CASE STUDY 3

COMPARISON OF THE EU AND US EXPERIENCES WITH RESPECT TO CONTROLLING EMISSIONS FROM HIGH EMITTING VEHICLES

4 October 2004

1. INTRODUCTORY OVERVIEW

The major air pollutants emitted from road traffic - petrol and diesel vehicles - are nitrogen oxides, particles, hydrocarbons, carbon monoxide and different toxic substance, e.g. heavy metals and polycyclic hydrocarbons. Several measures have been taken in Europe as well as in the US, Canada, Japan and other countries to address these emissions. The measures included emissions limit values (discussed in case study 1 and 4) and improved fuel quality (discussed in case study 1 and 4). The emissions of pollutants from new vehicles have been reduced significantly within the last 20 years. The largest improvements were obtained through the introduction of three-way catalysts on petrol cars including lead free petrol, reduced sulphur in diesel and petrol fuel, engine technology and different methods (e.g. filters) to reduce particle emissions.

A small fraction of the car fleet accounts for a large share of the emissions in many countries. A number of approaches have been undertaken to address emissions from these "high emitting" vehicles. We considered two specific approaches—inspection and maintenance (I/M) and vehicle scrappage programmes.

2. COMPARISON OF THE TWO APPROACHES

Below we briefly describe the efforts of the EU-15 and US to address these high emitting vehicles through I/M and scrappage programmes. Greater details on the legislation adopted and regulation implemented in the EU-15 and US is discussed in Annex II and III, respectively, to this section.

2.1. EU

Member States are responsible to develop national regulations that meet the Roadworthiness Framework Directive. The Roadworthiness Framework Directive was first implemented in 1977 and updated several times, latest in 1996. The directive includes safety as well as air emissions, and covered in the first versions only commercial vehicles, but now also private vehicles. These programmes require compulsory vehicle inspection to ensure that the vehicle owner has done the necessary maintenance in order for the emission control system to function properly. Testing must be conducted at least every two years once the vehicle is four years old. Most Member States test more frequently.

The Roadworthiness Framework Directive has followed up with Directive 2000/30/EC on "The technical roadside inspection of the roadworthiness of commercial vehicles circulating in the Community", which gives possibilities for roadside inspections. The latest Directive 2003/26/EC of 3 April 2003 "adapting to technical progress Directive 2000/30/EC of the European Parliament and of the Council as regards speed limiters and exhaust emissions of commercial vehicles" include possibilities for use of OBD (On Board Diagnostic) as an alternative to the tests, provided a proper function of the OBD systems.

Petrol vehicles are tested for CO, HC and NO_x. Non-catalyst petrol vehicles are to be tested for the carbon monoxide content of their exhaust gases with limit values of either 3 or 4.5 percent, dependent on the vehicle's age or against more stringent reference values supplied by the industry. Petrol vehicles with three-way, lambda-controlled catalytic converters (TWC) were, from 1 January 1997, required to undergo a test for carbon monoxide content of the exhaust. The limit value, at 0.3 percent vol. CO is an order of magnitude more severe than for conventional petrol fuelled vehicles. Air/fuel ratio is also tested. The test of diesel vehicles include also particulates (smoke). A new directive from 2003 requires Member States to supplement the roadworthiness test for heavy commercial vehicles with roadside inspections.

Several countries within and outside Europe have implemented scrappage schemes during the 1990s. Incentives for scrapping old cars were given by Greece (1991-1993), Hungary (1993 up to the present) Denmark (1994-1995), Spain (1994 up to the present), France (1994-1996), Ireland (1995-1997), Norway (1996) and Italy (1997-1998). Two main types of scrappage schemes are used. The first type, cash for-for scrappage, gives a certain reward for any scrapped car, whatever the subsequent replacement decision taken by the consumer. The bonus is awarded even if a replacement vehicle older than the scrapped one is purchased, or if no other cars are bought to replace the scrapped one. The second type, the cash-for-replacement, gives a bonus conditional upon a specific kind of replacement (typically, but not necessarily, a new model car).

Other measures. Tax incentives have been successfully used in some countries related to passenger cars complying earlier with new more strict emission standards or with low fuel consumption, with both promoting the earlier shift to newer and less polluting cars. Low emission zones are established or under consideration in some larger cities promoting less polluting heavy duty vehicles.

2.2. US

Federal guidance has been provided on Enhanced I/M programmes; however, the states are given discretion in how the programme is implemented. The USEPA issued guidance in November 1992 on Enhanced I/M programmes. The Enhanced I/M regulations issued by EPA received a significant amount of protest from states with existing I/M programmes. As a result, EPA issued a revised regulation in September 1995—the Inspection/Maintenance Flexibility Amendments—that created a less stringent programme that allowed certain states flexibility in their programme implementation.

State by State I/M Approach. Since there are no required guidelines for designing enhanced I/M programmes under the Clean Air Act, the approaches that have been introduced vary by State and often by cities within the State. However, as a part of EPA's review of SIPs, the I/M programme in each area is subject to approval by EPA and subsequent sanctions for failure, see case study 2. EPA considers the I/M programme in Phoenix, Arizona as the model I/M program, noting that it "most closely resembles EPA recommended program". As such, the majority of analysis has considered the effectiveness of this programme. The programme in Phoenix, Arizona is a centralized biennial programme that uses IM240 testing for vehicles model year 1981 and newer that are under 3,856 kg gross vehicle weight. Older vehicles and all-wheel drive vehicles are subject to an idle test. Vehicles from the most recent two year period are exempt from testing.

Vehicle scrappage programmes have been implemented to a limited extent. The USEPA issued guidance in 1993 for those states interested in implementing an early vehicle retirement program; however, the programmes implemented have been limited in scope and duration as most have been pilot programmes. California included a "voluntary accelerated vehicle retirement" programme in its 1994 SIP for the South Coast. The programme aims to buy and scrap up to 75,000 light-duty vehicles per year for vehicles that are older than 15 years. The programme has yet to be fully funded and is currently under review within the state.

2.3. Comparison between I&M in Phoenix, Arizona, the EU, Japan

The key elements of the I&M programmes in the US, EU, Canada, and Japan are not directly comparable, but the main components are shown in Table 1 and Table 2 for the EU, Phoenix, Arizona in the US, and British Columbia in Canada. Further details and comparison, some of which is not possible to put into a table format, are discussed following the tables. Overall, it is difficult to compare the "cutpoint" values that determine whether a vehicle passes or fails. More important, however, is that the Phoenix and British Columbia programmes – which can be considered examples of "best practice" in North America – test for hydrocarbons and NO_x, which the EU tests effectively do not. Moreover, tests under these two programmes are closer to actual driving conditions.

Table 1 I&M Requirements in relation to age of the vehicles and frequency of Testing.

	EU		Phoenix, Arizona		British Columbia	
Vehicle Types	**First I&M**	**Frequency**	**First I&M**	**Frequency**	**First I&M**	**Frequency**
Cars<3500 kg and < 8 passengers	4 years	Every 2 years	4 years	Annual: 1967-80 Biennial: 1981+	3 years	Biennial: <1992 Annual: 1992+
Taxies and ambulances	1 year	Every year	4 years	Annual: 1967-80 Biennial: 1981+	3 years	Biennial: <1992 Annual: 1992+
Large vehicles	1 year	Every year	4 years	Annual: 1967-80 Biennial: 1981+	3 years	Biennial: <1992 Annual: 1992+

Note: The EU I&M programmes are developed to control safety as well as exhaust emissions.

Table 2. Testing Type and Requirements for I/M Programmes

Program	**Test Type**	**Cutpoints**		
		HC	**CO**	**NO_x**
EU				
Petrol TWC	CO idle		max 0.5%	
	CO (2000 rpm)		max 0.3	
Petrol non-TWC	CO idle		4.5/3.5 %	
Phoenix, Arizona				
LDGVs; LDGTs; HDGVs; MC	1981-95: IM147	0.5 g/km	7.4 g/km	1.2 g/km
	<1981: Loaded Idle	220 ppm	1.20%	
	1996+: OBD			
British Columbia Air Care: Phase II				
LDV, LDT, HDV	1992+: IM240	0.25 - 0.81 g/km	4.97 - 14.91 g/km	0.93 - 2.49 g/km
Passenger car	< 1991: ASM/Idle	85 - 446 ppm	0.50 - 9.50 %	761 - 7400 ppm
	< 1991: Idle	71 - 1076 ppm	0.37 -5.74 %	
Light-Duty Truck	< 1991: ASM/Idle	115 - 950 ppm	0.60 - 9.50 %	1005 - 7400 ppm
	< 1991: Idle	143 - 1076 ppm	0.74 -5.74 %	
Heavy-Duty Truck	< 1991: ASM/Idle	130 - 950 ppm	0.70 - 9.50 %	2000 - 7400 ppm
	< 1991: Idle	250 - 913 ppm		

Notes: LDGVs = light-duty gasoline vehicles; LDGTs = light-duty gasoline trucks; HDGVs = heavy-duty gasoline vehicles; MC = motorcycles; OBD = on-board diagnostic; HDV = heavy-duty vehicle. The AirCare programme varies rates by vehicle rate and age. It was impossible to show in this table all the variation in rates, thus ranges are shown. For more information on the rates, see: http://www.aircare.ca/pdfs/AirCareStandards.pdf. The EU I&M programs include the Lambda test (1+ 0.03) for petrol TWC vehicles, coefficient of absorption < 2.5/3 m-1 for diesel vehicles and visual inspection of emissions of all types of vehicles.

The EU I&M programme focuses on gasoline as well as diesel vehicles. Motorcycles are not included. The Phoenix program, on the other hand, includes gasoline vehicles and motorcycles. The Japanese programme requires inspection for passenger vehicles, as well as, motorcycles. Both the EU and Phoenix programmes include exhaust emissions tests as well as visual inspection related to emissions, e.g. gas caps. Both the EU and Phoenix programmes exempt cars that are less than four years old, while the British Columbia programme exempts cars that are 3 or fewer years old. The EU exempts taxies, ambulances, and large vehicles that are 1 year or less old, while the Phoenix programme exempts these vehicles until they are older than four years. The Japanese programme exempts cars less than three years from a "renewal inspection". The EU programme requires that cars be tested biennially and taxies, ambulances, and large vehicles are tested annually. The Phoenix programme requires biennial testing for all vehicles model year 1981 and older and annual testing for vehicles between model year 1967 and 1980. In Japan, cars are required to renew their inspection every two years. The regular mandatory tests in the EU have in recent years been supplemented with roadside inspections on commercial vehicles, including the same exhaust measurements and emission limits.

The main difference between the EU, Phoenix, and British Columbia programmes are the type of exhaust test. The tests in the EU take place under idle conditions or the so-called high idle condition (without load at 2000 rpm), and only CO is measured for gasoline vehicles and absorption coefficient (light absorption) for diesel vehicles. Tests can be supplemented or partly replaced by data from on-board diagnostic (OBD) systems. Stronger control, e.g. of diesel vehicles has been introduced in some EU countries, e.g. lower limits on the absorption coefficient related to the certification requirements of newer vehicles.

The testing procedure used in the Phoenix and British Columbia programmes varies by vehicle age. In the Phoenix program, vehicles older than 1981 are tested using a loaded idle, which is relatively similar to the EU 2000 rpm idle. Unlike the EU, the Phoenix programme uses a well-defined load and test conditions, on a dynamometer, for vehicles between 1981 and 1995. These later tests are more related to normal driving conditions and can potentially find deficiencies. Such tests also enable testing for NO_x, as is done in the Phoenix program, which is not often tested in idle programmes since NO_x emissions are usually low if the vehicle is not run under load. These programmes are more expensive than idle tests. OBD is also included in the US programmes for vehicles from 1996 and more recent years.

As a result of the differences in testing types used by the EU, compared with the Phoenix and British Columbia programmes, it is difficult to compare the stringency of the rates (i.e., the "cutpoints") at which the vehicles pass or fail the inspection. However, the major difference between the cutpoints in Phoenix, British Columbia, and the EU is which pollutants have defined rates. The EU does not have defined cutpoints for HC and NO_x. In contrast, the British Columbia programme has cutpoints for HC and NO_x for all vehicle ages and the Phoenix programme has HC cutpoints for all vehicles and NO_x cutpoints for vehicles older than 1980. In addition, the Phoenix and British Columbia testing procedures are more closely related to actual driving conditions. It should be noted, however, that they are more expensive.

3. ASSESSMENT OF EFFECTIVENESS OF I&M PROGRAMMES

It is difficult to fully assess the effectiveness of I/M programmes in the EU-15 and US since each programme has taken on a variety of forms due to national/state discretion on programme implementation. Therefore, we present assessments of the effectiveness that highlight estimates of the various programmes either as they have been estimated to be implemented or through analysis of the implementation of specific programmes.

3.1. Environmental effectiveness

In-use TWC cars in Europe have been found to have on average lower emissions than the legislated emission standards, even in the case of the 'biased' total sample of the study. Moreover, it was found that catalysts can exceed the 80 000 km durability requirements and live much longer; the causes of high emissions are confined to engine operation problems rather than the catalyst itself.

One analysis conducted in the EU concluded that the problem of high emitters seems to be less pronounced in Europe than in the US: observing the random test sample, 20 percent of the vehicles accounts for not more than 45 percent of CO and NO_x emissions and less in HC emissions (LAT et al 1998). Identification of high emitters can be achieved through CO measurement and in some cases through NO_x measurement; there are no HC-only gross polluters.

The potential in terms of emissions reduction in the EU of a properly operating I/M programme for TWC cars has been estimated on the basis of the test results to be in the order of 35 percent for CO, 25 percent for HC and 5 percent for NO_x. However, because of the somewhat 'biased' total sample, in real-world conditions this potential should be lower, probably less than half of the above.

The estimated emissions reductions of US state programmes that have been evaluated were 6 to 40 percent for NO_x, 14 to 68 percent for HC and 13 to 74 percent for CO (see *Table 2* in US case study) Since the Phoenix programme is considered a "model" programme it is useful to consider the results from evaluations that considered this programme. Emissions of vehicles before testing and after repair in the Phoenix programme have been found to be reduced by 7-29 percent for NO_x 15-37 percent for HC, and 15-36 percent for CO (Ando et al. 1999; Wenzel 2001).

The results varied significantly with vehicle type. Emissions reductions of NO_x in the Phoenix, Arizona programme were found to be the greatest from passenger cars (9 percent), with the smallest reductions (5 percent) from light-duty trucks between 2722 and 3856 kg gross vehicle weight. Further, several studies have found evidence of "disappearing vehicles"—vehicles that failed the test but are apparently never required to pass—and other studies have raised concern about the longevity of the repairs.

3.2. Cost-effectiveness

There are a number of costs that go into operating an I/M program, including: test or inspection cost, motorist costs (e.g., travel and queuing time), resource cost of repair (e.g., parts and labour), cost of re-inspection, fuel economy savings, administration costs, enforcement costs, and evaluation costs. The effectiveness depends also on the emission reduction potential and the percentage of vehicles repaired.

The cost of reductions has been estimated in some US states for HC and NO_x have been estimated to be 4 - 8 M$/ktonne compared to 4 – 90 M€/ktonnes in the EU (EEC,2000; EPA, 1992b; Harrington et al., 2000; California I/M Review Committee, 2000). In the Phoenix program, the costs have been estimated to be 4 M$/ktonne (Harrington et al., 2000). However, the estimates are extremely uncertain and depend on the car fleet, which is very different in the Northern and Southern parts of the EU. Several researchers have highlighted modifications to the programmes that could make them more cost-effective. For example, remote sensing has been considered in both regions as a more cost-effective methodology to identify high-emitters.

From a European study under AutoOil II (EEC, 2000) the following conclusions were drawn:

- For 1995 the current procedure according to 92/55/EEC proves to be a very cost-effective procedure.
- For countries with a continuing high share of non-catalyst cars this situation continues to be valid during the coming years.
- As soon as there is a high share of catalyst equipped cars in the fleet, dynamic testing over a short driving cycle turns out to be much more cost-effective, provided that such testing can be organised in a system with centralised inspection stations with a high throughput per testing lane.

- For diesel cars the present test and a dynamic test do have approximately the same effectiveness.
- The On Board Diagnostic (ODB) systems are considered to be an effective supplement or expansion of the Roadworthiness Framework Directive.

4. ASSESSMENT OF EFFECTIVENESS OF BUY-BACK/SCRAPPAGE SCHEMES

While no analysis has been conducted on all buy-back/scrappage programmes implemented, several studies have considered specific programmes. Since each of these programmes has been implemented in different ways and impacts vehicle fleets with differing characteristics, it is difficult to fully compare these separate programmes. Presented below are the results from several studies considered during the course of the project.

4.1. Environmental effectiveness

A number of concerns have been raised in both regions about the effectiveness of scrappage programmes in achieving emission reductions. Several key concerns are: (1) vehicles retired in the programme will be near their useful life and the programme will therefore have a limited impact on emissions; (2) older vehicles may migrate to other parts of the region as a result of the market response for vehicles; and (3) large price increases for all vintage vehicles could lead owners to extend the life of their vehicles by undertaking more maintenance on older vehicles (Dixon and Garber, 2001).

The scrappage programmes in the EU have found the highest emission reductions when they are implemented in relation to introduction of new technologies with significantly lower emissions, e.g. the TWC and particle filters. Old cars are not necessarily high-emitters.

The estimated emission reduction in e.g. the Danish scrappage scheme was estimated to be 0.6-1 percent with replacement of approximately 6 percent of the car fleet.

According to analysis conducted of a hypothetical California program, scrappage of 75,000 light-duty vehicles per year for vehicles that are older than 15 years would result in reductions of over 4 percent (Dixon and Garber, 2001). This programme aimed at reductions in the South Coast of California is estimated to yield benefits in the area and in the rest of California.

This analysis also found that the programme would lead to an in-migration of vehicles into the South Coast region due to the increase in vehicle prices in the region. Of the 750,000 cars scrapped over the period between 2001 -2010, 184,000 vehicles are predicted to be induced into the region since it is estimated that the programme will lead to an increase in price for used vehicles in the South Coast and therefore induce vehicle sales into the region.

4.2. Cost-effectiveness

The total cost of all existing programmes has not been estimated, but some pilot and ex-ante analyses have provided some information in the US. To a large extent, the costs of the programme depend on the price paid to buy/scrap the vehicle. The price depends on a variety of factors including the market dynamics in the given locale. Analysis of the estimated costs required to scrap 75,000 vehicles in California ranged from $400 to 965 per vehicle.[1] The estimated ex-ante cost of a proposed California scrappage programme was 2-30 M$/ktonnes (Sierra Research, 1995; Kavalec and Setiawan, 1997; CARB, 1998; Dixon and Garber, 2001). No estimates were found under the schemes analyzed in the EU.

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[1] CARB staff (2000) used ranges between $400 and 800 per vehicle. Econometric analysis conducted by Kavalec and Setiawan (1997) estimated a cost of $785 in 1999 and $965 in 2010.

5. CONCLUSIONS

A full comparative analysis between the two regions was limited due to a variety of factors. The I&M programme in the EU varies significantly from that in Phoenix, Arizona (the "model" US program) and British Columbia in Canada. Key differences include the type of vehicle focused upon (e.g., gasoline, diesel, and motorcycles), the frequency of the testing for different vehicles, the exhaust test types. Below we highlight several conclusions for the comparison that we were able to conduct.

- The Phoenix programme tests motorcycles, while the EU does not. Diesel vehicles are tested in the EU, but not in the Phoenix programme.

- The major difference between the EU and the Phoenix I&M programmes is the exhaust test types utilized. The tests in the EU takes place under idle conditions or the so-called high idle condition (without load at 2000 rpm), and only CO is measured for gasoline vehicles and absorption coefficient (light absorption) for diesel vehicles. The testing procedure used in the Phoenix programme varies by vehicle age. Vehicles older than 1981 are tested using a loaded idle, which is relatively similar to the EU 2000 rpm idle. Unlike the EU, the Phoenix programme uses a well-defined load and test conditions, on a dynamometer, for vehicles between 1981 and 1995.

- The US I&M programmes are probably more efficient and may disclose more gross polluters, because the test are performed under more realistic driving conditions, but the cost of the more advanced tests in the US is higher.

- Only a few studies were found that analyzed the various efforts to control emissions from "gross emitters". Many of these studies were aimed at analyzing the impacts of select programmes. While many of these studies considered the emissions reductions achieved by these programmes, few evaluated the cost-effectiveness of the programmes.

- Analysis in both regions has found that I&M programmes can have an impact on emissions reductions. The extent of this reduction and whether or not it is the most effective means to address "high-emitters" has been raised as a concern regarding the US programme. It is unclear from the analysis whether or not this is a concern in the EU.

- I&M policies have been found to be relatively cost-effective in some regions; however, there are a variety of design issues of concern that could influence the emissions reductions benefits and therefore the cost-effectiveness. One concern relates to vehicles that have failed emissions tests but continue to be used. Several analysts have highlighted improvements, such as the use of remote sensing, that could help improve the cost-effectiveness of these programmes.

- OBD system will probably be developed further in the future, when all vehicles will have electronic control of engine function. This can lead to better control of emissions and can be made more difficult to tamper.

- Limited analysis of the cost-effectiveness of the cash-for-scrappage programmes has been conducted. Given the limited analysis available and the need to compare these costs with other emissions reductions, it is difficult to determine the relative cost-effectiveness of these types of programmes

- The cash-for-scrappage programmes in the EU have been estimated to be more cost-effective than the cash-for-replacement programmes. These studies also concluded that small scale programmes are more cost-effective than the large programmes, especially if they are focussed on technology shifts.

- A variety of other economic incentives like tax instruments have been applied in Europe with some success, especially in the parts of Europe, where taxation is a normal economic instrument.

CASE STUDY 3 – ANNEX I

THE EU EXPERIENCE WITH RESPECT TO CONTROLLING EMISSIONS FROM HIGH EMITTING VEHICLES

4 October 2004

1. INTRODUCTION

1.1. Overview

This case study evaluates the efforts of various countries to address the problem of older, high-emission cars. We will focus on old cars, because the legislation and measures to control polluting emissions from new cars are rather well known and comparable in the USA and EU. The lifetime of cars often is more than 10 years.

Possible measures tried in various countries have included:

- maintenance and inspection requirements
- bans on cars over a certain age and buyback programmes (scrappage schemes)
- other measures

1.2. Emissions

Emissions of NO_x, CO, VOC and CO_2 from road transport based on model calculations (ForeMove/Copert, EEA, 2002) are shown in *Figure 1*.

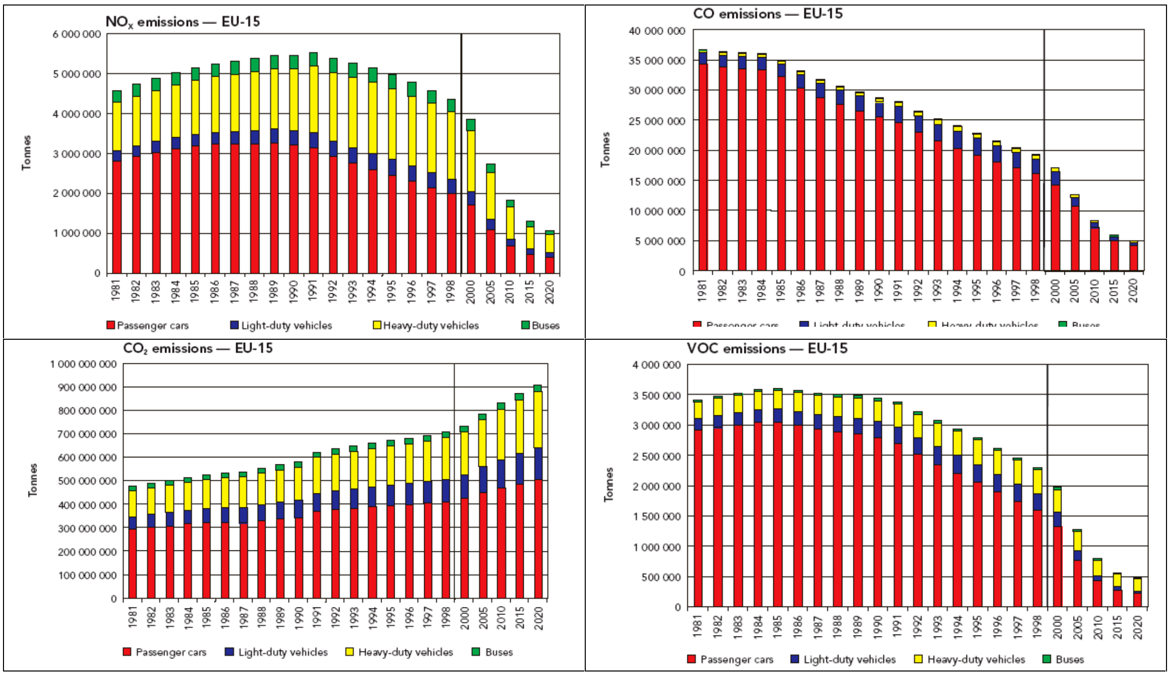


Figure 1 The emissions of NO_x, CO_2, CO and VOC from road transport for the year 1981-1998 and projections up to 2020 based on model calculations, (EEA, 2002).

A substantial decrease in emissions of air pollutants has taken place and is also projected up to 2010–20, while CO2 emissions are projected to increase — largely due to increasing passenger car transport. The reduction in NO_x emissions during 1980–98 is primarily due to the introduction of three-way catalysts in new petrol-engine cars. Changes in emissions from light duty vehicles and heavy duty vehicles are small, but generally can be said to have increased until 1998. The measures taken or planned seem to lead to further significant reductions for all types of vehicles.

The age of the passenger vehicle fleet is shown for the EU-15 countries in *Figure 2*. The number of vehicles is expected to continue to increase and the average age is around 8 years, but many vehicles are more than 10 years old. However, it is well known that a small fraction of the vehicles – e.g. 10% - are gross polluters on account of old technology, bad maintenance or tampered engines. They are not necessarily old cars.

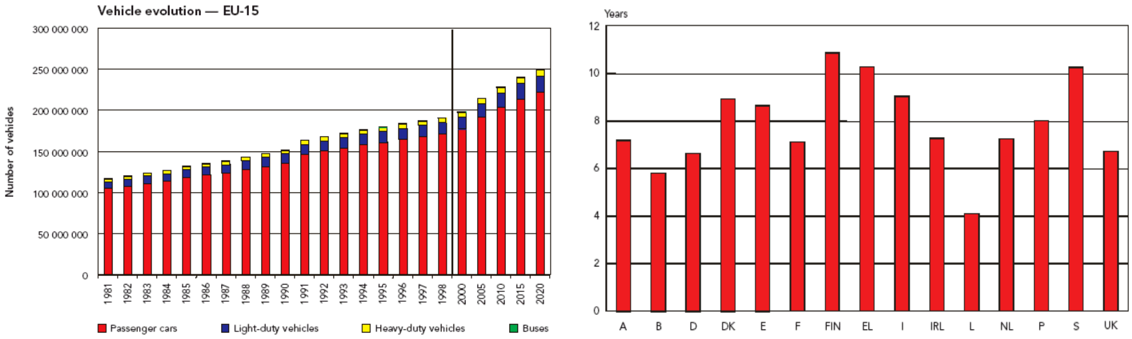


Figure 2 Number of vehicles in each category from 1981 to 2020 (left) and the mean age of the passenger car fleet in 1995 (right) for EU-15 (EEA, 2002).

2. THE LEGISLATION IMPLEMENTED AND MEASURES APPLIED

A long series of directives and other types of legislation in the EU regulate the emissions from new vehicles. The legislation on existing vehicles is more limited. However, initiatives have also been taken nationally.

2.1. Inspection and maintenance (I&M)

The Roadworthiness framework Directive (77/143/EEC) dates back some twenty years and originally only included trucks, buses, taxis and ambulances within its scope. The Directive included a list of items to be tested and inspected such as brakes and emissions but did not specify how these should be tested, nor the pass/failure criterion. Nevertheless, at the time, this Directive's requirements were new for several Member States. For others, it merely re-affirmed long established testing procedures.

Since 1977, the directive has been modified many times and now includes within its scope the inspection of cars and light vans and it also gives detailed requirements for the testing of vehicle brakes and exhaust emissions (Directive 92/55/EEC). The Roadworthiness framework Directive and all its amendments are covered in Directive 96/96/EC on "The approximation of the laws of the Member States relating to roadworthiness tests for motor vehicles and their trailers". It is the responsibility of the Member States to formulate the national regulations at least in accordance with the directive, which include compulsory inspection, i.e. in relation to emissions. The purpose of compulsory vehicle inspection is primarily to ensure that the vehicle owner has carried out the necessary maintenance in order for the emission control system to function properly. A periodic inspection includes all sorts of inspections and tests, not only for emissions. Along with the basic durability requirements, maintenance is of central importance to obtain the intended effect. The emission tests carried out as part of the vehicle inspection includes visual inspection of the emission control system, in order to check that the required, approved equipment are fitted to the vehicle.

Measurement of emissions include for example, for petrol fuelled vehicles, carbon monoxide and hydrocarbons at idle and high idle speed as well as the air/fuel-ratio (lambda value), and for diesel vehicles, smoke opacity at free acceleration.

The enhancement of existing I&M programmes may cause economic and environmental effects similar to those of scrappage incentives (see below). If the regulation introduces stricter environmental and safety standards for all cars and the I&M programmes manage to enforce them, there will be an increase in the average cost faced by owners to keep a vehicle in 'fair' working condition. This is likely to increase the costs of keeping an old vehicle compared to newer ones.

All private cars older than 4 years in Denmark have to be tested for emissions every two years. If they fail the test, they must be repaired to comply with the standards. The test is combined with safety tests. The obligatory test requirements for vans and HDV are stricter and start when cars reach 2 years old.

2.1.1. Passenger-cars and light goods vehicles

Passenger-car roadworthiness testing was introduced through Directive 91/338/EEC. The requirement to test passenger cars established the precedent that the community, in pursuing policies to improve the safety and environmental performance of vehicles on its roads, also needed to take account of privately owned vehicles. Up until this directive, roadworthiness testing at the Community level had only concerned commercial vehicles (and ambulances). Light goods vehicles were included within the scope of the Directive by Directive 88/449/EEC.

The minimum roadworthiness inspection frequency for light goods vehicles and passenger cars is every two years once the vehicle is four years old, but most Member States test more frequently.

2.1.2. The Scope of the Current Vehicle Emission Test Requirements—I&M Testing

Directive 92/55/EEC requires 'conventional' petrol engined vehicles to be tested for the carbon monoxide content of their exhaust gases with limit values of either 3.5% or 4.5%, dependent on the vehicle's age or against more stringent reference values supplied by the industry. Petrol vehicles with three-way, lambda-controlled catalytic converters (TWC) were, from 1 January 1997, required to undergo a test for carbon monoxide content of the exhaust. The limit value, at 0.3% vol. CO is an order of magnitude more severe than for conventional petrol engined vehicles. Air/fuel ratio is also tested. Diesel vehicles need to be tested for the opacity of the generated exhaust smoke during a transient, 'free acceleration' engine test where the engine is accelerated against its own inertia. The test became mandatory from 1 January1996.

2.1.3. Random Roadside inspections

Directive 2003/26/EC requires Member States to supplement the annual roadworthiness test for heavy commercial vehicles with targeted, unannounced roadside inspections of both the vehicle's safety and environmental performance. Vehicles that are not roadworthy as a result of a random inspection, wherever they are registered may be prohibited from free circulation. The diesel smoke opacity check of Directive 96/96/EC is used as the standard for the inspection's environmental performance. This proposal results from the first Auto-Oil programme.

2.2. Fleet renewal and scrappage schemes

Several countries within and outside Europe have implemented scrappage schemes during the 1990s. Incentives for scrapping old cars were given by Greece (1991-1993), Hungary (1993 up to the present) Denmark (1994-1995), Spain (1994 up to the present), France (1994-1996), Ireland (1995-1997), Norway (1996) and Italy (1997-1998).

The main objectives of the schemes have usually been listed as follows:

- Stimulation of the national car industry and the national economy by boosting new car purchases.

- Improvement of transport safety by introducing newer, safer vehicles.
- Reduction of car exhaust emissions.

A report was prepared for the "European Conference of Ministers of Transport" (ECMT, 1999). In the present case study only the environmental issue related to the schemes is examined. The economic goal of stimulating the national car industry was only mentioned by those countries with a large national vehicle manufacturing industry, but it is not treated in the present report.

Two main types of scrappage schemes are used. The first type gives a certain reward for any scrapped car, whatever the subsequent replacement decision taken by the consumer. The bonus is awarded even if a replacement vehicle older than the scrapped one is purchased, or if no other cars are bought to replace the scrapped one. The second type gives a bonus conditional upon a specific kind of replacement (typically, but not necessarily, a new model car). The first one leaves the possibility for the consumer to choose other means of transport (public transport, motorcycles, bicycles, etc.), while the second one constrains the consumer to replace his vehicle with another one, within a given timeframe. The two groups of scrappage programmes are referred to as cash-for-scrappage and cash-for-replacement schemes.

The introduction of a scrappage incentive will have substantial effects on the market, i.e. increasing sales, while the scheme is working. However, the characteristics of the cars sold under the two kinds of programmes will be different. Moreover, the time pattern of the increase in sales is also likely to be quite different.

2.3. Other measures

A tax incentive was successfully used in Germany by reforming the annual vehicle taxation in July 1997. The changes introduced by the German government granted tax credits for passenger cars complying with EURO3 and EURO4 and simultaneously increased the tax paid by non-catalysed vehicles. This has considerably accelerated the vehicles replacement rate and favoured the introduction of cleaner vehicles. Another similar example is the Hungarian government's introduction of policy measures. In this case, the tax burden on older vehicles was not increased in absolute terms, but taxes were considerably reduced for cleaner vehicles, thereby encouraging the purchasing of 'greener' cars and the replacements of old, 'dirty' vehicles. A similar system exists in Denmark, where the tax is lower for "greener" cars, but related to fuel consumption and type (petrol or diesel).

From the environmental point of view, another alternative to scrappage schemes may be given by retrofitting programmes. These can either be mandatory or implemented through economic incentives (subsidies, tax credits, etc.). Mandatory programmes will raise the cost of holding old, non-catalyzed vehicles. Voluntary, incentive-driven, retrofit programmes will involve different changes. In general, the cost of retrofitting a vehicle is considerably lower than the cost of replacing it with a cleaner, newer car. Scrappage schemes and retrofitting programmes should target two different categories of vehicles. The first should be directed at older cars in relatively poor condition that could not run for many km with well-working retrofitting devices. Retrofitting could be more efficiently directed at relatively newer vehicles with better maintenance conditions.

Low emission zones are established or considered in several large urban areas, e.g. Berlin and Copenhagen. The requirements can lead to earlier replacement of older vehicles and is especially related to heavy duty vehicles. The experience is still limited.

Before being admitted the EU, Sweden introduced stringent limits for all vehicle classes, i.e. to meet the conformity guarantees, as in US legislation. Since 1996, the biggest cities have restricted the types of heavy duty vehicles, which can enter the city centres to those conforming to the EURO 2 standards, those which are less than 8 years old and older vehicles retrofitted with equipment to reduce emissions (CONCAWE, 2002).

Random in-use conformity tests are performed on a number of vehicle types every year. This is intended to check whether the manufacturer is still supplying products that comply with the approved design regarding both construction and performance. The Swedish Environmental Protection Agency is responsible for the tests. A few vehicles are borrowed from the owners to represent a vehicle model. Vehicles that have been in service for about 3-4 years are tested. If a vehicle model fails, the manufacturer will face sanctions, ultimately having to recall all the vehicles belonging to that particular model for modification of malfunctions in the emission control system. For example, catalysts have been replaced.

A warranty for emission related deficiencies must be issued to the customer for every new vehicle offered for sale in Sweden. It means that the manufacturer must repair any deficiency in the emission-control system of any vehicles he has sold, or intends to sell, discovered at periodic vehicle inspection by the authorities. For passenger cars, this applies for the first five years or up to a maximum of 80 000 km.

3. ASSESSMENT OF EFFECTIVENESS – I&M

3.1. Environmental effectiveness

The aim of a Working Group under Auto-oil II was to examine the potential of periodic I&M programmes to reduce, in a cost-effective manner, pollutant emissions. The work done for the Commission Services team (Joint Commission Services (JCS) study on In-Use Vehicle Emissions—LAT et al 1998) formed the main basis for the analysis.

The principal focus of the joint study was on the testing of catalyst equipped cars built to the Euro 1 standard (i.e. in conformity with Directive 91/441/EEC). Whilst conventional spark-ignition and diesel cars were also covered by the study, work on other motor vehicles, in particular heavy commercial vehicles, was conducted in parallel. The joint study reviewed all short tests that have been used for in-use passenger car testing. The performance of these short tests was evaluated in terms of their ability to identify high emitting cars (i.e. vehicles emitting more than 50% above the emission standards) and the results compared with emission levels measured according to both European legislated and real-world driving cycles. The study examined whether emission measurements under load were better at identifying high emitting cars than measurements at idle speed for petrol engined cars, especially those with a three way catalyst (TWC), or via the free acceleration test (FAS) for diesels. For each particular solution, its cost (covering installation and operation) and effectiveness in reducing actual and future emissions of the fleet were quantified.

The main conclusions were:

Three-way Catalyst (TWC) equipped vehicles. In-use TWC cars in Europe have been found to have on average lower emissions than the legislated emission standards, even in the case of the 'biased' total sample of the study. Moreover, it was found that catalysts can exceed the 80 000 km durability requirements and live much longer; the causes of high emissions are confined to engine operation problems rather than the catalyst itself.

The problem of high emitters seems to be less pronounced in Europe than in the United States: observing the random test sample, 20% of the vehicles accounts for not more than 45% of CO and NO_x emissions and less in HC emissions. Identification of high emitters can be achieved through CO measurement and in some cases through NO_x measurement; there are no HC-only gross polluters.

The potential in terms of emissions reduction of a properly operating I/M programme for TWC cars has been estimated on the basis of the test results to be in the order of 35% for CO, 25% for HC and 5% for NO_x. However, because of the somewhat 'biased' total sample, in real-world conditions this potential should be lower, probably less than half of the above.

Non-catalyst and oxidation catalyst equipped vehicles. For these cars the test requirements of the current Directive were found to be very effective with, for example, the potential to achieve a 15% reduction in CO emissions. However, reducing the CO cut-point from the currently legislated 3.5% to 1.5% (or alternatively testing against manufacturers' reference values) should bring further gains.

Diesel vehicles. The present regulated free acceleration test and the dynamic tests had approximately the same environmental effectiveness, i.e. emission reduction potential of about 25% in PM for all short tests. However, due to a high number of errors of commission (vehicles wrongly identified as faulty) the additional cost of unnecessary repair made the FAS test method much more costly and therefore less cost-effective. Furthermore, assuming that attention increasingly focuses on ultra-fine particles and that the introduction of after-treatment devices eliminates visible smoke, opacity measurement may become obsolete. Work being done by the International Motor Vehicle Inspection Committee (CITA), on behalf of DG Transport will establish testing techniques and measurement methods for low emission diesel engines, i.e. in order to measure PM.

Remote Sensing. Remote sensing has a number of advantages over conventional test methods: it can measure the emissions from a very large number of vehicles, measurements can be made without any inconvenience to the vehicle driver, and a fully automated system would allow measurements to be performed with little man-power effort.

3.2. Cost-effectiveness

In EEC, 2000 the conclusion is drawn that up till recently the procedure set out in Directive 92/55/EC in the European Union was very cost-effective. For countries that continue to have a high share of non-catalyst cars this will be the situation during the coming years. Conversely, as soon as there is a high share of TWC cars in the fleet, dynamic testing over a short driving cycle becomes more cost-effective, provided that such testing can be organised in a system with centralised inspection stations and a high throughput per testing lane.

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

The cost-effectiveness, as an example, was calculated for the Netherlands (a typical north European country with a large share of TWC equipped cars), and compared with Greece (a typical south European country, with continuing high share of non-TWC cars). The total emissions potentially avoided by application of different I&M systems.

Table 1 The potential emission avoided of pollutants per year (ktonnes) (EEC, 2000)

	CO	VOC	NO_x	PM
92/55/EEC	30.6	2.66	4.40	0.40
Static	28.5	2.43	3.15	
Dynamic ra	29.7	2.24	2.20	0.40
Dynamic me	36.0	2.48	5.02	

The potential cost effectiveness is obtained by dividing the total cost of inspection and maintenance by the potential amount of pollutant avoided. No attempt has been made to share the costs over the different pollutants, since this would require a weighting of the importance of the different pollutants, which is not available. On the other hand, simply sharing the cost over the cumulative amount of ktonnes avoided, irrespective of the pollutant, would relate the cost-effectiveness mainly to the amount of CO avoided, since this is numerically the largest amount, although not necessarily the most important effect. The resulting figure represents the amount of MEURO/ktonne that would apply, if the measures were exclusively taken to avoid that particular pollutant, with the following condition: the cost-effectiveness of the abatement of CO, HC and NOx has been exclusively related to the costs of I/M for Otto engined vehicles. The costs of the abatement of PM have been exclusively related to the I/M costs of diesel engined vehicles. It should be noted, however, that the inspection cost of the diesel vehicle in the dynamic test is based on a high use of that test equipment (10 000 vehicles per year per lane). In practice that would mean that this cost is only realistic if the same equipment is also used for the inspection of Otto engined cars! The resulting cost-effectiveness is given in *Table 2*.
The figures relate to the potential effectiveness and therefore represent only a potential cost-effectiveness. In actual fact it should not be assumed that all vehicles are repaired to the point that their emissions represent the average of the non-identified cars.

Table 2 Cost-effectiveness calculations for the Netherlands, 1995, (EEC, 2000).

	I&M system	ktonnes avoided	MEURO/ktonnes	% repaired
CO	92/55/EEC	30.63	4.51	37.8
Otto only	Static	28.53	3.91	24.3
	Dynamic ra	29.74	6.81	53.7
	Dynamic me	35.99	4.96	41.6
VOC	92/55/EEC	2.66	51.87	37.8
Otto only	Static	2.43	45.92	24.3
	Dynamic ra	2.24	90.28	53.7
	Dynamic me	2.46	71.81	41.6
NO_x	92/55/EEC	4.40	31.41	37.8
Otto only	Static	3.15	35.37	24.3
	Dynamic ra	2.20	91.94	53.7
	Dynamic me	5.02	35.58	41.6
PM	92/55/EEC	0.40	32.44	26.1
Diesel only	Dynamic ra	0.40	20.03	8.7

- Comparisons with calculations for Greece showed the I&M system based on Directive 92/55/EEC is still more cost effective because there are more non-TWC cars.
- From the study the following conclusions were drawn:
- For 1995 the current procedure according to 92/55/EEC proves to be a very cost-effective procedure.
- For countries with a continuing high share of non-catalyst cars this situation continues to be valid during the coming years.
- As soon as there is a high share of catalyst equipped cars in the fleet, dynamic testing over a short driving cycle turns out to be much more cost-effective, provided that such testing can be organised in a system with centralized inspection stations with a high throughput per testing lane.
- For diesel cars the present test and a dynamic test do have approximately the same effectiveness.

4. ASSESSMENT OF EFFECTIVENESS OF SCRAPPING SCHEMES

4.1. Schemes in European countries

Greece was the first European country to introduce scrappage schemes, from January 1991 to March 1993. The first scheme was applied in the Athens area with the purpose of accelerating the introduction of catalyzed cars and improving air quality in the region. A 40-60% reduction in the excise duty on new cars was given as a bonus to anybody purchasing a new model, conditional upon the scrappage of a car older than ten years. Other reductions in car registration taxes and road charges were given outside the scrappage scheme, to anybody who purchased new cars equipped with catalytic devices. The scrappage programme was then extended to the whole of Greece. Both programmes expired in 1993.

Hungary. In September 1993 the city of Budapest in Hungary introduced a programme directed at eliminating the many old, two-stroke-engine cars and vans still in use (Trabant, Wartburg, Barkas models). Owners of a two-stroke-engine car who scrapped and replaced it with one of five new environmentally friendly models chosen by the government, were eligible for a bonus of Ft 100 000 (about US$ 500). As an alternative option, they could obtain a one-year, free pass for themselves and their families on the public transportation network in Budapest if they did not replace their old car. The program, which is still operating, was later extended to the whole of Hungary. In this case, incentives were awarded to the owners through car dealers and/or scrap operators, provided that they managed to purchase and scrap a minimum number of 200 two-stroke-engine cars per year. Scrappage incentives have also been given for replacing old buses and trucks (or their engines) with cleaner ones.

Denmark introduced at the beginning of 1994 a DKr 6 500 bonus (875 EUR) for anybody who scrapped a car older than ten years, independently of the choice of replacement vehicle. The scheme lasted until the end of June 1995. The size of the incentive given progressively decreased (every six months). An overwhelming majority of vehicles were scrapped in the first six months: about 100 000 cars, slightly more than 6% of the fleet. About 11% of the owners replaced these with a new model and 19% bought another model older than ten years. A few households did not buy any replacement vehicle. The scheme was estimated to have caused between 0.6% and 1% reduction in the HC and NOx emissions of the Danish fleet.

France implemented its first scrappage scheme (Prime à la casse) in February 1994. An incentive of Fr 5 000 (about US$ 950) was awarded if people scrapped cars that were older than ten years and replaced them with new models. This corresponded roughly to 6% of the average cost of a new car in 1994. Further discounts were offered by car manufacturers and car dealers. The scheme ended in June 1995. A second scheme (Prime qualité automobile) worth a bonus of Fr 7 000 ran from October 1995 to the end of September 1996. The minimum age was lowered to eight years. The bonus was reduced to Fr 5 000 for the replacement of relatively small sized cars. The two schemes saw scrappage of an overall number of 1 560 000 vehicles. A maximum scrappage rate of 8% was reached in 1996. The number of cars scrapped net of those that would have been scrapped even without the scheme was estimated at about 700 000 (CCFA, 1997).

Spain introduced (in April 1994) a similar scheme (Plan Renove I), giving tax relief ranging from Pta 85 000 to 100 000 (US$ 630-750) as a bonus for people who scrapped a car older than 10 years and replaced it with a new model. The 6 month scheme was renewed in October and ran to the end of June 1995 as Plan Renove II, with the minimum age for scrappage lowered to 7 years. In 1994 and 1995, respectively, 211 000 and 146 000 vehicles were scrapped and replaced under the schemes, corresponding to 11.5% and 7.4% of the fleet. The number of vehicles replaced net of what would have been replaced anyway was estimated to be 199 000 units in 1994, with a negative result of 23 000 in 1995 (Licandro and Sampayo, 1997). In 1996, a substantial reduction in the vehicle registration tax gave another incentive - independent from scrappage - to new car demand. The scrappage scheme was made permanent from April 1997.

Ireland. From June 1995 those who scrapped their cars (with a minimum age of ten years) and replaced them with a new-model vehicle could reclaim I£ 1 000 (1,270 EUR) of the registration tax on the new car. The scheme - initially supposed to last until December 1996 - was extended to the end of 1997. In 1995, 1996 and 1997, respectively, 5 140, 19 400 and 35 000 vehicles were scrapped - out of a fleet that had roughly 990 000 cars in 1995 and grew to 1 134 000 in 1997. The majority of the vehicles scrapped under the scheme were 10-12 years old.

Norway introduced a scrappage incentive in 1996. NKr 5 000 (600 EUR) was given for scrapping a vehicle older than ten years. There was no compulsory replacement for the scrapped car. A considerable part of scrapped cars were replaced with second-hand vehicles. The incentive caused an extra 150 000 vehicles to be scrapped (7% of the fleet) with respect to the ‘natural’ annual scrapping rate.

Italy was the last European country to introduce incentives for accelerated vehicle retirement. From January 1997 the government awarded bonuses ranging from L 1.5 million to L 2 million (roughly 775 – 1,000 EUR) for each vehicle scrapped, according to the size (engine displacement) of the replacement car bought. The incentive was conditional on a new car being bought and on car manufacturers/dealers further reducing the car’s price by an amount equal to the bonus. The programme expired in September 1997. It was then extended for 4 months with a fixed bonus of L 1.5 million for all car sizes. In 1997, about 1 148 000 old cars (about 4% of the fleet) were retired under the scheme.

From February to September 1998 a second scheme was introduced. This time an incentive of L 1.25 million or L 1.5 million was given, provided that the new replacement model had an average fuel consumption (whether diesel or gasoline) between 7 and 9 litres per 100 km or less than 7 litres, respectively. From October 1997, bonuses were also given if the new replacement models purchased were fuelled with LPG, methane or electricity. In the case of electric vehicles, the scrappage incentive is L 3.5 million and there is no expiry date for the scheme.

A year-long scrappage programme for motorcycles was also introduced by the Italian government in 1998.

4.2. Conclusions on scrappage schemes

The scrappage programmes in EU were all implemented some years after introduction of TWC, generally in order to get rid of the non-catalyst cars. The programmes were generally based on a bonus, if cars older than around 10 years were replaced by new cleaner cars. In some cases (e.g. in Denmark) it was not a condition to buy a new model with TWC. The number cars scrapped were 4-12% of the car fleets. The scrappage programmes were in some countries initiated in the largest cities, but later expanded to the whole country. Most of the programmes expired after a few years.

ECMT, 1999 concluded that in the short run, cash-for-replacement schemes of the kind implemented in France and Italy increased the demand for new models much more than the cash-for scrappage schemes. However, the increase seemed to be due to earlier replacement decisions and may lead to severe subsequent decline in new car sales - particularly in those countries where the size of the fleet is stable or very slowly increasing. When comparing the average growth rates in the longer term, the difference between cash-for scrappage and cash-for-replacement schemes, as regards the increase in new car sales, may become smaller.

There are two main factors concerning the fleet's renewal that may have significant effects on the environment. The first is the change in air pollutant emissions due to the replacement of old vehicles by new ones. As newer vehicles usually have much better performances than the very old ones. From an environmental point of view, it is believed that speeding up fleet renewal by getting rid of the 'dirtiest' model years can substantially curb atmospheric pollution.

The second factor is the accelerated transformation of natural resources (used to build new vehicles) into waste (the leftovers of old vehicle scrappage processes) through car construction and dismantling. Accelerating the car scrappage rate may have relevant negative environmental effects as it increases all the impacts related to the vehicle: production, scrapping, dismantling and the recycling processes.

To make a scrappage programme effective from the environmental point of view, i.e., to increase the emission reductions of the pollutants concerned the following has to be considered.

The difference between the average emission rate of the vehicles scrapped and the average emission rate of the replacement vehicle must as large as possible. They have to ensure that the vehicle scrapped is properly selected among the 'gross emitters' and that the replacement vehicle is reasonably clean. The selected vehicles should have a significant remaining life. It must be remembered that all vehicles scrapped with an incentive would be scrapped anyway in a few years time. Too short rest life will result in a dead-weight loss. The selected vehicles should run on a certain minimum amount of km per year. It would not be beneficial to pay for scrapping a vehicle that was little used.
To obtain a large reduction in the emissions considered, it is important to replace a large number of cars.

Two main methods exist to increase the difference between the average emission rates of scrapped and replacement vehicles. The first focuses on the 'dirtiest', older vehicles. In practical terms, this has been done mainly through age constraints imposed on the eligibility of vehicles and through the use of inspection programmes to test emission rates. The second focuses more on the replacement vehicles that are chosen among the 'cleanest' available models. The most common requirement introduced for this purpose has been the constraint of purchasing a new model to replace the scrapped one.
The programmes implemented in Denmark and Norway has chosen the first approach. They have imposed requirements on the selection of the retired vehicles rather than on the new vehicles. All the other European schemes, apart from the Hungarian one, have rather chosen the second approach.

4.3. Environmental achievements

4.3.1. Air pollutants

The technological progress in the last decades together with the strengthening of environmental regulations, has lead to substantial reductions of the average emissions for most pollutants. Within EU, the actual regulation in force sets standards for CO, HC and NO_x emissions at more than 90% lower, than the first limits introduced by Directives 70/220/EEC, 77/102/EEC and (98/69/EC, and amendments). Further reductions will take place within the coming years, also on PM.

The EU standards apply to new vehicles introduced into the market. They cannot be considered as representative for the vehicles that are already in use. As a vehicle ages, its emissions are likely to increase. Therefore, a car belonging to type of model from a number of years ago is likely to show higher emission patterns with respect to new models, not only because of the stricter regulations in force at the different time of the vehicle's construction, but also because of its poorer working conditions. This is why a vehicle's age is usually taken as a proxy for its average emissions.

In addition, the fleet's ageing is not likely to have the same effect on the emissions of all pollutants considered. For instance, CO emission rates show a higher correlation with car age than NO_x - the latter depending essentially on the combustion temperature, which is not so closely linked to the engine conditions. However, there also some other indications that older cars can perform well with relatively low emissions.

Some problems may also arise with the replacement cars. When the vehicle retirement scheme does not require the purchase of new model cars, it is usually assumed that the replacement vehicle is an 'average' model, representative of the fleet in use. The average emissions of the fleet in use are probably lower than those of the older, scrapped vehicles. But some replacement vehicles might be 'gross emitters' themselves, if no other selection criterion is adopted by the programme (or by the regulation in force) to avoid it. A survey made during the implementation of the Danish scheme, where no particular requirement was introduced for the substitution vehicle showed that about 19% of the replacement cars purchased were older than ten years. These kinds of problems are avoided in cash-for replacement schemes imposing the purchase of new model cars. It is very unlikely that a new model turns out to be a 'gross emitter' in its first three or four years of life; the period usually considered for the assessment of the scheme.

4.3.2. CO_2

Renewal of the car fleet may also have influence on the emissions of green house gases (CO2), which is closely related to the fuel consumption. An investigation carried out by ACEA is illustrated in Figure 3. It is seen that the fuel consumption decreased until 1986, and was nearly constant (and in periods increasing) the following years. The fuel consumption is also depending on other parameters, e.g. the engine displacement, higher speed etc.

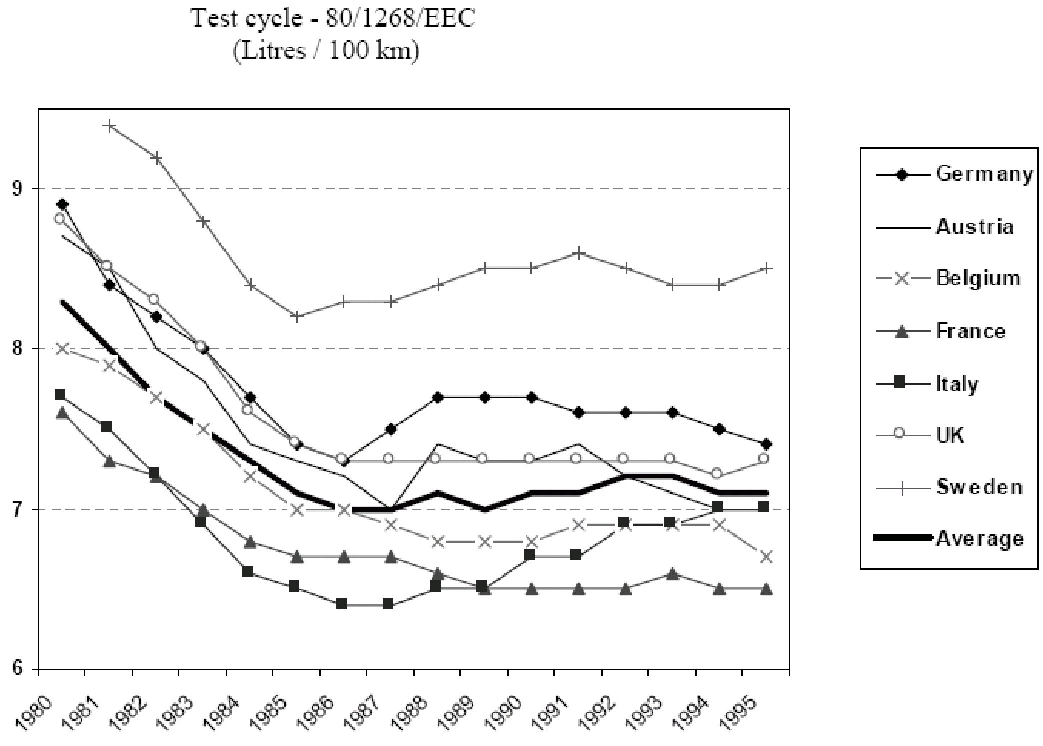


Figure 3 Weighted fuel consumption of all new cars. (ACEA, 1999)

4.3.3. A Danish approach

The Bill on the scrap vehicle bonus was passed on 17th of December 1993. According to the explanatory notes on the bill, the purpose of the scrap vehicle bonus was to speed up the renewal of old cars in order to reduce environmental pollution (Transportrådet, 1995).

Each person who decides to scrap his passenger car - more than 10 years old - in the first six months of 1994, received a bonus of DKK 6,500 from the Danish Government. The bonus scheme lasted until the 30th of June 1995. The scrap vehicle bonus for passenger cars decreased every six months. It was thus DKK 4,500 in the second half of 1994 and DKK 2,500 in the first half of 1995. The bonus rates for light commercial vehicles were DKK 3,500, 2,400, and 1,400 respectively in the three half-year periods.

In the first six months of 1994 just under 101,000 passenger cars were scrapped with a bonus. The 101,000 scrapped cars are distributed among 96,000 families. Approximately 5,000 families have thus received a bonus for more than one car.

In the years, before the bonus scheme became effective, approximately 36,500 cars on average were scrapped every six months. The bonus has thus sped up the scrapping of approx. 64,000 cars (Kveiborg, 1999).

The large number of cars being scrapped in the first six months of 1994 resulted in a reduction of the fleet of cars by just under 25,000 passenger cars. Although the sale of brand-new cars also increased heavily in this period, it could only partly make up for the numerous cars being scrapped. The heavy sale of brand-new cars continued in the second half of 1994, and at the turn of the year the size of the fleet of cars had almost reached the level of the year before.

It is difficult to give an exact estimate of how much the scrapping of the additional 64,000 cars has been advanced. It was estimated that the scrapping of old cars was advanced one year on average in average.

This period of time has been determined on the grounds that scrapping of cars in the second half of 1994 and the first half of 1995 was way below the usual scale of scrapping. In the second half of 1994 only approx. 23,000 cars were scrapped as compared to the usual amount of approx. 36,500 cars. Similarly, the number of cars being scrapped in the first half of 1995 was below average. An overall estimate indicates that at least half of the additional scrapping of cars has been advanced for less than one year, and that the remaining part has been advanced for somewhere between one and two years.

Public expenditure on the scrap vehicle bonuses amounts to approx. DKK 800 million (107,544,466 EUR) (of this approx. DKK 4 million went to scrapping of commercial vehicles). The expenses must, for one thing, be recovered through an advancement of already planned increases in petrol taxes in 1996. The advancement of the increase in taxes was expected to boost revenues by approx. DKK 615 million (82,643,210 EUR).

Furthermore, the scrap vehicle bonus has led to a modest increase in the sale of new cars. The real rate of return on revenue in connection with these escalating sales was approx. DKK 40 million (5,376,218 EUR).

All in all, the Danish government made a net expenditure of approx. DKK 150 million (20,166,713 EUR) on scrap bonuses.

Retrofitting of catalysts was considered in Denmark during the late 1990s, but was not considered cost effective compared to other measures. In addition, the fraction of non-catalyst cars and by this the emissions from non-catalyst cars would be small within a few years.

4.4. Cost-effectiveness

The cost-effectiveness is very different under the different condition in the different countries. The most cost effective scrappage schemes are those, which lead to removal of old technology engines with new less polluting technologies. Removal of old cars alone does not lead to large environmental achievements.

5. Assessment of other legislation and measures

A large variety of other programmes have been initiated in the different European countries. An example is assessment of retrofitting of catalysts on petrol cars in Denmark. This programme has not been initiated more widely because the number of non-catalysts cars now is relatively low and most of them will be out of use within a few years.

Programmes in Sweden, UK and Switzerland on retrofitting programmes on trucks, buses and off-road vehicles have been implemented.

Implementation of low emission zones is under consideration in Berlin and Copenhagen.

Different taxation systems are applied in different European countries. The variety of influences has led, traditionally, to large differences in the overall strategies followed in the Member States. These differences apply both in terms of the overall level of dependence on the sector for a contribution to total revenues, and to the choice of instruments and their precise implementation. The operation of 15 different vehicle tax systems within the EU has resulted in tax obstacles, distortions and inefficiencies. In Germany a tax relief possibility was introduced in 1997 and will remain in force until 2005 (CONCAWE, 2002). The EURO 3 and EURO 4 cars benefit from tax relief until 31/12/2005 or until it reaches 250 DM (petrol) or 500 DM (diesel) for EURO3 and 600 DM and 1200 DM respectively for EURO 4 vehicles. The tax is differentiated in relation to emission classes as shown in the table. Vehicles, which are classified in a higher tax class can be moved to a lower tax class, if it can be demonstrated that it comply with a lower emission class.

Table 3 German limited purchase tax exemption for low emissions passenger cars.

Vehicle	Tax Exemption (DM/vehicle)
Euro 3	
- Petrol	250
- Diesel	500
Euro 4	
- Petrol	600
- Diesel	1200

Table 4 Emission standards in the EU

Car group	Tax Rate (DM)and Effective Date		
	From 01/01/01	From 01/01/04	From 01/01/05
Euro 3			
Euro 4			
- Petrol	10.0	13.2	13.2
- Diesel	27.0	30.2	30.2
Euro 2			
- Petrol	12.0	14.4	14.4
- Diesel	29.0	31.4	31.4
Euro 1			
- Petrol	21.2	21.2	29.6
- Diesel	45.1	45.1	53.5
Other vehicles related to ozone alerts			
- Petrol	29.6	29.6	29.6
- Diesel	53.5	53.5	65.1
Other vehicles not related to ozone alerts			
- Petrol	41.2	41.2	49.6
- Diesel	65.1	65.1	73.5
Older cars			
- Petrol	49.6	49.6	49.6
- Diesel	73.5	73.5	73.5

Incentives for retrofitting passenger cars have been given in Germany, since 1985 and Hungary. Some Swedish and British cities (Stockholm, Goteborg, Malmo, and London) have also recently implemented retrofitting programmes for trucks and urban buses, respectively. These experiences have had relatively good results.

5.1. A German approach

The reduction of the emissions on the German vehicles was e.g. obtained by retrofitting of three–way catalysts. Originally it was considered not technically possible, but effective systems, which could be installed on most of the petrol cars, were invented in Germany during the mid 1990s. The emission reductions were around 95%. There was a great potential in Germany, especially due to the many old cars in the former DDR.

6. Conclusions

6.1. EU situation

The assessment of the cost effectiveness of getting rid of "gross emitters" (mainly old cars) has to be based on the average cost per tonne of emission avoided. Until now only a few attempts to quantify this were made and all of them in the US and Canada.

However, almost no empirical estimates are available for the cash-for-replacement programmes. All the elements discussed in ECMT, 1999 and the scarce, available data lead to the conclusion that they are far less cost-effective as compared to cash-for-scrappage programmes. Accordingly, the limited evidence collected suggests that they are less cost-effective than I&M enhancement policies.

It was also concluded that the small-scale programmes are much more efficient than large-scale ones. Second, scrappage programmes become relatively more beneficial in 'sensitive areas' where the damage due to atmospheric pollution is higher. The study, however, did not take into account the fact that an increase in the value of older vehicles (caused by the scrappage incentive) may have postponed some replacement decisions of lower-income families and, therefore, actually have caused some 'gross emitters' to live longer.

Assessments of scrappage schemes cannot be made only on the basis of emission standards or average emission factors for different model years but depend on economic variables affecting the behaviour of car owners and on the cost of the scheme. Where the cost per tonne of pollutant reduced is high, other environmental policy measures should be considered instead of scrappage programmes. The structure of taxation in relation to the ownership and use of vehicles is a key element in determining the overall economic incentive for vehicle stock turnover. The cost-effectiveness of scrappage schemes may be undermined if they run counter to incentives arising from the existing structure of taxation (for example, if older vehicles pay lower annual vehicle charges than new cars). Both the size of the emission reduction achieved and cost-effectiveness depend heavily on the detailed design of scrappage programmes.

Different types of scrappage schemes have been implemented in several European countries. The most significant effects were obtained where very bad cars could be replaced with clean cars, i.e. the old car fleet in Eastern Europe after the Communist "Wall" was brought down. However, the effects are very much dependant on the economic situation in the country.

Inspection and maintenance is a much more generally applicable instrument to reduce the emissions from the existing car fleet.

6.2. The Eastern European countries

In ECMT, 1999 it was also concluded that in Eastern European countries, the economic conditions suggest that cash-for-replacement schemes that require a switch to a new-model car are not going to be successful. New cars are very expensive with respect to the average purchasing power of the Eastern European households. In general, those families who can afford to buy a new model do not own an old, poorly maintained car or if they do, they would soon replace it anyway, even without the incentive. On the contrary, the owners of the "gross emitters" cannot afford to purchase new models. The incentives they need in order to buy these would be too high to make the scheme feasible and efficient. The cash for scrappage schemes may be the more useful.

The situation would be slightly different if cash-for-replacement schemes were directed only at heavy-duty vehicles. Buses and Lorries are usually owned by firms, whose purchasing power is high relative to low-income households. There is, however, very limited experience with scrappage schemes that target trucks and buses. Therefore, it is difficult at the moment to draw meaningful conclusions as to their possible success or the cost-effectiveness of reducing atmospheric emissions. These kinds of schemes are worth further examination.

Since most Eastern European countries are actually facing very rapid fleet growth, with a relatively high number of new registrations every year, the policy-makers should focus on measures aimed at boosting the purchase of cleaner cars, independently of scrappage decisions. These measures could either be environmental regulations, e.g., stricter emission standards for newly registered cars, or economic incentives to buy 'greener' vehicles. These policies would offer the opportunity of obtaining, in the mid-long term, the advantage of high, motorization levels, while simultaneously avoiding some of the environmental disadvantages that have characterized the Western fleets in the recent past. Scrappage schemes may still have an important role in getting rid of old 'gross emitters', both from the environmental and the industrial point of view. However, they will be relatively less relevant, compared to their role in Western European countries.

CASE STUDY 3 – ANNEX II

THE US EXPERIENCE WITH RESPECT TO CONTROLLING EMISSIONS FROM HIGH EMITTING VEHICLES

4 October 2004

1. Controlling Emissions from High Emitting Vehicles in the United States

1.1. Introductory Overview

The US Clean Air Act (CAA) address mobile source air emissions through a combination of vehicle emissions standards, fuel standards, and voluntary transportation demand reduction measures. Of these programmes, the focus of the following sections will be on U.S. approaches for mitigating emissions from existing passenger vehicles, focused on two specific efforts: inspection and maintenance (I/M) programmes and vehicle scrappage programmes.

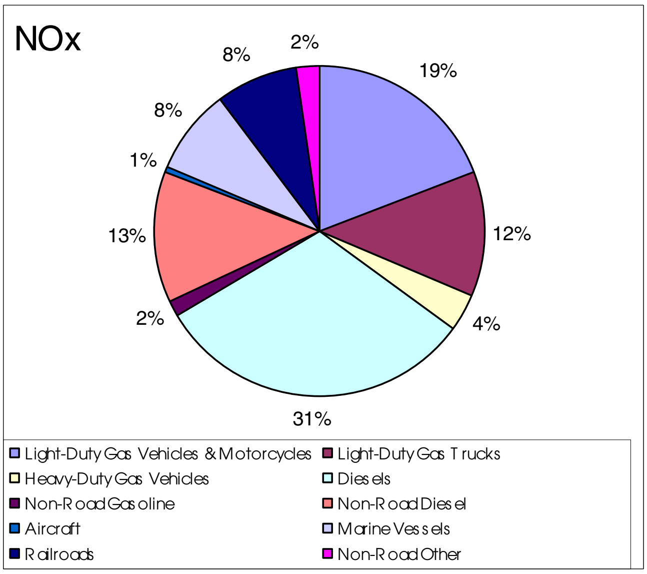
Inspection and Maintenance (I/M) programmes were first introduced in the U.S. in the late 1970s as a result of a provision in the 1977 Clean Air Act Amendments (CAAA) developed in response to evidence of divergence between new vehicle emission certification and in-use emissions. [2] The states followed by developing programmes that varied in detail, but all made the vehicle owner responsible for bringing the vehicle for inspection and repairing any deficiencies. By the late 1980s, the USEPA had concluded that certain aspects of state programmes were causing the programmes to fail and recommended that Congress make it difficult for states to continue those aspects.

Under the 1970 CAA, nonattainment states were required to include measures such as land-use and transportation controls if necessary to meet the national ambient standards. In the 1977 CAAA, Congress provided states more time to meet the requirements to attain standards for automotive pollution provided that all reasonable measures were implemented. The Act outlined eighteen transportation control measures.

1.2. Emissions Sources

In the United States, transportation emissions have declined since 1970 as a result of a variety of factors, including regulatory requirements and improvements in technology. Since 1970, NO_x and VOC emissions from on-road transportation sources have declined by 34 and 71 percent, respectively (EPA, 2003).[3] Despite this progress, transportation emissions still remain a significant source of U.S. emissions. In 2001, transportation accounted for 82 percent of national CO emissions, 56 percent of NO_x, 42 percent of VOC, 2 percent of PM_{10}, and 6 percent of $PM_{2.5}$ (EPA, 2003). Of transportation sources, on-road diesel is the largest share of NO_x emissions, followed by light-duty gas vehicles and motorcycles (see figure 1).

[2] 1977 Clean Air Act Amendments, Title I, section 110, 2(g).
[3] During the same period NOx and VOC emissions from non-road vehicles have increased by 57 and 62 percent, respectively.



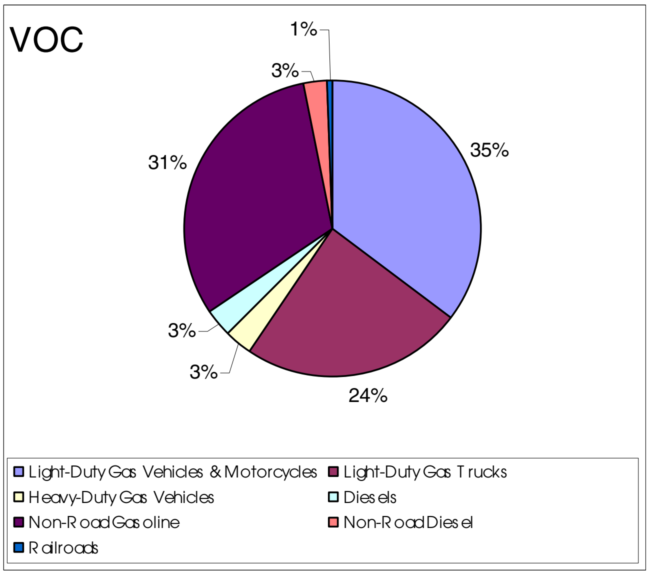


Figure 1: US Transportation Emissions by Source in 2001 (USEPA, 2003)

Of these total emissions, it is generally acknowledged that a small fraction of the vehicles in operation contribute a significant share of the emissions. Estimates typically show that 50 to 60 percent of on-road emissions from light-duty vehicles are generated by 10 percent of the dirtiest vehicles (NRC, 2001). As a result, a large amount of attention has been given to reducing emissions from the "high-emitting" vehicles.

2. LEGISLATION AND MEASURES IMPLEMENTED

2.1. Inspection and Maintenance

The 1990 CAAA required the USEPA to develop a new "Enhanced I/M" programme that would have to be in place in 23 states with serious ozone and carbon monoxide problems within 18 months.4 The Enhanced I/M programmes were to have centralized inspection centres and to require vehicle inspections annually, unless a state could demonstrate that their current I/M programme would be as effective at reducing vehicle emissions. EPA was required to issue regulations by November 1991 and states were required to implement the programmes by November 1992.

2.1.1. Federal Guidance

The USEPA issued guidance in November 1992 on Enhanced I/M programmes. The regulation required that areas switching from test-and-repair to test-only programmes begin testing 30 percent of vehicles subject to enhanced I/M by January 1995, and all areas were required to begin inspecting every vehicle by January 1996. The regulation also contained three elements aimed at alleviating the issues that were perceived to be the principal problems of existing state I/M programme (EPA, 1992). First, the new regulations required that the waiver limit be at least $450 (in 1989 levels) and adjusted for inflation.[5] Prior to the regulation, the waiver limit in most states—$50-75—was below the level of many repairs. Second, EPA developed a detailed emission test protocol that included automatic analysers and a dynamometer test, "IM-240".[6] EPA had concluded that emissions during idling were not well correlated to emissions during vehicle acceleration and a mechanic could manipulate idling so

[4] Specifically, the states with serious, severe, or extreme ozone nonattainment areas with 1980 urban populations of 200,000 or more; serious and certain moderate carbon monoxide nonattainment areas with urban populations of 200,000 or more; and areas with a population of 100,000 or more in the Ozone Transport Region.
[5] The waiver limit was $620 in 2000 when adjusted for inflation.
[6] A dynamometer simulates the operation of a vehicle under different driving conditions.

that a vehicle would pass the I/M programme. Third, the new regulations included a provision that limited the amount of emission credits for SIPs that could be accounted from a test-and-repair programme to 50 percent of a test-only programme. EPA had concluded that mechanics in a test-and-repair programme may have an incentive to fail a clean vehicle and make repairs that are not needed or pass a vehicle that should have failed.

The Enhanced I/M regulations issued by EPA received a significant amount of protest from states with existing I/M programmes. After states that had adopted the Enhanced I/M program—Maryland and Maine—suffered from computer crashes, claims of badly trained operators, and long queues, the issue rose to the national political level. As a result, Congress attached a provision to the National Highway System Designation Act of 1995 that prevented EPA from requiring a centralized testing system using IM-240 and prevented EPA from automatically discounting the SIP credits generated from decentralized or hybrid programmes. The Act allowed states 120 days to submit revisions to their Enhanced I/M programmes by proposing temporary programmes and required EPA to approve these programmes on an interim basis if the proposed credits for each element contained good faith estimates and the programme complied with the 1990 CAAA.

As a result, EPA issued a revised regulation in September 1995—the Inspection/Maintenance Flexibility Amendments—that created a less stringent programme that allowed certain states flexibility in their programme implementation.[7] Many states needed emissions reduction credits from an enhanced I/M programme to meet the 15 percent VOC reduction requirement by 1996, as required in the CAA.

2.1.2. State by State Approach

Since there are no required guidelines for designing enhanced I/M programmes under the Clean Air Act, the approaches that have been introduced vary by State and often by cities within the State. However, as a part of EPA's review of SIPs, each area's I/M programme is subject to approval by EPA and subsequent sanctions for failure (see case study 2). Box 1 describes the various elements of I/M programmes and briefly discusses the application of these in states. A full overview of the specifics of the state programmes is available from the USEPA.[8]

EPA considers the I/M programme in Phoenix, Arizona as the model I/M program, noting that it "most closely resembles EPA recommended program". As such, the majority of analysis has considered the effectiveness of this programme. *Table 1* provides details on the specifics elements of the Phoenix enhanced I/M programme.

[7] 40 CFR 51.
[8] See: www.epa.gov/otaq/epg/420b03012.pdf

Table 3 Details on Phoenix, Arizona Enhanced I/M Program

Location	**Network Type**	**Test Type**	**Cutpoints**			**Visual Checks**	**Evap Tests**	**Frequency**	**Vehicle Types**	**Model years**
			HC	CO	NO_x					
Phoenix, Arizona	Test Only	1981-95: IM147	0.5 g/km	7.4 g/km	1.2 g/km	Catalyst, air pump, PCV, gas cap	Pressure; Gas Cap	Annual: 1967-80 Biennial: 1981+	LDGVs; LDGTs; HDGVs; MC	1967+ vehicles less than four years old exempt
		<1981: Loaded Idle	220 ppm	1.20 %						
		1996+: OBD								

Notes: LDGVs = light-duty gasoline vehicles; LDGTs = light-duty gasoline trucks; HDGVs = heavy-duty gasoline vehicles; MC = motorcycles; OBD = on-board diagnostic

The programme in Phoenix, Arizona is a centralized biennial programme that uses IM240 testing for vehicles model year 1981 and newer that are under 3,856 kg gross vehicle weight. Older vehicles and all-wheel drive vehicles are subject to an idle test.

2.2. Transportation Control Measures: Vehicle Scrappage Programmes

In 1971, the USEPA defined transportation control strategies as "measures designated to achieve the aggregate reduction of emissions necessary for attainment and maintenance of a national standard [of air quality]." The agency listed ten examples, which fall into three general categories: emissions control measures, traffic control measures, and mass transit measures. EPA required states to develop transportation control plans (TCPs) and incorporate these plans into their SIPs. Most states refused to submit TCPs since such measures as parking restrictions and high taxes or surcharges on parking were highly controversial. As required by the Act, EPA responded by promulgating federal TCPs for nineteen major metropolitan areas, which included many of the unpopular measures that states had refused to introduce. After significant upheaval in Congress and at the local level, EPA essentially abandoned their efforts to introduce federal TCPs.

The 1990 CAAA gave the USEPA the authority to provide information on the formulation and emission reduction potential of Transportation Control Measures (TCMs) that could be adopted by states as a part of their SIPs, including programmes to “encourage the voluntary removal from use and the marketplace of pre-1980 model year light duty vehicles and pre-1980 model light duty trucks”—so-called scrappage programmes.[9]

While the Act gave states the discretion to adopt TCMs, it required that States with severe or extreme ozone and serious carbon monoxide nonattainment areas submit a SIP revision requiring employer trip reduction programmes for companies with 100 or more employees to "reduce work related vehicle trips and miles travelled by employees," and stipulates that employers must increase commuter vehicle occupancy to a level “not less than 25 percent above” the regional average.[10] This programme was highly controversial and was later abandoned in favour of a voluntary commute reduction programme of tax incentives aimed at employees and employers.[11]

The USEPA issued guidance in 1993 for those states interested in implementing an early vehicle retirement programme (EPA, 1993). The guidance outlines the elements of a programme that can

[9] 1990 Clean Air Act Amendments, Title I, section 108 f(1).
[10] Clean Air Act Amendments, Public Law No. 101-549, 104 Stat. 2399, 1990.
[11] For information on EPA’s current commuter programmes, see http://www.bwc.gov/about/index.htm

automatically qualify to calculate emissions reductions using a pre-determined calculation methodology. Programmes that deviate from the guidelines issued by EPA are subject to review in order to approve the quantification methodology for assessing SIP creditable reductions. The guidelines are: (1) vehicles should be registered continuously in the nonattainment area for the past 12 months in order to ensure that vehicles are not imported into the area specifically to be sold into the program; (2) eligible vehicles are required to be operable and driven to the location to ensure that the vehicle would be operated in future years; (3) owner must present a valid inspection and maintenance certificate; and (4) programmes with more than 2,500 vehicles are required to track certain information (e.g., mass emissions, vehicles miles travelled, and expected remaining useful life) for a sample of the vehicles.

In 1997 the EPA introduced the Voluntary Measures Policy to provide states with more flexibility in earning mobile source SIP credits. Eligible measures, including TCMs, were recognized as difficult to quantify and thus limited to 3 percent of projected SIP emissions reductions required under the NAAQS.[12] These include many of the TCMs required – but rarely adopted – under the 1990 Amendments (see Box 2 below).

Box 2: Specific Transportation Control Measures in the 1990 Clean Air Act Amendments

improved public transit programmes;
restriction of certain roads or lanes to, or construction of such roads or lanes for use by, passenger buses or high occupancy vehicles;
employer-based transportation management plans, including incentives;
trip-reduction ordinances;
traffic flow improvement programmes that achieve emission reductions;
fringe and transportation corridor parking facilities serving multiple occupancy vehicle programmes or transit service;
programmes to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use;
programmes for the provision of all forms of high-occupancy, shared-ride services;
programmes to limit portions of road surfaces or certain sections of the metropolitan area to the use of non-motorized vehicles or pedestrian use, both as to time and place;
programmes for secure bicycle storage facilities and other facilities, including bicycle lanes, for the convenience and protection of bicyclists, in both public and private areas;
programmes to control extended idling of vehicles;
programmes to reduce motor vehicle emissions, caused by extreme cold start conditions;
employer-sponsored programmes to permit flexible work schedules;
programmes and ordinances to facilitate non-automobile travel, provision and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel, as part of transportation planning and development efforts of a locality, including programmes and ordinances applicable to new shopping centres, special events, and other centres of vehicle activity;
programmes for new construction and major reconstructions of paths, tracks or areas solely for the use by pedestrian or other non-motorized means of transportation when economically feasible and in the public interest; and
program to encourage the voluntary removal from use and the marketplace of pre-1980 model year light duty vehicles and pre-1980 model light duty trucks.

[12] For more information, see http://www.epa.gov/otaq/transp/traqvolm.htm

3. ASSESSMENT OF THE EFFECTIVENESS—I/M PROGRAMME

3.1. Environmental Effectiveness

3.1.1. Emissions

Measuring the emissions results of I/M programmes is complicated since the emissions of an individual vehicle can be extremely variable under typical driving conditions, emissions tests are inconsistent, and a variety of methods are used (NRC, 2001). Emissions reductions from I/M programmes are influenced in a number of ways, including improved maintenance, repairs to emissions equipment prior to the test in anticipation of the test, repair of vehicle as a result of failure, duration of the repairs undertaken, and early scrapping or transfer of vehicle outside the testing region (NRC, 2001). While no studies have been conducted evaluating the overall emissions reductions attributable to I/M programmes across the U.S., several studies have considered the impacts of specific programmes. These analyses have varied in scope and structure, since some were conducted as a part of state evaluations and others are the results of independent analysis. In addition, the programmes vary in the way they are implemented, which can have a significant impact on the effectiveness. The I/M programmes where analysis has been conducted show that the programmes have reduced emissions from those vehicles tested and repaired, although those estimates have generally been lower than predicted by models.13 Table 2 provides a summary of the HC, CO, and NOx emissions reductions estimated from a number of existing I/M programmes for all vehicle types tested.

[13] The two models widely used are EPA's MOBILE model and California's EMFAC model.

Table 2 Average Emissions Reductions of I/M Programmes

	Average Emissions (g/km)		Percent Reduction
	Before Repair	After Repair	
California I/M Review Committee (1993)			
HC	3,07	2,18	25%
CO	30,1	41,4	14%
NOx	1,32	1,17	11%
Sun Company (Cebula 1994)			
HC	3,00	0,96	68%
CO	43,0	10,56	75%
NOx	1,80	1,26	30%
Total Petroleum (Lodder and Livo 1994)			
HC	2,27	1,54	32%
CO	28,36	20,74	27%
NOx	--	--	--
California I/M Pilot Project FTP (Patel et al. 1996)			
HC	2,08	1,03	51%
CO	22,3	12,9	42%
NOx	1,27	0,76	40%
Arizona Enhanced I/M (Ando et al. 1999)			
HC	1,67	1,06	37%
CO	25,1	16,0	36%
NOx	1,95	1,39	29%
Arizona Enhanced I/M (Wenzel 2001)			
HC	0,42	0,35	15%
CO	5,95	5,04	15%
NOx	0,85	0,78	7%
California Enhanced I/M (CARB 2000)			
HC	0,83	0,71	14%
CO	9,57	8.33	13%
NOx	0,68	0,63	6%
Source: Revised from table 3 in Harrington and McConnell 1999			

As can be seen by the table above, estimates of these programmes show that emissions reductions from vehicles before and after testing range between 6 and 40 percent for NO_x, 14 and 68 percent for HC, and 13 and 74 percent for CO.

3.1.1.1. Results by Vehicle Type

The emissions reductions achieved from an I/M programme can vary by vehicle type. For example, analysis from the Phoenix I/M program, described earlier, shows the level of variation achieved according to vehicle type and pollutant (Table *3*).[14]

[14] The Phoenix program is an oft studied program as it is the closest to EPA's Enhanced I/M guidelines.

Table 3 Emissions Reductions In Phoenix I/M programme by Vehicle Type

	Emissions Per Vehicle (g/km)						Percent Reduction		
	HC		CO		NOx		HC	CO	NOx
	Initial	Final	Initial	Final	Initial	Final			
Cars	0,36	0,30	5,25	4,29	0,73	0,67	15,4	11,4	5,28
LDT1	0,47	0,42	6,80	6,05	0,92	0,86	7,83	6,90	3,91
LDT2	0,59	0,49	8,14	7,00	1,42	1,35	9,94	8,70	2,80
All	0,04	0,35	5,95	5,04	0,85	0,78	9,01	9,51	4,47

Note: Cars are passenger cars; LDT1 are light-duty trucks less than 2722 kg gross vehicle weight; LDT2 are light-duty trucks between 2722 and 3856 kg gross vehicle weight.
Source: Reproduced from Wenzel, 2001a.

Emissions reductions of NOx are greatest from passenger cars (9 percent), with the smallest reductions from LDT2 (5 percent). For HC, the largest emissions reductions occur from LDT2 (16 percent) and the smallest reductions occur from LDT1 (13 percent).

3.1.1.2. Emissions Leakage

The extent to which cars operating in an area with I/M programmes are transported out of the testing area can have an impact on the emissions benefit of the programme. The programme may induce such an occurrence (e.g., a vehicle fails a test and the owner chooses to sell the car instead of repairing it) or it may be the result of natural fleet turnover in the region (e.g., the vehicle would have been sold outside the area irregardless of the program). Depending on where the vehicle now operates (e.g., if the vehicle remains in operation in the I/M area or is sold to an area that contributes to the air quality in the I/M area), such an occurrence may impact the air quality in the I/M area.[15] While no conclusive analysis has been conducted, several studies have found evidence of “disappearing vehicles”—vehicles that failed the test but are apparently never required to pass. One study estimated that the share of disappearing vehicles in the Arizona I/M programme may be as high as 25 percent of failing vehicles (Ando et al., 1999). Further, another analysis of the Arizona programme has estimated that over half of the cars failing the test were still being driven in the I/M area at least two years after they failed (Wenzel, 2001b).

3.1.1.3. Emissions Deterioration

The amount of time that an I/M induced repair remains effective in reducing emissions can also have a significant impact on the benefits of the programme. While there have been some estimates of the impact of this issue, further analysis is needed (NRC, 2001). A number of studies have found mixed results. Some analysis has found that the repairs last less than two years and in some cases less than one year (Lawson, 1993; IMRC, 2000, McClintock, 1998a; Wenzel, 2001b; and Rajan, 1996). Other analysis has found that the impact of some repairs has a longer impact on emissions reductions (IMRC, 2000).

3.1.2. Impacts

While it would be desirable to translate emissions reduction estimates into impacts on air quality, such analysis is complicated since it is difficult to separate the emissions reductions of I/M programmes from other emissions reduction policies and from other anthropogenic and natural factors that influence air quality (NRC, 2001). Even estimates of CO emissions reductions on air quality, which is generated mostly from light-duty vehicles, have proven complicated (Scherrer and Kittelson, 1994 and ENVIRON, 1998). As a result, no definitive results have been produced on the environmental impacts of I/M programmes.

[15] It is important to note that I/M programmes cover the nonattainment areas, so the impact of transport of emissions into the I/M area is generally reduced.

3.2. Costs

There are a number of costs that go into operating an I/M program, including: test or inspection cost, motorist costs (e.g., travel and queuing time), resource cost of repair (e.g., parts and labour), cost of reinspection, fuel economy savings, administration costs, enforcement costs, and evaluation costs (NRC, 2001).

3.2.1. Cost-effectiveness

Several studies have considered the costs and effectiveness of I/M programmes. *Table 4* presents the results of these assessments.

Table 4 Estimates of Cost-Effectiveness of I/M Programmes

	$/tonnes (HC + NOx)
Generic I/M Programme (EPA, 1992b)	3992
Arizona (Harrington et al., 2000)	4997
California (California I/M Review Committee, 2000)	3992-8165
Source: NRC, 2001	

Several researchers have suggested modifications to the existing programmes to make them more cost-effective, including changing the cut-points, profiling high- and low-emitters, exempting certain model years, and using remote-sensing. Several studies have found that loosening cut-points may be more cost-effective (Harrington and McConnell, 1993; Ando et al., 2000). It has been suggested that profiling vehicles likely to be high-emitters and requiring more frequent testing of those vehicles may improve the overall cost-effectiveness (EPA, 1999b). Others have suggested using the model year exemption as a means to improve the cost-effectiveness. A study of California found that I/M is significantly more cost-effective on pre-1991 vehicles than on new vehicles (IMRC, 2000). Some analysts have found that using remote-sensing to identify failing vehicles instead of conventional testing or using remote-sensing between I/M testing may improve the overall cost-effectiveness (Harrington and McConnell, 1993).

3.2.2. Costs and Benefits

The overall costs and benefits of the I/M programme were estimated by EPA prior to introduction of the regulation. This analysis found that compared to a situation with no I/M program, the new I/M programme is estimated to have an overall cost of $671 million (in 2001 dollars) and monetized benefits of $247-1,120 million per year (OMB, 2003). Similar analysis has not been conducted after the introduction of the I/M programmes to consider whether these cost-benefit estimates have occurred in practice.

3.3. Compliance and Enforcement

Measurement of compliance with I/M programmes can be measured by considering the compliance of individuals participating in or operating the state systems. Two separate measures can be considered.

First, do motorists comply with the mandates of the I/M programmes as implemented in the various regions? States are required by EPA to have at least 96 percent compliance rate (96 out of 100 vehicles complying); however, states are not required to report actual compliance rates to EPA. While the issue of compliance rate has not been fully evaluated, several studies have shown that motorists have found means to avoid the mandates of I/M programmes. Some areas have found that motorists illegally register their vehicles outside the I/M programme and still drive the vehicles in the area of the state covered by the programme (Stedman et al., 1997 and McClintock, 1999b). In addition, data collected in some regions has shown that a number of high-emitting vehicles fail to appear for another test after failing the initial inspection (Wenzel 1999a; Wenzel et al. 2000; Ando et al., 2000). A number of these vehicles are found to still be operating in the region despite having failed the inspection (Wenzel 1998a; Wenzel et al. 2000).

Second, are the testing stations complying with the requirements of the programmes as designed in the regions? Vehicle inspectors have been found to use a process called "clean piping" where they test a clean vehicle but enter into the database the vehicle identification number of dirty vehicle (NRC, 2001). In this way, a vehicle that would have failed the test shows up as a vehicle that has passed. States now use video cameras in testing stations to prevent this practice.

3.4. Administrative Feasibility

No assessment of the overall ease of administration of the programme has been conducted. For many state governments, a large portion of the administration of the programme is conducted by private contractors. While no information is available on the state government resources dedicated to management and operation of I/M programmes, one measure of overall administration cost can be reflected in the size of the I/M industry (to manage, operate, and analyze results).[16] One estimate places this industry as a billion dollar operation (Coninx, 1998).

3.5. Political Acceptability

Since the inception of I/M programmes, EPA guidelines and specific state programmes have been the subject of intense scrutiny, disagreement, and political debate. As a result, states subject to the I/M provisions have moved forward with some form of enhanced I/M, but many have been unwilling to fully implement the programme as outlined by EPA in its original form (NRC, 2004).

In addition, recent reviews of the programme have raised serious technical concerns and have highlighted that these programmes have been less effective than originally forecast (NRC, 2001). As such, these programmes are likely to undergo subsequent review on their technical and political merits.

4. ASSESSMENT OF THE EFFECTIVENESS—BUY-BACKS

A limited number of scrappage programmes have been introduced by states seeking to include the programmes in their SIPs, including the California programme.[17] California included a "voluntary accelerated vehicle retirement" (VAVR) programme in its 1994 SIP for the South Coast. The programme aims to buy and scrap up to 75,000 light-duty vehicles per year for vehicles that are older than 15 years. The program, as included in the SIP, is to reduce emissions of reactive organic gases (ROG) and NOx by 23 metric tonnes per day in 2010. In addition, California made the programme available to other jurisdictions in the State. The programme became California law in 1995 and assigned responsibility for programme design and implementation to the California Air Resources Board. The programme has yet to be fully implemented and it is unclear if the state legislature will appropriate the level of funding necessary to achieve the programmes goals. In 2003, California revised the South Coast SIP and placed the VAVR programme in the long-term, "black box" measures category (SCAQMD, 2003).[18] To date, the programme has been implemented as a pilot programme in a number of regions in the state with a limited number of vehicles participating.

Since the programme has yet to be fully implemented and estimates are unavailable on the impacts of the current implementation level, we have chosen to highlight results of estimated impacts of the

[16] This cost is typically paid by vehicle owners through a fee for each vehicle tested.
[17] According to EPA, 6 scrappage programmes have been implemented to date, not including the California measure included in the South Coast SIP.
[18] The revised SIP was submitted to EPA in January 2004 for approval.

programme once fully implemented—namely, encouraging the early retirement of 75,000 vehicles per year in 2010.

4.1. Environmental Effectiveness

A number of concerns have been raised about the effectiveness of this programme in achieving emissions reductions. Several key concerns are: (1) vehicles retired in the programme will be near their useful life and the programme will therefore have a limited impact on emissions; (2) older vehicles from outside the South Coast may migrate to the region as a result of the market response for vehicles; and (3) large price increases for all vintage vehicles could lead owners to extend the life of their vehicles by undertaking more maintenance on older vehicles (Dixon and Garber, 2001).

One analysis that sought to consider the impacts of these three concerns was conducted of the proposed South Coast programme. This analysis found that this programme is estimated to lead to reduction in the number of vehicles 15 years or older by 147,000 and an increase in the number of vehicles less than 15 years old by 87,000 in the South Coast (see *Table 5*). The programme is estimated to reduce emissions in the South Coast by 12 metric tonnes per day in 2010—a decrease of about 4 percent.[19]

Table 5 Estimates of Impact of California Scrappage Programme in 2010

	With Program	Without Program	Difference	Percentage Difference
Vehicles in South Coast (thousand metric tonnes)	10.946	11.001	-54	-0,5
0-14 years old	9.151	9.072	79	0,9
15+ years old	1.795	1.929	-133	-6,9
Vehicles in Rest of California (thousand metric tonnes)	14.837	14.912	-75	-0,5
0-14 years old	11.596	11.635	-39	-0,3
15+ years old	3.241	3.278	-36	-1,1
Emissions (metric tonnes per day ROG plus NOx)				
South Coast	308	319	-12	-3,8
Rest of California	501	503	-3	-0,5

Source: Dixon and Garber, 2001

According to this analysis, the programme is also estimated to have impacts in the rest of California as a result of the interaction of the programme with the market for vehicles in California. In the rest of California, the programme is estimated to decrease the number of vehicles 15 years or older by 40,000 and vehicles less than 15 years old by 43,000. This is estimated to lead to emissions reductions in the rest of California of 3 metric tonnes per day—less than 1 percent.

This analysis also found that the programme would lead to an in-migration of vehicles into the South Coast region due to the increase in vehicle prices in the region. Of the 750,000 cars scrapped over the period between 2001 -2010, 184,000 vehicles are predicted to be induced into the region since it is estimated that the programme will lead to an increase in price for used vehicles in the South Coast and therefore induce vehicle sales into the region. The impact on emissions depends on the make-up of the migrating vehicles. In the analysis, it is predicted that 145,000 of the in-migrating vehicles—almost 79 percent—will be less than 15 years old.

4.2. Costs

The total cost of all existing scrappage programmes has not been estimated; however, results from pilot studies and ex-ante analysis can provide some information on the cost-effectiveness of such a programme.

[19] The study estimated that the "credible" range of emissions reductions for the program was between 8 and 28 tpd.

4.2.1. Cost-effectiveness

Administrative costs of the programme are often assumed at $100 per vehicle (CARB, 1998; Alberini et al., 1994). The cost effectiveness of the programme largely depends on the level of the payment—the "bounty"—paid to vehicle owners to induce scrappage. Bounties from small-scale pilot programmes ranged from $500 to 600 per vehicle (Alberini et al., 1994). Analysis of the estimated costs required to scrap 75,000 vehicles in California ranged from $400 to 965 per vehicle.[20] For the analysis of the California programme conducted by Dixon and Garber, it was assumed that the cost per vehicle would range between $500 and $1500 (Dixon and Garber, 2001). *Table 6* shows estimates of the cost-effectiveness of the California programme. Additional analysis has developed a set of emissions reduction supply curves showing the expected emissions reductions at various bounty levels (Hahn, 1995; Alberini et al., 1996).

Table 6 Cost-Effectiveness Estimates of California's VAVR Programme (dollars per metric tonne of ROG plus NO_x)

Sierra Research, 1995	$7439
Kavalec and Setiawan, 1997	$3810 – 6078
CARB, 1998	$2359 – 6895
Dixon and Garber, 2001	$3357 – 30209

4.3. Compliance and Enforcement

As mentioned above, the California programme has yet to be fully implemented and is currently under review in the revised SIP. This could be taken as a sign of overall non-compliance by the State as insufficient funding has been provided to meet the level of scrappage outlined in the SIP. However, the programme was to be fully implemented by 2010 so California has time to remedy this issue.

4.4. Administrative feasibility

Since the programme has yet to be fully implemented it is impossible to ascertain the ease of administering such a programme.

4.5. Political Acceptability

One possible sign of the political acceptability is the fact that the programme was included in the South Coast SIP in the first place. The inclusion of specific measures in the SIP is one possible sign that the programme has garnered some level of support within the State. However, support for implementation of the programme has not fully materialized since sufficient funding has yet to be made available.

[20] CARB staff (2000) used ranges between $400 and 800 per vehicle. Econometric analysis conducted by Kavalec and Setiawan (1997) estimated a cost of $785 in 1999 and $965 in 2010.

CASE STUDY 3 – ANNEX III

THE CANADEAN EXPERIENCE WITH RESPECT TO CONTROLLING EMISSIONS FROM HIGH EMITTING VEHICLES

4 October 2004

1. Controlling Emissions from High Emitting Vehicles in Canada

1.1. Introductory Overview

In 1993, the Canadian Council of Ministers of the Environment announced the formation of a working group to develop a National Code of Practice for light-duty vehicle I/M programmes. The code provides guidance to provinces that choose to introduce I/M programmes since the Canadian Federal government does not have authority over provincial regulations. The code was approved in 1994 and revised in 1997.[21]

1.2. Emissions Sources

In 1995, Canadian transportation emissions accounted for 39 percent of national CO emissions, 52 percent of NO_x, 21 percent of VOC, 2 percent of PM_{10}, and 6 percent of $PM_{2.5}$ (Environment Canada, 1999). Similar to the United States, on-road diesel is the largest share of transportation NO_x emissions, followed by light-duty gas vehicles and motorcycles (see figure 1).

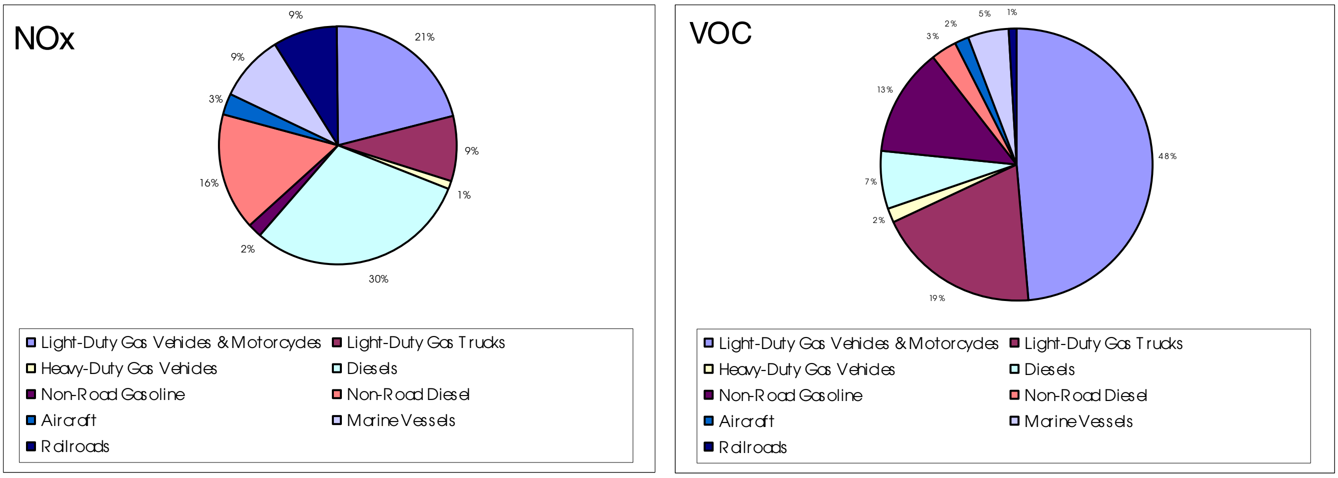


Figure 1: Canadian Transportation Emissions by Source in 1995 (Environment Canada, 1999)

2. Legislation and Measures Implemented

Canada has introduced inspection and maintenance (I/M) and vehicle scrappage programmes in a number of provinces and cities.

2.1. Inspection and Maintenance Program

In 1992, the government of British Columbia began an inspection and maintenance program—called AirCare—in Vancouver and the Lower Fraser Valley as a part of a regional Air Quality Management Plan.[22] The AirCare programme utilizes a decentralized testing system with 12 locations dispersed throughout the region. All passenger vehicles are tested using a dynamometer with model years after 1992 utilizing IM240 and pre-1992 vehicles utilizing ASM/Idle testing. The on-board diagnostic system is inspected on vehicles 1998 or older. Most vehicles undergo gas cap pressure and anti-tampering inspections. All diesel vehicles are tested for smoke opacity levels using D147 testing procedure. In January 2001, the programme was revised (AirCare II) to utilize IM240 testing for all

[21] See: www.ccme.ca
[22] For more information, see: www.aircare.ca

1992 or older vehicles and reducing the frequency of testing for these newer vehicles from annual to biannual testing.

In addition, the province of Ontario has conducted an I/M programme since 1999 called Drive Clean.[23] Under Drive Clean, vehicle owners can take their vehicle to a test-only facility or an approved test-and-repair facility. The programme requires biannual testing for vehicles beginning in the third calendar year after their model year.

2.2. Vehicle Scrappage Programmes

According to Environment Canada, there are currently seven scrappage programmes in Canada.24 The "Scrap-It" programme in Vancouver, British Columbia began as a pilot demonstration programme of removing 1,100 vehicles from the Lower Mainland and Victoria, with programme funding from a variety of organizations.25 Only vehicles that have failed the AirCare I/M test, are 1983 or older, have been insured within British Columbia for the past two years, and can be driven to the recycling site are eligible. Participants can choose to scrap their vehicle and receive one of three incentives: $750 (Canadian dollars) towards a new car, $500 towards a used car, or a British Columbia Transit pass for one year.

3. ASSESSMENT OF THE EFFECTIVENESS—BRITISH COLUMBIA I/M

A number of studies have been conducted evaluating the effectiveness of the AirCare programme in British Columbia.

3.1. Environmental Effectiveness

3.1.1. Emissions

Estimates of the AirCare programme have found that the programme has led to reductions in emissions in the region. The AirCare programme conducted an analysis using actual emissions data from the testing vehicles and compared it to an assumed scenario where the AirCare programme did not exist. The analysis used EPA's MOBILE model to estimate the total emissions reductions of the programme over each year.[26] The results show an estimated reduction in emission. Between 1992 and 2000, AirCare estimates that the programme has led to an overall reduction in NO_x, HC, and CO of 49, 64, and 53 percent, respectively (PVTT, 2001). Other estimates conducted in the early years of the programme found that the NO_x and VOC emissions reductions of the programme were significantly lower higher than those estimated by the programme operators (Coninx, 1996).

AirCare also provides estimates on the level of reduction attributed to repairs and other factors (e.g., fleet turnover). Theses estimates show that the majority of NO_x reductions (38 percent) are attributed to other factors, whereas the majority of HC reductions (34 percent) are attributed to vehicle repairs.

A more recent analysis of the programme estimated that the direct benefits from vehicle repairs conducted in the AirCare II programme has reduced NO_x emissions by 5 percent (506 tonnes) in 2001 and 7 percent (594 tonnes) in 2002 (PVTT, 2003). In addition, 22,604 vehicles failed inspection in 2001 and never reappeared for testing in 2001and 24,355 vehicles fell into that category in 2002. AirCare assumes that these vehicles are likely to be scrapped, placed in storage, or sold outside the area.

[23] For more information on Drive Clean see: www.driveclean.com/info/download.html.
[24] See: www.ec.gc.ca/transport/scrappage.htm
[25] These organizations were the British Columbia Automobile Dealers Association, Canadian Petroleum Products Institute, BC Hydro, and Vancouver and Victoria Regional Transit Commissions.
[26] It is important to note that analysis has criticized the ability of EPA's MOBILE model to evaluate emissions reductions from I/M programmes (Harrington et al., 1999).

3.1.2. Impacts

Similar to the I/M programmes in the US, it is difficult to calculate the effect of the AirCare programme on air quality in the impacted region.

3.2. Costs

When completing the Repair Data Form, repair facilities are required to provide information on the actual costs of repairs and the estimated costs of conducting all necessary emissions-related repairs. Using this data, the AirCare operators have compiled information on the average costs of repair over the life of the programme (see table 1).

Table 1: Average Repair Costs

Programme Year	Canadian Dollars
1	207
2	177
3	188
4	217
5	244
6	254
7	265
8	261

Source: PVTT, 2001

3.3. Compliance and Enforcement

It is difficult to fail to comply with the AirCare programme since a vehicle cannot be registered or receive insurance in the AirCare region without complying with the requirements. However, the AirCare programme notes that there are several ways that a vehicle could continue to be operated in the region without complying. As noted above, a number of failing vehicles do not reappear for testing in that calendar year. The programme estimates that the total non-compliance rate is less than 1 percent (PVTT, 2003).

3.4. Administrative Feasibility

While no quantitative assessment of the ease of administering the Canadian I/M programmes has been conducted, some have highlighted the significant resource costs for equipment, real estate, and training (Coninx, 1998). Similar to the U.S., a large share of the administration of the programme is conducted by private contractors.

3.5. Political Acceptability

While no exact analysis has been conducted on the political acceptance of the Canadian I/M programmes, they appear to be generally supported by Canadian Federal and provincial representatives, non-profit organizations, and industry. In addition, the two programmes in operation, in British Columbia and Ontario, have continued to operate which is possibly a sign of support for the programmes. There has, however, been concern raised that the programme is unnecessary given the air quality situation in Canada, technical problems of the program, costs, and merit of the programme compared to alternative strategies (Coninx, 1998).

CASE STUDY 3 – ANNEX IV

THE JAPANESE EXPERIENCE WITH RESPECT TO CONTROLLING EMISSIONS FROM HIGH EMITTING VEHICLES

4 October 2004

1. Controlling Emissions from High Emitting Vehicles in Japan

1.1. Introductory Overview

The Japanese *Air Pollution Control Law* passed in 1968 outlines a comprehensive set of regulations to control emissions from stationary and mobile sources. Of these programmes, the focus will be on Japanese approaches for mitigating emissions from diesel vehicles. As outlined in the Air Pollution Control Law, "the Director General of the Environment Agency shall establish maximum permissible limits on the amount of exhaust gases from motor vehicles generated under certain conditions and emitted into the air".[27] Japan adopted regulations limiting CO exhaust emissions from gasoline vehicles beginning in 1966 and has updated and revised the standards on several occasions. In addition, the *First Basic Environment Plan* (1994-2000) stressed the importance of reducing diesel NO_x and fine particulate emissions in urban areas.

In the late 1980s, it became apparent that strengthening emissions standards for stationary and mobile sources was going to be insufficient in achieving air quality standards in large cities driven by increasing road traffic. Therefore, Japan began to establish measures aimed at reducing emissions from existing vehicles. The focus of the following sections will be on the Japanese response to controlling emissions from existing diesel vehicles, in particular, through retrofit or replacement requirements and bans on diesel vehicles in certain areas.

1.2. Emissions Sources

In Japan, overall NO_x emissions have declined by 22 percent between 1970 and 1992 (OECD, 2002). Despite this overall progress, transportation emissions are still a dominant source of Japanese emissions. The transportation sector accounts for the largest share of national NO_x emissions—50 percent—and the second largest share of NMVOC emissions—13 percent (OECD, 2002).

2. Legislation and Measures Implemented

A number of recent efforts have been introduced within Japan including the motor vehicle and NO_x and PM Laws and the Tokyo diesel retrofit requirement.

2.1. Motor Vehicle NO_x and PM Laws

The Ministry of Environment (MOE) adopted the "Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides Emitted fro Motor Vehicles in Specified Areas" in 1992—The Motor Vehicle NO_x Law.[28] The regulation designated certain areas with significant air pollution due to NO_x emissions from motor vehicles—specified areas—and required that the national government develop measures to reduce the total volume of automobile NO_x in the areas. In total, 196 communities in the Tokyo, Saitama, Kanagawa, Osaka, and Hyogo Prefectures have been designated as specified areas. The prefectural governors in the designated areas are also responsible for formulating plans and comprehensive measures to reduce the total automobile NO_x emissions. The overall goal of the Law was to meet the national air quality standards by 2000, which implied a reduction in transportation NO_x emissions of 27 percent below 1990 levels (OECD, 2002).

The Motor Vehicle NO_x Law was amended in 2001 to strengthen the existing NO_x requirements and include particulate matter controls—the Automotive NO_x and PM Law.[29] This law introduced

[27] Japanese Air Pollution Control Law, Article 19, available at: www.env.go.jp/en/lar/alaw/alch3.html
[28] See: www.env.go.jp/en/lar/amobile/index.html
[29] "Law Concerning Special Measures to Reduce the Total Amount of Nitrogen Oxides and Particulate Matter Emitted from Motor Vehicles in Specified Areas".

emission standards for specific categories of in-use highway vehicles, including commercial vehicles and diesel powered passenger cars—gasoline powered cars are not included. These in-use vehicles must meet the 1997/1998 new vehicle emissions standards retroactively through replacement of vehicles with cleaner models or retrofitting with approved control devices.[30] The vehicles have a grace period to comply with the requirements according to vehicle type (see Table 1).

Table 1: Grace Period for Japanese Automotive NOx and PM Law

Vehicle Type	Years from Initial Registration
Light commercial vehicles (GVW ≤ 2500 kg)	8
Heavy commercial vehicles (GVW > 2500 kg)	9
Micro buses (11-29 seats)	10
Large buses (≥ 30 seats)	12
Special vehicles	10
Diesel passenger cars	9

2.2. Tokyo Diesel Retrofit Requirement

The Toyko Metropolitan Government adopted an "Ordinance on Environmental Preservation" in 2000. The Ordinance contains the "Countermeasure against Vehicle Pollution" programme which contains: (1) diesel emission control regulation (diesel retrofit program); (2) vehicle environmental management plan requirement for businesses; (3) requirement for use of low emissions vehicles in business fleets; (4) "idling stop" practice; (5) prohibition of heavy-oil fuels; and (6) vehicle pollution inspectors.

The diesel retrofit programme requires that existing diesel buses, trucks, and special category vehicles that operate in the city (both registered in the city and those that travel to the city) be retrofitted with particulate matter emissions control systems based upon the certification standard currently met by the vehicle (see Table 2).

Table X: Tokyo Diesel PM Reduction Requirements and Categories

Standard Met	Tier 1		Tier 2	
	PM Reduction	Category	PM Reduction	Category
≤ 1989/1990	>60%	1	>70%	3
1993/1994	>30%	2	>40%	4
1997/1998/1999	n/a	n/a	>30%	5

Each vehicle is required to install retrofit technology by 2003 for Tier 1 and 2005 for Tier 2 or seven years after the vehicle was first registered, whichever is later. Vehicles that are retrofit are affixed with a sticker designating the approval number of the PM control device. Vehicles that fail to meet the retrofit requirements will be banned from travel in the TMG area. Vehicles failing to meet the standard are subject to a fine of up to 500,000 yen.

[30] For more information on the specific limits, see: www.env.go.jp/en/lar/regulation/mv.html