	£67,580,348	0.7174	£94.20	2%
N4 – 4-gas analysers, vehicle specific procedure and limits	Euro 4 only	£83,923,252	0.7560	£111.01	0.5%
	Incremental costs	£83,923,252	0.7406	£113.32	0.5%
N5 – 4-gas analyser + low idle test	Euro 4 only	£53,637,445	0.6557	£81.80	0.15%
	Incremental costs	£53,637,445	0.6403	£83.77	0.15%

Three scenarios were considered for lowering FAS pass/fail limits:

- PL2 and PH3 apply a lower pass/fail limit that applies to all vehicles
- PL3 and PH4 apply lower pass/fail limits that are vehicle type specific, and
- PL4 and PH5 apply a lower default pass/fail limit + the option that manufacturers can declare higher limits for some vehicle types when appropriate.

The absolute cost effectiveness (rather than incremental) of these options follows:

PL4, PH5 > PL3, PH4 > PL2, PH3

i.e. options PL2 and PH3 are the more attractive. However, in terms of errors of commission the options follow

PL2, PH3 >> PL3, PH4 ~ PL4, PH5

i.e. options PL2 and PH3 are the least attractive.

The cost effectiveness of options PL2 and PH3 are around £650 /kg for light-duty vehicles (cf. £15,000 - £21,000 for the "do nothing option) and £125 /kg for heavy-duty vehicles (cf. £770 /kg for the equivalent "do nothing option).

The improvement in cost effectiveness caused by the introduction of lower limits for light-duty vehicles (around a factor of 27) is higher than for heavy-duty vehicles (around a factor of 6). This is principally because the fraction of vehicles anticipated to be faulty at the time of testing is predicted to be much lower for heavy-duty vehicles than for light-duty vehicles. Another way of expressing this difference is to appreciate that in 2015 the current (and planned) pass/fail limits identify few light-duty or heavy-duty vehicles. Lower limits are predicted to **significantly increase** the number of light-duty vehicles identified, but **increase by a smaller proportion** the number of heavy-duty vehicles identified because levels of maintenance, and compliance with Operator Licence conditions cause far fewer heavy-duty vehicles to be faulty and require rectification.

The cost effectiveness calculated here for light-duty vehicles, in absolute terms, is £430 /kg for a test delivering 50% of the emissions savings potential (ESP) in 2010 (£680 /kg in 2015) whereas the Phase 2 iteration gave values of £111/kg for a test delivering 50% of ESP in 2010 (£159/kg in 2015¹²). The principal difference between these two sets of figures is the consequence of this cost effectiveness calculation assuming a new test only applies to Euro 4 (and later) emissions standard vehicles.

In absolute terms for heavy-duty vehicles Phase 2 gave £1.09/kg in 2010 and £2.10/kg in 2015, whilst this Phase gives £94/kg in 2010 and £97/kg in 2015. The vast majority of this difference is because the PM emissions from Euro 4 vehicles are specified to be 5x cleaner than Euro 3 vehicles, which leads to a lower ESP. This is compounded by the argument that because of maintenance programmes, and complying with the Operator Licence the fraction proportion of vehicles faulty at time of test is taken as 10%.

Conclusion 4

Higher specification meters add cost but little benefit for **current** pass/fail limits.

The increased cost of opting for higher specification instrumentation does not generate increased emissions savings for the range of pass/fail limits likely. It does, however, reduce the number of vehicles incorrectly failed.

¹² taken from table A5.22 of Phase 2 report

A5.5.2 CONCLUSIONS REGARDING NO_x COST EFFECTIVENESS

Conclusion 5

The current FAS test leads to a small positive NO_x benefit.

Table A5.18 summarises the extent to which the current in-service FAS test produces a small NO_x emissions saving, although principally for PM control. This arises because the FAS test does detect some vehicles with EGR faults, even though these are at the lower end of the “excess NO_x emitter” range.

If it is viewed that the FAS test exists for other (PM) reasons then the cost of this test for NO_x abatement could be said to be £0. This would lead to a cost effectiveness of £0 required to achieve the small amount of NO_x emissions saved. This is potentially a misleading figure, and hence “Not applicable” is entered in the appropriate cells of Table A5.18.

Conclusion 6

The lowering of FAS limits is predicted to lead to further NO_x benefit.

Lowering the pass/fail limit for FAS testing is predicted to identify vehicles whose EGR valves are stuck over a wider range. Their rectification would directly lead to a higher emission saving.

Conclusion 7

A new test using a 4-gas analyser is possible and predicted to generate NO_x savings greater than 0.5 ktonnes/year in 2015.

It has been demonstrated that the functionality of EGR units can be assessed using a (slightly modified) 4-gas analyser. Testing options discussed in Annex 1 include:

- a) use a 2 engine-speed idle test + limits that apply to all vehicles,
- b) use a 2 engine-speed idle test + vehicle type specific limits, or
- c) use a low idle test.

The cost effectiveness calculated for these options are somewhat similar, around £70 ± £10 /kg in 2010 and £97 ± £15 /kg in 2015. Within these spreads the cost effectiveness of these options follow the order:

Option b > Option a > Option c i.e. Option c is the most attractive.

In terms of errors of commission these follow:

Option a > Option b > Option c i.e. Option c is the most attractive.

Conclusion 8

The unloaded idle test is the most attractive of the three options.

A5.6 Cost of repair

A5.6.1 FOR VEHICLES THAT FAIL THE FAS TEST

The cost of repair for light-duty vehicles can range from £0 to several thousands of pounds. The former is when a vehicle, typically a passenger car being tested at a local garage, only just fails the smoke test, often because of poor preconditioning of the exhaust system. After being driven using high engine speeds on a nearby road it passes the FAS test at the second attempt. In these cases the testing garage often subsumes the additional cost of the test at no additional cost to the owner. At the other end of the repair cost spectrum a very high mileage vehicle might require a new engine and fuel injector system (e.g. a taxi that has a high mileage and yet is quite young). The cost of these items and the labour required to fit then is estimated to be £4,000.

A weighted mean repair cost is calculated as outlined below.

% of failures	Repair	Cost	Weighted cost
30%	further preconditioning or minor adjustments,	£0	£0
59%	small repairs	£30	£17.70
10%	new injectors	£600	£60
1%	new engine and fuel injection system	£4,000	£40
	Average repair bill		£117.70

The £30 /vehicle small repair fee is an estimate of the **additional** average cost. Many vehicles could be rectified by having a routine service (albeit later than the manufacturers specify). This "late" service fee is viewed here as part of the expected normal cost of vehicle ownership, and consequently is not included in the £30. Averaged over all failures this gives an average repair bill of £117.70 per vehicle that fails the FAS test. Of the current rate of failure of the MOT emissions test is 1.5%, the figure used in Section 4.2, then this gives an average cost of £1.766 per vehicle tested.

The situation is different for heavy-duty vehicles because the test station does not undertake repair, and because generally the cost of parts is significantly higher than for light-duty vehicles. A similar analysis for these vehicles gave an estimate for the average repair bill for heavy-duty vehicles as £686, as detailed below.

% of failures	Repair	Cost	Weighted cost
89%	small repairs or minor adjustments,	£400	£356
10%	new injectors	£1,800	£180
1%	new engine and fuel injection system	£15,000	£150
	Average repair bill		£686

Given the average cost of repairing each vehicle that fails the test (estimated here) and the failure rates discussed earlier, the cost of repair for all the vehicles tested can be calculated as shown below for 2005.

Table 5.19 Estimate of cost of repair in 2005 for vehicles failing the annual roadworthiness emissions test

	No of tests (see Table 5)	Failure rate	No of fails	Av cost of repair	Cost of repair
Light-duty vehicles	6,977,651	1.5%	104,665	£117.7	£12.31 M
Heavy-duty vehicles	554,965	1.38%	7,659	£686	£5.25 M
TOTAL costs of repair					£17.56 M

For the various testing options the number of vehicles that are estimated to fail the test are given in the relevant part of Section A5.4.2 and A5.4.4. The overall repair cost for an option is simply:

For light-duty vehicles Number of vehicles tested x failure rate x£117.70, and
 For heavy-duty vehicles Number of vehicles tested x failure rate x£686.00,

where the forecasts of the numbers of vehicle tested are given in Table A5.5 and Table A5.6 for light- and heavy-duty vehicles, respectively.

A5.6.2 FOR VEHICLES THAT FAIL A NO_x EMISSIONS TEST

It was anticipated that the cost of repair for light-duty vehicles that fail a NO_x emissions test is easier to estimate than was the case for those that failed a FAS test because it is presumed that failure is only a consequence of a failed EGR unit.

However, discussions with a number of different garages revealed a range of different EGR unit complexities and costs (see discussion in Section A5.4.3). (More modern units tend to be more reliable but more expensive to rectify if they develop a fault). Hence an average cost of repair is taken as £80 /unit. The presumed 2% failure rate, and number of tests given in Table A5.5, when combined with the average repair figure, leads to overall costs of repair if all defective vehicles are identified of:

Year	2010	2015
Max cost of repair	£6,030,000	£16,150,000.