Front Cover

Motor Vehicle Inspection In the National Capital Region (NCR) of Delhi

RECOMMENDATIONS FOR SHORT, MEDIUM, AND LONG TERM

“A PLAN FOR PROGRESS”

by

Lennart Erlandsson
MTC AB, Sweden

Michael P Walsh
International consultant, USA

March 7, 2003

CENTRE FOR SCIENCE AND ENVIRONMENT, DELHI

Right to clean air campaign

CSE blew the lid on smog and smogmakers in 1996 in its book *Slow murder: The deadly story of vehicular pollution in India*. The study found that the problem of vehicular pollution in India was the result of a combination of outdated engine technology, poor fuel quality, lack of transportation planning and bad maintenance of vehicles on road.

CSE exposed that the government was indulging in the game of blaming the victims of air pollution by forcing on them a system of pollution under control certificates. The hype over this periodic drive to test tailpipe emissions of cars in the absence of strong action in other areas, was cosmetic and diverted public attention from more serious issues of technology and transportation planning. But the connection between poor urban air quality and multiple factors such as these eluded most Indian citizens. To help citizens see through the smokescreen of pollution, to understand this vital **CONNECTION,** and protect public health the *Right To Clean Air Campaign* was launched in November 1996. Since then we are consistently campaigning to:

- **improve the decision-making processes related to air quality planning**
- **build up pressure on the government for more transparent policy mechanism**
- **raise public awareness about poor urban air quality and risks to public health**

If you agree with us, remember to give us your support.

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"It began during the high summer of 1995, when I saw a large number of cars line up in the heat to get their emission levels checked. Even as an environmentalist, I was not aware of all the contours of this highly technical problem of vehicular pollution. But this tailpipery struck me as a little imbecilic; as if only vehicle maintenance was at the heart of the problem. This was not the key policy measure industrialised countries took to reduce air pollution."

— Anil Agarwal

WHY THIS STUDY?

We initiated this technical evaluation as we strongly believed that the country's inspection and maintenance programme for in-use vehicles, crafted as 'pollution under control certificate' (PUC) scheme, was inherently flawed. We dismissed this as the worst form of 'tailpipery', when we launched our campaign in 1996. This was the time India had adopted the ludicrously lenient mass emissions standards for new vehicles with no fuel quality norms in place, and transport plans did not even link traffic management with pollution control. Yet the authorities obsessed with tackling this serious public health problem only from the tail end, placed the blame on the victims of air pollution first. People were targeted with a poorly designed in-use vehicle inspection programme, even before the government, automobile industry and the refineries got their acts together.

We reviewed the PUC scheme as early as 1996 in our book *Slow Murder: The Deadly Story of Vehicular Pollution in India* to understand if this programme could make a difference to any city's air. Clearly not, as the poorly kept test data showed that the system rarely failed any vehicle. Corruption, lack of proper audit, the sheer volume of tests, inadequate norms and test procedures and very low level of compliance destroyed this programme. Instead of this charade, it would have been simpler and effective to remove the visibly smoking vehicles from the roads.

While we condemned the PUC scheme, there were no other initiatives forthcoming to refine the quality and the content of the programme. This scheme remained unchanged while mass emissions standards for new vehicles were tightened three times in Delhi since 1991. In July 1998, the Supreme Court of India stepped in and directed that "*comprehensive I&M programme be started by the transport department and private sector by March 31, 2000.*" But continuing official apathy pushed the PUC programme further back. This was also the time when Court's intervention triggered other important changes in Delhi including the advancement of Euro II emissions standards, improvement in fuel quality norms, moving public transport, three-wheelers and taxis to CNG.

The automobile industry, the only patron of PUC, set about giving it a facelift by adding a few gizmos — a Web camera for automatic imaging of number plate at the time of the testing and a computer for automatic data recording. These cosmetic upgrades quashed all incentives to make the programme truly effective. Strangely enough, industry was left to design the inspection framework for its own products and there was no discussion in the public domain on what makes in-use inspection effective. Since the government never made the attempt to assess the effectiveness of the programme, the state transport departments became obsessed with expanding the network of the computerised PUC centres.

Why did we get involved?

We took notice when the Delhi government made a similar announcement in June 2002 to computerise nearly 400 PUC centres in Delhi as well. Since we got the opportunity to be involved in the consultative process with the Delhi transport minister Ajay Maken, we decided to take a closer look. We found that nothing had changed in the programme since our last review in 1996. All vehicles had to meet uniform and outdated norms and follow very basic test procedures irrespective of technology levels. The enforcement mechanism was still so weak that less than 20 per cent of the vehicles were in compliance.

We analysed PUC test data collected randomly from about 13 stations for the tests conducted during the Delhi government's special enforcement drive from June to August 2002. The average failure rate was even less than 10 per cent. While 13 percent of petrol cars and two-wheelers failed, less than one per cent of trucks failed and the entire sample of diesel buses passed. Unbelievably, the commercial diesel fleet in the city was the cleanest chart buster!

We went to the field as well. We found that even with the camera and the computer it was easy to circumvent the test procedures and manipulate results. We were stunned to notice how test booth operators 'advise' drivers to beat the system. For instance in diesel vehicles, instead of rapidly accelerating to full throttle as mandated under the current free acceleration test procedures, booth operators encourage drivers to accelerate gently and partially to keep the smoke reading within the permitted limit. Similarly, in petrol vehicles, because only carbon monoxide is measured, any competent driver can readily adjust the air-fuel mixture to lean range in carburetted vehicles to temporarily lower CO emissions to pass the test.

We felt the strong need for a proper technical evaluation and a public review of the programme to ensure that an effective inspection system is in place before new investments are allowed in this farcical programme. Business and investment plans should not precede policy and planning and present a situation that is *fait accompli.*

It was therefore, agreed that CSE would come back with a proposal for an appropriate plan for vehicle inspection programme in Delhi that the government could implement.

In the meantime, the problem of emissions from on-road vehicles caught the attention of the Supreme Court once again. In the ongoing public interest litigation on air pollution in Delhi, the *Amicus Curiae*, Harish Salve, submitted to the Supreme Court on July 15, 2002, *"It has been reported that 'pollution under check system' being operated under Delhi Transport department leaves much to be desired. It is submitted that the Bhure Lal committee should be directed to examine the system and define the in-use emission norms and to direct any improvement that it may consider appropriate."* The Supreme Court has put this on record and has directed its advisory committee Environment Pollution (Prevention and Control) Authority (EPCA) to examine the matter.

EXPERTS' PROFILE

Michael P Walsh
International consultant
USA

Michael P Walsh, former director of motor vehicle pollution control with the Environmental Protection Agency, US, has spent his entire career working on motor vehicle pollution control issues at national, and international levels. He has extensive and unique international experience with motor vehicle pollution control strategies — unleaded gasoline, alternative fuels, inspection and maintenance, emission control technology, emissions standards and regulations. He has served as the chairperson of the World Bank Advisory Panel to the Mexico City Transport/Air Quality Management Program and in a similar capacity with the Chinese National Environmental Protection Agency. He currently co-chairs the US EPA's Mobile Source Advisory Subcommittee. He has also served as chairperson of the transportation subgroup of the IPCC Good Practices in Emissions Inventory Workgroup. The United Nations Environment Program has recently published two of his reports to assist developing countries in addressing motor vehicle pollution problems. He is the first recipient of the US EPA lifetime achievement award for air pollution control.

Lennart Erlandsson
Motor Test Centre AB
Sweden

Lennart Erlandsson, general manager, Motor Test Centre (MTC AB), Sweden, one of the largest motor testing centres in Europe, has worked extensively on issues related to vehicles, fuels, and inspection and maintenance. He has served as the secretary in a governmental committee dealing with environmental classification of vehicles and fuels. He has been the Swedish delegate in the working group on "Environmental Friendly Transport System in the Baltic States". He has served as an expert for the Swedish Consumers Organisation in matters related to emissions and fuel consumption. Further he has managed Tehran Transport Emission Reduction Project. He was a member of the Swedish delegation in COST 319 (Emission Factors and Function), and also at CATEC-97 in Beijing, China. He also represented at UNECE Task Force on Emission Inventories. Additionally, he has been deeply involved with many CNG programmes around the world. He has conducted two technical evaluations of CNG bus technology in Delhi for the Centre for Science and Environment.

We immediately decided to do an independent technical evaluation of the current PUC system with the aim of designing and charting a plan of implementation for an improved vehicle inspection programme in Delhi. For this, we invited international experts — Michael P Walsh, US-based international expert in vehicle technology and emissions who has helped many governments round the world to design strategies to control vehicular emissions, and Lennart Erlandsson, vehicle technology expert from Motor Test Centre, (MTC AB) Sweden who has been involved in many such programmes in different countries.

They visited Delhi during the first week of October, 2002 and completed their study based on field visits and consultation with concerned agencies. They have presented their plan of action. *'A Plan for Progress'* presents the road map for establishing a centralised inspection system in a phased manner with commensurate and improved test procedures and standards for different vehicle categories and technology levels, and administrative and institutional framework needed for independent audits and quality control. This is a task-by-task policy guide to direct smooth implementation of the vehicle inspection system in Delhi.

The challenge

A city like Delhi with an incredible mix of vehicle technologies and vintage, different technology levels, and its uniquely large fleet of CNG vehicles requires a specially designed inspection system that is based on more advanced tests procedures and standards, and capacity for enforcement.

The only important change in the official attitude so far is the acknowledgement by the union ministry of road transport and highways that the state governments can introduce tighter emission norms for in-use vehicles. This was placed on the agenda in the recently held 30th meeting of the Transport Development Council, group of state transport ministers, on January 16, 2003. It is time to make use of these legal provisions to effectively upgrade the city-based systems. But paradoxically, the state governments are not legally empowered to develop standards and test procedures on their own.

What is likely to hold back progress in Delhi is delay in putting in place the improved test procedures and appropriate norms needed for an improved centralised inspection system (as recommended by our experts). This is the responsibility of the central government. But the central government is merely tinkering with the PUC norms instead of developing advanced test procedures alongside. This is not acceptable. If the city governments, including the Delhi government, want to take advance action the minimal provision of PUC must not weigh down progress. This report brings out that even the new PUC norms that are under consideration are too lenient to make an impact.

Moreover, any testing programme for diesel vehicles should be able to address the problem of particulate emissions, the cause of great health concern in the city. The government ignores the growing body of evidence as presented in this report, that the current smoke opacity measurements are not representative of the particulate emissions from diesel vehicles as there is poor correlation between smoke opacity and particulate emissions.

In view of the known limitations of the current free acceleration smoke opacity test mandated for diesel vehicles this report recommends the immediate adoption of transient loaded mode test procedures, — testing mass emissions by simulating on-road driving speed on a chassis dynamometer, — for commercial vehicles on a priority basis in Delhi. This would help to overcome the limitation of the current system, prevent manipulation and evasion, and, allow the measurements of particulates and nitrogen oxides. The adoption of advanced test procedures for diesel vehicles is still not on the official agenda.

It would be an even bigger challenge to create state of the art private centralised inspection facilities with strong government supervision and independent audits to maintain the integrity of the programme in Delhi. The city government must put in place a system for auditing the entire inspection process.

Ultimately, management of in-use emissions must be built on the principles of both consumer and manufacturers' responsibility. That even new vehicles pollute heavily cannot be blamed entirely on the grounds of poor maintenance. International experience shows that inherent technical defects in emissions control systems can be responsible for high emissions. But detection of systematic failure in the components that have bearing on emissions is not possible in the current PUC tests.

We had stoked the debate over manufacturers responsibility when the new reincarnate of two-stroke two wheelers fitted with catalytic converters of very low durability rolled out around year 2000. EPCA had then proposed a ban on two-stroke technology. For us the only alternative to a ban could be an emissions warranty so that the manufacturers take the responsibility for on-road performance. In response the two-wheeler industry conceded to emissions warranty. But clearly, establishing a principle is not same as enforcing it. Emissions warranty cannot be pegged to a dismally primitive PUC as it can never track systemic failures in batches of vehicle in the market.

The challenges are many. Today, very few strategies exist to control emissions from in-use vehicles. The Delhi government has taken important steps in capping the age of commercial vehicles and converting the old fleet of diesel buses, three-wheelers and taxis to CNG, which have indeed made a lot of difference to the capital's air. But there are still no immediate emission control strategies for millions of diesel trucks, other commercial vehicles, two wheelers and diesel cars on road. Only an effective inspection system can keep them clean. More important, even the new fleet of vehicles running on clean fuels like CNG and those meeting improved mass emissions standards would also require strong policing — necessary to maintain their low emissions during their useful life on the road.

This report thus concludes that a major overhaul, redesigning and upgrading of the current system is urgently needed for it to make any significant impact on Delhi's air. If polluting vehicles are not tracked through a rigorous and credible inspection system any gain from improvements in technology can easily be lost.

We would like to take this opportunity to express our gratitude to all agencies that have cooperated with our experts. This study would not have been possible without financial support from the Swedish International Development Cooperation Agency (SIDA). We wish to offer them our sincere thanks.

We hope that '*A Plan for Progress*' as presented in this report will become the basis for the implementation of the inspection and maintenance programme in Delhi. Vehicle inspection programme cannot win public support unless it is made more credible and demonstrates effectively that it can actually help in cleaning the city's air.

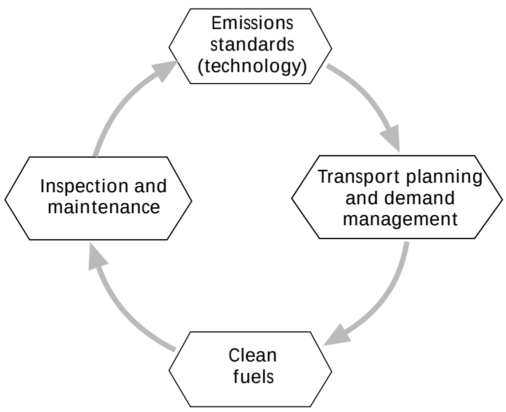
Right to Clean Air Campaign **March 7, 2003**
Centre for Science and Environment
New Delhi

"A PLAN FOR PROGRESS"

1. BACKGROUND AND INTRODUCTION

The goal of a motor vehicle pollution control programme is to reduce vehicular emissions to the degree reasonably necessary to achieve healthy air quality as rapidly as possible. A comprehensive strategy to achieve this goal includes four key components: increasingly stringent emissions standards for new vehicles, specifications for clean fuels, programmes to assure proper maintenance of in-use vehicles, and transportation planning and demand management. These emission reduction goals should be achieved in the most cost effective manner available.

Figure 1: Elements of a comprehensive vehicle pollution control strategy



Although significant measures have been carried out in recent years to control mobile source emissions in Delhi, there is still much to accomplish to reach acceptable levels of ambient air quality. Some of the steps carried out in recent years include tightening of new vehicle emissions standards, lowering sulphur in diesel and petrol to 500 ppm, lowering benzene in petrol to one per cent, and shifting public transport vehicles from diesel to compressed natural gas (CNG). These have lowered particulate and other toxic emissions from vehicles and improved air quality. However, air quality levels remain well above healthy levels and additional control measures are needed. One of the most important of the remaining potential measures that could bring about significant additional emissions reductions is to upgrade the existing inspection and maintenance (I/M) programme.

This paper will review the role of I/M in a comprehensive motor vehicle pollution control strategy, summarise the international experience with a good I/M programme, review and critique the current pollution under control (PUC) programme and the steps currently underway to improve it, and provide a similar review and critique of the fitness check and inspection of commercial vehicles in Delhi. Finally, the report will conclude with a series of recommendations to create a fully successful I/M programme in Delhi.

Between September 27 and October 5, 2002 we carried out a series of visits and met representatives from concerned agencies to learn about the inspection system in

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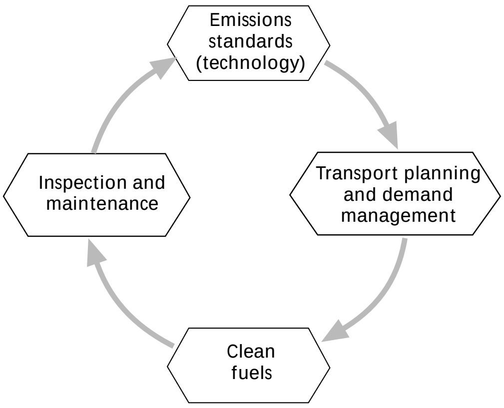

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Between September 27 and October 5, 2002 we carried out a series of visits and met representatives from concerned agencies to learn about the inspection system in

Delhi and investigate the possibilities of introducing an enhanced system for vehicle inspection. We met with representatives of the following organisations:

Government Regulatory Agencies
i. State Transport Authority (STA), Department of Transport, NCT Delhi
ii. Central Pollution Control Board
iii. Burari Inspection Centre

State Transportation Company
Delhi Transportation Corporation, (Bawana Depot)

Certification Agency
Automotive Research Association of India (ARAI)

Instrument Manufacturers
i. AVL India Pvt Ltd
ii. Modi Measurement Systems Pvt Ltd
iii. Rotax Marine Pvt Ltd
iv. TTC Laser Machines Pvt Ltd
v. Perfect Marketing & Engineers

Representatives of the Automobile Manufacturers
i. Society of Indian Automobile Manufacturers (SIAM)
ii. Tata Engineering
iii. Ashok Leyland
iv. Maruti Udyog Limited

Other Organisations
Association of State Road Transport Undertaking (ASRTU)

Minor malfunctions can increase emissions significantly. Major malfunctions can cause emissions to skyrocket. A small number of vehicles are responsible for significant fraction of overall emissions

2. THE ROLE OF I/M IN A COMPREHENSIVE MOTOR VEHICLE POLLUTION CONTROL STRATEGY

Safer traffic conditions and optimal respect for the environment are dependent on the general condition of vehicles as well as other factors such as the behaviour of the driver and road conditions. In addition to improving safety, the experience from projects all over the world demonstrates that one of the most economical and fastest ways of improving the ambient air quality is to introduce a system for vehicle inspection or to enhance an already existing system and further improve the quality or type of fuel used. A vehicle inspection programme checks the general conditions of a vehicle at regular intervals to assure that it is in a good state of repair and that existing pollution controls are functioning properly. Today's internal combustion engines rely on effective functioning of emissions controls to keep emissions low. Minor malfunctions in these systems can increase emissions significantly and major malfunctions can cause emissions to skyrocket. The purpose of an I/M programme is to assure that a vehicle is properly maintained and used.

Experience shows that a relatively small number of vehicles with serious malfunctions can be responsible for a significant fraction of overall emissions. The major objective is to identify these dirtiest (high emitting) and unsafe (with major malfunctions of vital components) vehicles and get them repaired. But it is rarely obvious which vehicles fall into this category, as the emissions themselves may not be noticeable and emissions control malfunctions do not necessarily affect vehicles driveability. Effective I/M programmes can identify problem vehicles and assure their repair. I/M can play a very important role in ensuring that in-use vehicles actually achieve what they are technically capable of.

3. DEMONSTRATED IMPACT OF I/M ON AIR QUALITY

It has been well established that properly designed and operated I/M programmes are capable of reducing emissions significantly. For example, in one recent evaluation of the long term benefits of the British Columbia I/M programme, it was determined that over the first eight years of the programme, hydrocarbon (HC) emissions were reduced by 34.3 per cent, carbon monoxide (CO) by 38.4 per cent and nitrogen oxide (NO_x) by 10.3 per cent.[1]

In an effort to determine the mass emissions reductions from the programme, a sample of 957 vehicles was tested in the laboratory before and after normal repairs. The results are summarised in graph 1.

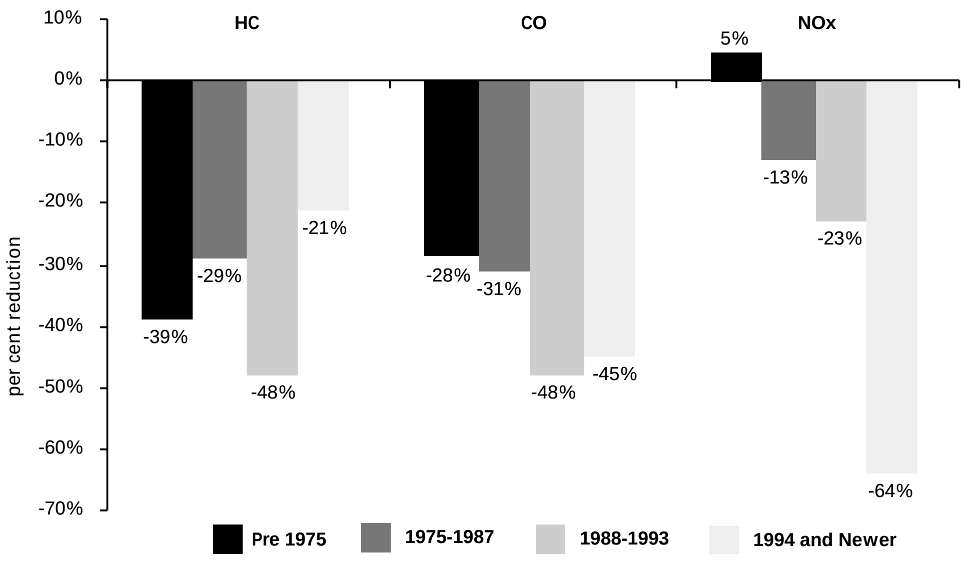
Substantial decreases in average emissions are evident in all cases but one. An increase in average NO_x emissions of 4.5 per cent was observed among the oldest vehicles. The newest vehicles on the other hand tended to show NO_x reduction of 13 to 64 per cent.

It has been demonstrated that a properly designed centralised I/M programme results in very high quality test programme

In addition to the emissions reductions, the audit programme found that fuel economy for the failed vehicles improved by approximately 5.5 per cent for an estimated annual savings of $72 per year per vehicle.

The audit programmes also demonstrated that the centralised programme resulted in a very high quality test programme. For example, after reviewing over 2 million tests, the auditor concluded that incorrect emissions standards were applied in only 1.1 per cent of tests. Not one instance was found where a vehicle was given a conditional pass or waiver inappropriately.[2] About 1 per cent of the failed vehicles were found to be receiving waivers even though their emissions were excessive, i.e., they exceeded either 10 per cent CO, 2,000 ppm HC or 4,000 ppm NO_x. If the cost

Graph 1: Emissions reduction following repairs of failed vehicles



limits were increased such that these percentages were halved, the auditor concluded that HC and CO reductions from the programme would each increase by about 5 per cent.

Available data also indicates that many vehicles are repaired adequately to remain low emitting. For example, almost 53,000 vehicles that failed the test the first year were repaired well enough to pass the following year.

Overall data confirms that I/M programmes, when properly performed in a centralised facility using a loaded mode test, can and do achieve a substantial reduction in emissions. Substantial fuel savings accompanies these reductions. According to the auditor, improving the programme to include evaporative testing, reducing or eliminating cost waivers, adding the IM240 test or tightening the standards could all increase the overall benefits significantly.[3]

There are no well defined criteria for authorising or registering PUC centres

As vehicle technology advances, more sophisticated test procedures are necessary. These procedures include loaded mode tests that use a dynamometer to simulate the work which an engine performs during driving.

Substantial advances are being made in I/M programmes. For the most advanced vehicles, those equipped with electronic controls of air-fuel and spark management systems and catalytic converters to reduce CO, HC and NO_x, a transient test which includes accelerations and decelerations typical of actual driving can provide additional emissions reduction benefits.

In general, I/M is most effective with centralised inspection systems. These programmes also cost much less overall and are more convenient for the public.

The United States National Academy of Sciences (US NAS) has recently recommended several improvements to I/M programmes.[4] A variety of issues were identified by the Academy as requiring careful attention — site selection, effects of engine load, attention to quality assurance and quality control, and achieving adequate coverage of the in-use fleet were specifically highlighted.

Summarised in Appendix A are the various test procedures that can be used in I/M programmes.

4. REVIEW OF THE POLLUTION UNDER CONTROL (PUC) PROGRAMME IN DELHI

PUC centre in Delhi

Technical revisions and measurements of emissions must be done in a way to convince people that the test is truly objective and there is no self-interest in carrying out these tests. It must be a high quality inspection. The equipment must be calibrated to ensure that it is in working order. The personnel must be well trained and familiar with the objectives of inspection. Test procedures must be appropriate for the technology being tested.

Contrast these principles with the actual experience in Delhi with the Pollution under control (PUC) programme.

Currently, there are nearly 400 PUC centres authorised by the Delhi transport department to carry out prescribed emission tests for all types of private vehicles. The PUC centres are either located at the premises of refuelling stations or service workshops. There are no well-defined criteria for authorising or registering PUC centres. Organisational structure is not conducive to objective, high quality tests. The authority responsible for authorising and registering PUC centres does not carry out a sufficient number of audits at the PUC centres. Systematic procedures for collection of test results for further analysis do not exist.

Another major problem with the PUC centres is maintenance and calibration of instruments. An Annual Maintenance Contract (AMC) with the manufacturers of the instrument for regular calibration and maintenance should be the pre-condition for authorisation or registration of the PUC centres. In reality, this seems to be rarely implemented or enforced.

Another and perhaps a fatal drawback of this system is that only 15-20 per cent of the vehicle population comes to the PUC centres for tests. The reasons can be summarised as follows:

— Lack of enforcement
— Poor system for identifying vehicles not visiting the centres
— Imperfect system of auditing

Perhaps the most important reason is the lack of public confidence in the system.

5. REVIEW OF THE PRESENT SYSTEM OF "FITNESS CHECK" AND INSPECTION OF COMMERCIAL VEHICLES

According to the instructions issued by the Government of National Capital Territory of Delhi Transport Department in April 2002: "*Inspection and Certificate of Fitness (COF) is mandatory for every transport vehicle at the time of registration, which is valid for two years from the date of issuance.*" The COF is thereafter renewed based on a new fitness check every year.

Inspection pit at the Burari inspection centre

A total of 30 tests and checks are prescribed under the rules. Fulfilment of these requirements should be assured with the results entered and stored in a computer. The inspector follows a checklist of all tests during the inspection. However, detailed descriptions of how to carry out each test or information about pass/fail criteria are not available. The following items should be checked, if/when applicable:

i)	Brakes	ii)	Steering gears
iii)	Suspension	iv)	Engine
v)	Overall dimensions of the vehicle	vi)	Horn
vii)	Lamps/signals	viii)	Chassis embossing
ix)	Speedometer	x)	Paint
xi)	Wiper	xii)	Dimensions
xiii)	Body	xiv)	Fare meter
xv)	Electrical	xvi)	Finishing
xvii)	Road Test	xviii)	Pollution
xix)	Transmission	xx)	Safety glasses
xxi)	Rear view mirror	xxii)	Spark plugs
xxiii)	High tension cable	xxiv)	Head lamp beam
xxv)	Other lights	xxvi)	Reflectors
xxvii)	Silencers	xxviii)	Dash board equipment
xxix)	Suppressor cap	xxx)	Other

The checklist provides space for making notes of deviations or remarks. After the inspection, 'Inspector 1' and 'Inspector 2' (working as a team) and also a representative of the vehicle (owner/driver) sign the checklist. The intent is that all concerned parties come to an agreement about the deviations.

Discussions with the inspectors indicate that at present only eight inspectors (divided in four teams) are working. The time taken for inspection of a diesel truck was estimated to be 5-10 minutes, a diesel bus 5-15 minutes and a CNG bus as much as 45 minutes. A special team assigned by STA carries out inspection of gas installation in CNG buses.

According to the information available from the manager of Burari inspection facility, about 150,000 vehicles come to the Burari inspection centre each year for fitness checks with an additional 6,000 vehicles that come for follow-up on type approval and pre-registration tests before they are allowed to be sold. The latter inspection is carried out on request from vehicle manufacturers. A simple calculation estimating an 8-hour working day and 300 working days per year and 10 inspectors, gives the average time for one inspection as 9.2 minutes.

While all commercial vehicles are supposedly required to undergo a mandatory annual "fitness check" at the Burari inspection centre, the present facility is completely inadequate with regard to either traffic safety tests or emission checks. During our visits to the Burari inspection centre only visual inspection of safety items was carried out and no test equipments were in working condition. For example, we observed one school bus without brakes on one of the rear wheels, and another bus with the rear shock absorber hanging loose. It is presumed that a majority of vehicles would fail if a control of the braking force on a brake tester were carried out. This should be of special concern in India where fatal accidents involving heavy-duty vehicles are common.

The present facility is completely inadequate with regard to either traffic safety tests or emissions checks

The actual "fitness check" at the Burari inspection centre is carried out without necessary equipment or instruments. While earlier visits showed some signs of a "computerised test lane", during this visit the consultants were just told that the instruments were not working.

The inspection procedures and the information given by one of the inspectors indicate that the procedures are fundamentally flawed. For example, the owner/driver is present when the vehicle is taken through the inspection drill. There is thus a strong possibility of influencing the results of the inspection. Officials do not carry out a test drive of the vehicle; rather, the driver is only asked "leading" questions, such as — the speedometer is working ok, isn't it? Just asking the driver to drive through the inspection lane for the brake test, and "brake as hard as you can and we will look for imprints" is considered sufficient. The steering was checked by the inspector by turning the steering wheel back and forth (5-10 cm), and at the same time observing the movements of the wheels. Needless to say, the present inspection system does not even come near the required quality.

The consultants were informed that the failure rate, despite the poor quality, was 4-5 per cent, which is somewhat alarmingly low compared to international experience. For example, consider the recent statistics from Sweden. About 33 per cent of all tested passenger cars in Sweden had to be re-inspected after adjustments. Out of these 33 per cent, about 20 per cent had failure in the braking system. About 25 per cent of all buses tested had severe malfunctions in the brake system requiring re-inspection of the vehicles after repair. The corresponding figure for light and heavy-duty trucks was 40 per cent.

Emissions tests of all commercial vehicles are apparently combined with the mandatory annual fitness check. During a visit to Burari earlier in 2002, the consultants were informed that measurements of tailpipe emissions were no longer carried out at Burari. Instead, the drivers first had to obtain a certificate from the PUC centre and then present it at the Burari inspection centre as proof of having passed the emissions test. This was conditional to the fitness check. This time, the consultants observed that emissions test for commercial vehicles had been brought back to Burari. But there was confusion amongst the vehicle owners. The consultants noted that some commercial vehicles were still going to PUC centres.

6. A PLAN FOR PROGRESS: DETAILED RECOMMENDATIONS RELATED TO THE "NEW SYSTEM OF I/M" IN DELHI

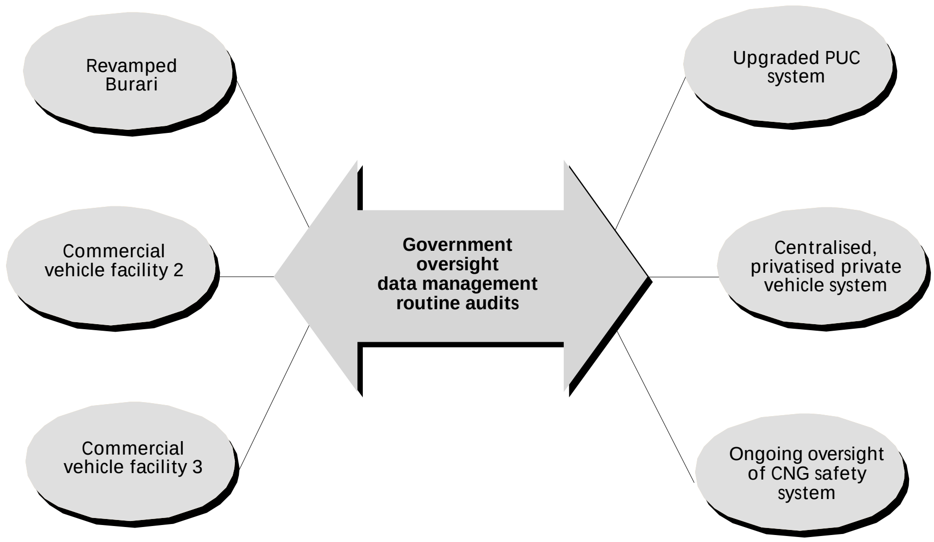
The main recommendations for further improvement of the present system and the introduction of a new enhanced system for vehicle inspection in Delhi are summarised below. A Gantt chart describing the steps necessary to implement these recommendations is attached. The principle recommendations are as follow:

Phase in a centralised inspection system with commensurate test procedures and norms for all categories of vehicles in Delhi

- **As a first step, we recommend upgradation of the Burari centre for commercial vehicles for combined emissions measurement with safety controls and fitness checks. Improve and upgrade emissions inspection at the PUC centres alongside, as discussed in a later section.**

- **We propose a phase-in plan for centralised inspection system with commensurate test procedures and norms for all categories of vehicles in Delhi. A complete phase-out plan of the numerous existing testing centres that are difficult to control and supervise must be scheduled. *Even while upgrading the PUC system, announce the plan to completely centralise & privatise the system in a given time frame.* The priority focus should be on the most polluting categories like the commercial vehicles. Thereafter, shift focus to other high emitters such as two-wheelers with two-stroke engines and vehicles with advanced emission control systems such as those with catalytic converters. Give CNG buses the highest priority for moving them to**

Figure 2: The overall strategy for a high quality I/M programme



centralised centres where more advanced testing facilities would be made available. Since commercial vehicles already need to go through routine annual fitness check and emissions tests, the Burari inspection centre should be immediately upgraded to meet the requirements.

A. INSPECTION OF COMMERCIAL VEHICLES

We propose a three-step approach to carry out inspection of commercial vehicles in Delhi.

Step 1: Substantially upgrade the Burari inspection centre

- Three fully equipped lanes with a capacity of 60,000 tests per annum on eight-hour shifts should be installed.
- One additional lane for three-wheelers with a capacity of 30,000 tests per annum on eight-hour shifts should also be installed.
- It is estimated that the cost per lane will be approximately Rs 10-15 million.
- Construction of the facility, purchase and installation of the equipment could be completed within a year or less.
- It is strongly recommended that the facility be built and operated by a private contractor selected through a competitive bidding process.

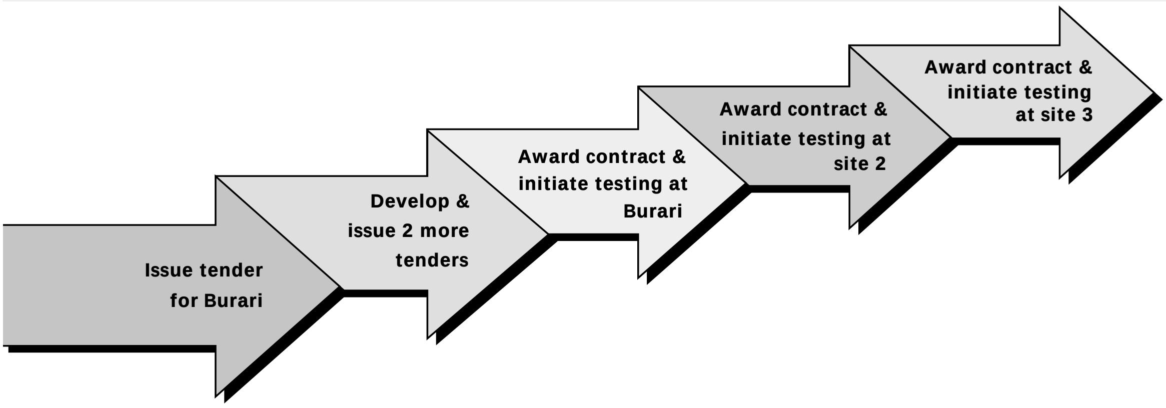
An international tender document should be developed and released to invite internationally recognised inspection companies together with local counterparts to establish three new fully equipped inspection lanes for four-wheel driven commercial vehicles and one new fully equipped inspection lane for three-wheelers.

The Burari centre should be privatised and to assure long-term transfer of know-how, the tender should describe in detail how this would be managed. The new Burari inspection centre should be in full operation one year after the release of the tender.

Step 2: Add a new privately built and operated inspection centre for trucks

As soon as the tendering process for the Burari inspection centre is initiated, a new tender should be released with a focus on inspection of trucks. The technical capability of the inspection lanes should be same as for the Burari inspection centre, but preferably, the location of this second inspection centre should be in south of Delhi to reduce travel distance of the vehicle to be

Figure 3: Sequence of events for commercial vehicle testing



inspected. The new second inspection centre should also be in full operation one year after the issuance of the tender document and close to the opening of the Burari centre.

- Three lanes focused on trucks should be included with a capacity to test 60,000 vehicles/annum per shift.

Step 3: Add a third new privately built and operated inspection centre for commercial light duty vehicles and three-wheelers.

The third inspection centre should be tendered at the same time as the second and in the same way as the other two. Two inspection lanes should be built for light-duty vehicles and one inspection lane for three-wheelers. With the third inspection centre in operation the demand for testing of commercial vehicles can be met. The inspection centre number three can be put in operation by middle of 2004.

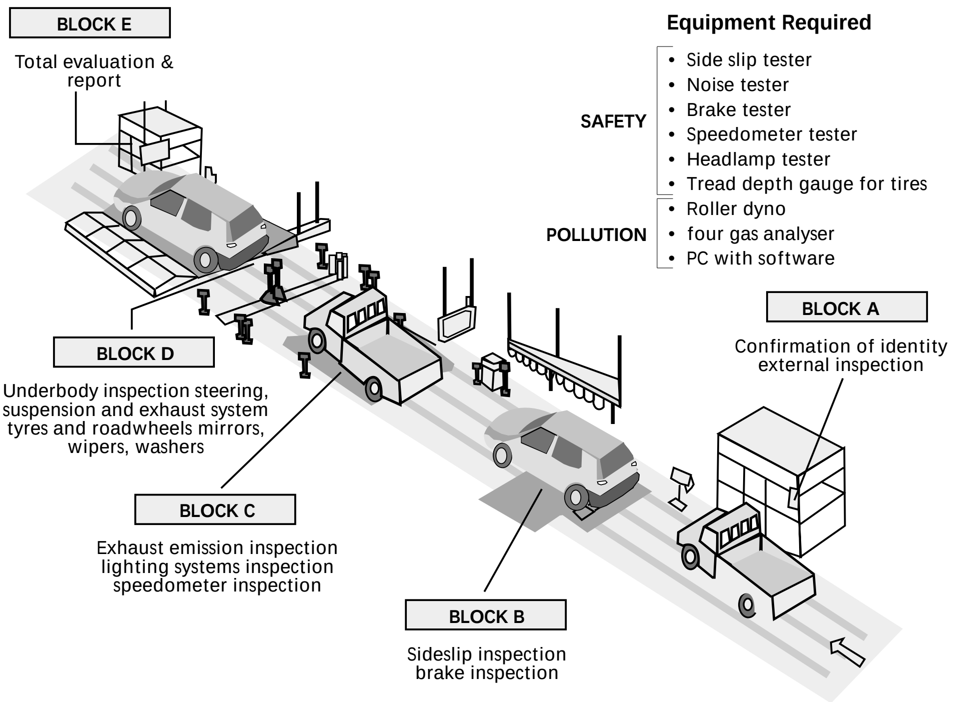
- Two lanes focused on light-duty vehicles and one lane for three-wheelers should be included.

B. UPGRADING OF PUC CENTRES

Several improvements are critically needed in the present PUC centres until the centralised inspection centres are fully established. It has been roughly estimated that instead of 400 centres currently in operation, about 100 centres would suffice to meet the volume of demand for emissions test in Delhi. Some immediate and major steps are required to upgrade the current PUC centres:

- For measurement of emissions from petrol and CNG vehicles, 4-gas analysers

Figure 4: A typical inspection scheme



certified for all four gases (CO, CO_2, HC and O_2) must be mandated. With 4-gas analysers and the possibility to calculate the lambda-value (air/fuel ratio), it will be possible to identify leaking and faulty exhaust systems as well as incorrect insertion of the test probe. Analysers should be approved by the concerned organisations according to Indian and international standards. Test results along with lambda-values should be stored in computers in each centre for future analysis.

Free acceleration test at Burari

- For measurement of emissions from diesel vehicles, upgrade instruments and test procedures to include measurement of engine revolution per minute (RPM), oil temperature, automatic indication whether the test itself is acceptable or not, and storage of test results, etc.
- Further, PUC centres should be equipped with web-cameras for taking pictures of the registration plates during the actual measurement. At the same time, with the newly developed test protocol, the certificate should show the actual measured values, relevant limit values, photo of the registration plate, vital vehicle data and an 'automatic' pass/fail decision.
- An integrated network of PUC centres must be created with independent management of each centre. It is necessary to set up a bidding process even for PUC centres. Those operating the PUCs should have no direct involvement in the repair of vehicles. Inspection centres should not have any connection with the gas filling stations or repair workshops, which is the norm today. These should be under independent management.
- Introduce annual registration of PUC centres based on availability of proper equipment and infrastructure, maintenance and calibration status of equipment, availability of trained operators, quality of test records, audit reports, and availability of sufficient space.
- Individual inspectors must be trained to perform the test properly, maintain equipment and follow methodology and schedule for calibration of the instruments. Photographs of trained inspectors along with the copies of their certificates for training should be displayed at PUC centre all the times.
- Training of PUC operators should be carried out both by the manufacturer of instruments as well as a competent authority responsible for supervising the system. A 'license' should be issued and displayed together with a photograph of the operator so that customers know that the operator is trained. Introduce regular mandatory training courses covering test procedures, revised norms, precautions to be taken while testing, health hazards, etc.

For measurement of emissions from diesel vehicles, upgrade instruments and test procedures

For petrol and CNG vehicles, adequate new limit values for idle and high idle measurements should be developed. Initiate a pilot project to identify suitable cut-points for each group of vehicles. Follow a timetable for a gradual phase-in of the relevant limits for various vehicle types. For vehicles with two-stroke engines new techniques of measurement must be developed, especially for measuring smoke during controlled conditions.

For diesel vehicles measurement of opacity must be improved. Measurement of engine RPM and oil temperature should be mandated and used for verification of a properly warmed up engine. The opacity meter should identify or validate after sufficient number of repeatable test cycles, if the test sequences are acceptable. The instrument should store test results or transfer them to the computer to be recorded in the PUC certificate.

C. GRADUAL SHIFT FROM PUC CENTRES TO CENTRALISED LANES FOR ALL VEHICLES

As soon as the three facilities for inspection of commercial vehicles are completed, other types of vehicles should be introduced into the new system.

- Replace the smaller PUC centres with fewer centralised but bigger centres capable of testing large number of vehicles at a time and keep them under strict surveillance. As centralised inspection facilities expand, keep phasing out the smaller centres.
- The frequency of measurement should be changed from once every three months to once a year for private vehicles in the improved system, but with no higher total cost to the vehicle owner. In this context, it must be made clear to all PUC operators that this system is temporary and transitional till a permanent centralised system is fully established.

Centralised inspection centres for passenger cars should be introduced and spread across the city. The size of these centres should be smaller than the ones for commercial vehicles but still large enough to cope with a significant number of passenger cars and two-wheelers each day. As proposed for commercial vehicles, similar but smaller centres for personal vehicles should also be operated by private enterprises and tendered in the same way as mentioned above. A phase-in programme needs to be determined. It is recommended to start the inspection programme for new catalyst vehicles (to maintain low emissions for a longer period) and for two-wheelers, specifically with two-stroke engines, since they are the major contributors to the poor air quality. The target for a complete conversion to a centralised inspection system should be 2006.

7. INSTRUMENTATION

The instrument used for emission measurement of petrol and CNG vehicles at PUC centres must be approved and certified. At present, only Automotive Research Association of India (ARAI) certifies instruments. The base requirements for the analyser is the ISO 3930 standard with some deviations, of which the most important is higher working temperature to adapt to conditions in India (+50°C). Unfortunately, as of yet, no instrument has been approved for measurement of HC in India. It is recommended that analysers be approved for all pollutants that can be measured on a single unit (4-gas or 2-gas analyser). In addition, a system for certifying opacity measurement instruments must be arranged for, if not already in place.

4-gas analyser in a PUC centre in Delhi

8. THE NEW FITNESS CHECK

The detailed programme for inspection of traffic safety related items is not elaborated further in this report. But one of the measures to be decided in the near future is suitable programmes for inspection, training of personnel and detailed planning of the inspection centres. In addition, enhancement of institutional arrangements is a high priority measure. Today, privately owned passenger cars are subjected to a "fitness check" only when the vehicle is new. Thereafter, this is not repeated before the age of 15 years and at that stage it is not possible to verify if tests have been repeated!

We wish to note that the components that are inspected under the current fitness check remain in the new inspection system; however, the method for control and classification of "pass" or "fail" must be substantially different from the current practice.

9. SPECIAL FOCUS ON SAFETY INSPECTION OF CNG BUSES

Significant improvement has been made since the previous visit of the consultants to evaluate safety aspects of CNG buses in Delhi. Another organisation, Association of State Road Transport Undertaking (ASRTU), has been given the responsibility for inspection of the CNG installations. This arrangement had been in place only for about two weeks at the time of our most recent visit. During that period, it had inspected about 35 buses; 28 of these were found to have significant problems. The most common failure was gas leakage (identified by a methane analyser), bad clamping of the gas pipes, pipes crossing each other, electrical wires not fixed to the chassis as required, gas pipes not fully visible, and protection for gas cylinders not properly arranged. Another failure was inadequate identification of gas cylinders. The inspectors indicated that they were still in the process of learning. The new system seems to have a good potential for the future although some routine administrative measures need to be looked at. These include:

- — The best way to inform the owner about discrepancies in the vehicle and 'pass' or 'fail' status of the vehicles after inspection (according to contract the result should be submitted to STA for further action)
- — How to keep owner of the vehicle away at the time of physical inspection (we can foresee a risk of owner trying to convince/influence the inspector to overlook deviations)
- — How to arrange suitable feedback to department of transport, Burari and ARAI
- — How to assure high competence and skill of assigned personnel (a programme for regular training must be in place)
- — How and who should audit the system with regard to control of CNG installations

10. GOVERNMENT RESPONSIBILITIES

This part will elaborate our recommendations on the administrative system, government responsibility and auditing of the I/M system.

The government should focus on development and implementation of a comprehensive auditing system rather than on vehicle inspection (supervising instead of inspecting) in the commercial facilities.

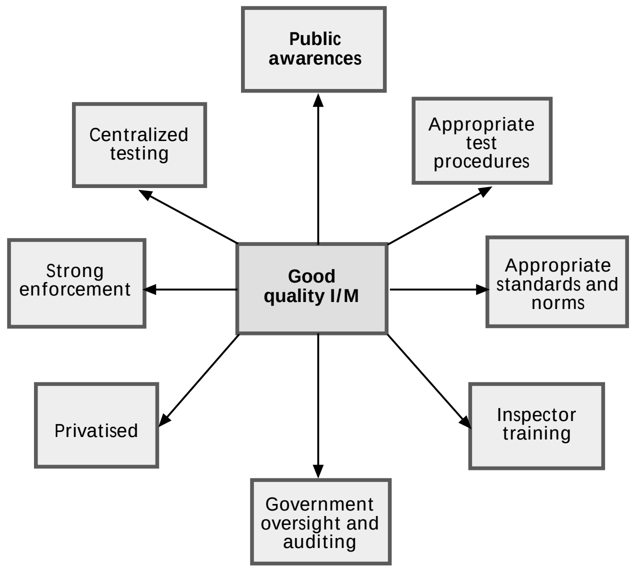
The government should focus on development and implementation of a comprehensive auditing system rather than on vehicle inspection

With regard to enforcement, it is clear that at present most vehicles are not even subjected to periodic emission inspection. A new system needs to be put in place that will deny renewal of annual insurance certificates to vehicles that do not have proof of having passed a valid inspection. Some vehicles with high mileage, like taxis, will need to be inspected more than once each year. Introduce a 'sticker system' for these categories. It is not considered useful to have a requirement only on 'paper' stipulating that private vehicles must be inspected at the PUC centres several times each year; rather, this should be replaced by a requirement for only one inspection a year as long as it is a high quality inspection which is rigorously enforced.

The government must put in place a system of auditing the entire inspection process. Elements of this system should include covert as well as overt audits, calibration checks, training oversight and strict enforcement and penalties wherever fraud or 'cheating' is noticed.

To assist in this auditing function, a new system of databases for validating the programme and assessing the results is necessary to make the system responsive and adaptive to the learning and feedback that flow from the audits.

Figure 5: Elements of a successful I/M programme



It will not be out of place to observe that for a good I/M programme a proper vehicle registration system should be in place to record actual vehicles on road. For inspection and re-inspection of vehicles, the registration office must be able to trace problem vehicles and track their inspection status. The registration system should also detect vehicles that have not been inspected on time or have failed. It is advisable to rationalise the registration system to meet these objectives.

It has been demonstrated that the actual vehicle registration data available from the state transport authority is not representative of actual number of vehicles on road. As a result, it is difficult to arrive at a realistic estimate of actual volume of inspection that would be required annually. For example, according to vehicle registration data the total cumulative number of registered buses in Delhi are about 41,483 (as on March 31, 2001) as opposed to 8,100 CNG buses currently on road. Registration data is not corrected based on scrappage and phase-out.

11. INSTITUTIONAL ARRANGEMENTS

Operating a mandatory vehicle inspection programme in a cost-effective manner would require orchestrating a lot of parallel activities by the local government or administration. This would include upgradation of the Burari inspection centre, improvement of PUC centres, framing of relevant measures and so on. The concerned local authorities, however, must shift their present focus from conducting inspection to supervision, analysis and modification of the system.

Some examples of important measures:

a. Introduce a system of stickers for vehicles passing the inspection. This will help in easy identification of vehicles yet to be inspected
b. Modify vehicle registration system in Delhi to be able to identify inspection status of the vehicles
c. Assign competent teams for auditing various functions of the system
d. Identification of responsibilities of concerned authorities
e. Initiate legal action such as fiscal penalty on owners for not following rules and regulations
f. Establishment of a network to collect and analyse essential information from PUC centres

g. Establishment of database for analysis
h. Establishment of channels for adjustments/modifications of the system
i. Launching public awareness campaigns to make people aware of what's going on (Public awareness should not be underestimated)

12. EMISSIONS WARRANTY AND RECALL PROGRAMME

The problem with poor durability of the engine also raises the question if it is time to introduce a 'Recall programme' in India/Delhi in which vehicle manufacturers will be responsible for adjusting/rebuilding vehicles not fulfilling set standards for emissions and durability. When systematic errors in the emission control system are verified in an in-use compliance test programme, the manufacturer of the vehicles has to modify all vehicles in the market free of charge within a specified number of years or limited driving distance. In the European emission directive (98/69/EC) for motor vehicles the responsibility of the vehicle manufacturers are defined. The Mashelkar Committee has already advocated a system of emission warranty, manufacturers' responsibility and a recall programme for India.

The problem with poor durability of engines also raises the question if it is time to introduce a 'Recall programme' in India

13. EMISSION MEASUREMENTS AND TEST PROCEDURES: VEHICLE CATEGORY-WISE RECOMMENDATIONS

To meet the present and future requirements of vehicle inspection programme, appropriate test procedures and limit values should be established immediately. A vehicle category-wise inspection programme must be established and appropriate training of personnel responsible for inspection organised. *For exhaust emissions measurement it is strongly recommended in this early stage to introduce loaded mode test procedures for heavy-duty vehicles and subsequently for light duty vehicles*. Measurement of only idle emissions is insufficient in the long run when engine technology will be more advanced and sophisticated.

We recommend the following improvements for different categories of vehicles.

A. DIESEL FUELLED HEAVY-DUTY VEHICLES (BUSES AND TRUCKS)

Consultants observe that there is still no clear official proposal to upgrade the test procedure for diesel vehicles. Consultation with the ARAI indicate that they have considered regulating operational parameters of free acceleration smoke test that are currently conducted in the PUC centres. But there is nothing firm on advancing the test procedures to loaded mode tests to address the special concern in diesel emissions.

Since heavy-duty goods vehicles and inter-state diesel buses are major contributors to the poor air quality in Delhi, they should be included in the new I/M programme from the very beginning and inspected at the upgraded Burari inspection centre (to be developed primarily for buses) and at the 'second facility' (for trucks). Adopt and implement transient loaded mode test for emissions measurement focusing on particulates and NO_x. When the test procedure is decided, new emission standards must be made official before the start of the programme. Relevant organisations in India and testing agencies such as ARAI in Pune should be made responsible for the development of a suitable test programme including limit values. In this context, experience of other countries in Europe and USA should be looked at.

B. TAXIS

Taxis in Delhi can be of various configurations, running on petrol, diesel, CNG or liquefied petroleum gas (LPG). From a technical perspective taxis (light duty vehicles) should be handled exactly in the same manner as other vehicles using the same type of fuel. Taxis should be brought to the enhanced I/M programme much faster than private cars. This group of vehicles should meet strict emission limit values from the very beginning and there is no need to use a phase-in of limit values. The policy in Delhi should be to only use newer taxis meeting new standards.

Taxis should be inspected more than once a year since they accumulate significantly higher mileage than private passenger cars.

For diesel taxis, free acceleration method is not sufficient as the measurement is not representative of actual emissions on road. For both diesel and petrol taxis loaded transient test should be developed together with appropriate limit values. A feasibility study could be a proper way to start the development of the new test procedure. When the test procedure is finalised, new emission standards must be established. Until the new I/M programme is established, taxis should be subjected to enhanced PUC controls.

Taxis should be moved to advanced I/M programme when the 'third facility' is erected, estimated to be within 1-1.5 year from the start of the project.

C. THREE-WHEELERS

Three-wheelers, both petrol and CNG, are considered 'commercial vehicles', and are subjected to mandatory annual fitness and idle CO emissions test. More than 15-year old vehicles with two-stroke engines are either scrapped or have moved out of the city.

CNG conversion has helped to deal with the problem of high hydrocarbon and particulate emissions from petrol two-stroke three-wheelers in the city. Now, issues are being raised with regard to the quality of conversion and durability of the engine. CNG three-wheelers and even new four-stroke CNG engines are emitting so-called "white smoke". Based on experience with development of CNG engines, the 'quality' of the piston rings appears to be an important factor. With poor quality piston rings it is possible that lubrication oil is leaking from the oil sump to the combustion chamber causing smoke. Experience from other countries with a large number of two- and three-wheeler using engines with small cylinder displacement shows that engines must be overhauled (example, change of piston rings) up to twice a year or every 30,000 km unless high quality piston rings are installed.

CNG vehicles must be included in the advanced inspection programme immediately at the upgraded Burari inspection centre

The test procedure for emission measurement for three-wheelers should preferably be a transient loaded mode test. Develop test procedures and new emission standards before the start of the programme. It is essential that limit values correspond to the level of vehicle technology. However, for this group of vehicles a phase-in programme of the limit values could be considered. Such a measure could target a maximum of 20 per cent failure rate that is likely to have greater public acceptance. The limit values must then be regularly revised and adjusted to reach the set target within a specified time. Until new I/M programme is established for three-wheelers they should be subjected to the enhanced PUC control discussed in the report.

D. CNG BUSES

CNG buses are currently subjected to three different controls — safety checks related to gas installations in the vehicle, annual 'fitness check' and emissions test. There is a need for further improvement in the inspection of gas installations to verify full identity of essential components and 'conversion kit' installed in the vehicle and compare them with type approval specifications followed by ARAI and other testing agencies.

The system of safety inspection in relation to the gas installations has improved recently. Originally, the inspection was carried out by the staff at Burari inspection centre but is now contracted out to a third party (Association of state road transport undertaking). The inspection system has been upgraded to assure that no leaks or other safety problems exist. These efforts need to be rapidly expanded so that every CNG vehicle gets a thorough inspection very quickly and then periodically thereafter. A detailed discussion of this issue is contained in the CSE report on *Safety of CNG Buses in Delhi* of August 2002 (L Erlandsson and C Weaver).

The current safety inspection system is time-consuming and can be considered a 'bottle-neck'. CNG safety inspection need not wait for the upgraded commercial vehicle inspection centres but may be expanded immediately. It is therefore, proposed to introduce a supplementary system where trained teams of inspectors can visit bus operators or depots and carry out inspection at those premises or at other suitable locations. Two points are worth noting:

- — It is possible to carry out checks at the existing DTC depots.
- — Increasing the number of competent teams authorised to carry out the checks and their training should be accorded very high priority.

There is a need for further improvement in the inspection of gas installations in CNG vehicles

CNG buses are checked for the maximum idle CO of 3.0 per cent. This is far too lenient, especially when all buses are equipped with catalytic converters. During an earlier visit to the Burari inspection centre we were shown statistics of about 300 emission measurements, indicating that 18 per cent of the tested buses had CO idle values of more than 3.0 per cent and about 60 per cent of the buses had CO values of more than 1.0 per cent. Those values should be compared with emission limits for CNG vehicles in the US where a maximum of 0.5 per cent CO at idle is accepted for buses. It is advisable to reconsider the present limit value of 3.0 per cent.

During consultation with the manufacturers of chassis/engines for CNG buses the issue of durability was discussed. Manufacturers of CNG engines include a catalytic converter in the exhaust emission control system in order to fulfil the standards for new vehicles/engines. But they only warrant the performance of the catalytic converter for a maximum of 72,000 km. What happens after this limit is unclear; according to our knowledge there is no requirement for changing the converter at specified driving distances and no specific control is carried out during the annual fitness check. The warranty limit of 72,000 km should be compared with the European requirements for manufacturers' responsibility and warranty, which is eight years or up to 500,000 km. This raises the concern whether it is time to introduce a 'Recall programme' in India/Delhi.

CNG vehicles and especially buses must be included in the advanced inspection programme immediately at the upgraded Burari inspection centre. The test procedure for emission measurement should be transient loaded mode test focusing on the measurement of NO_x. Develop test procedures, new emission standards for application in the programme. Until the new I/M programme is fully implemented for the various groups of CNG vehicles they should be subjected to the enhanced PUC system. Specially trained mobile teams will take care of the inspection of gas installation on vehicles at suitable locations to expand the total capacity.

Consultants have not assessed the LPG vehicles separately. LPG is not commonly used in Delhi though the consultants noticed that conversions are already underway. Vehicles using LPG as fuel must have an engine that is rebuilt from an original petrol engine. We are told that ARAI is now developing a regulatory system and a process to have LPG conversion approved in the same way as CNG installations. The fuel itself can also create problems depending upon the properties. LPG is heavier than air and in case of leakage, gas will remain close to the ground and not disperse as fast as CNG, thereby increasing the risk for explosion if the mixing rate between air and LPG is unfavourable. To summarise, LPG is more "dangerous" than CNG as a fuel.

Consultants recommend that LPG vehicles be included in the I/M programme in the same manner as others. Comprehensive regulations for conversions (e.g. type approval system) should be developed for both LPG installations in the vehicles as well as emission performance of both converted (petrol engine converted to operate on LPG) and dedicated LPG vehicles.

E. PETROL PASSENGER CARS

Delhi has introduced tighter emission requirements for new passenger cars, mandating advanced engine management control systems, catalytic converters and the use of unleaded petrol. It is now vital to introduce test methods for those vehicles to verify that essential parts and systems are in working order. The vehicle must meet requirements which are technically possible to achieve, for example, the same emissions standards when brand new.

For carburetted cars, simple idle test can identify malfunctioning systems. But modern cars equipped with electronic fuel injection and ignition systems and three-way catalysts may have defects — such as defective sensors and degraded catalyst efficiency — that may not show up in idle tests.

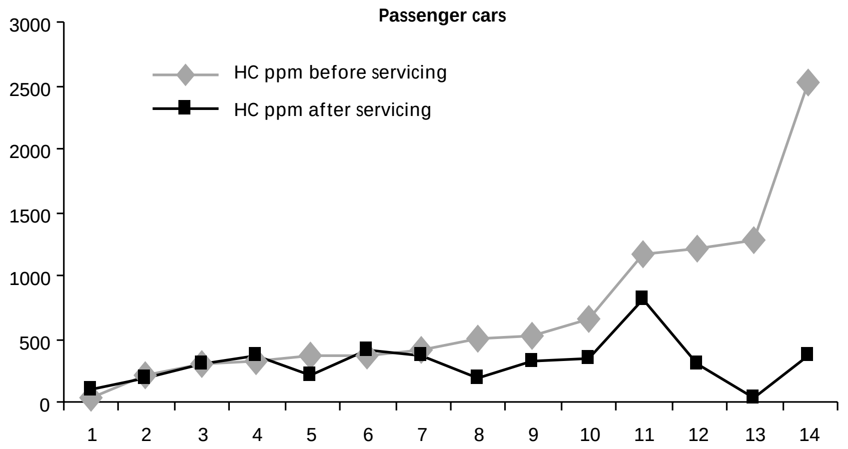
From a strictly technical point of view the proposed hydrocarbon values are too lenient

An intermediate approach towards moving to centralised I/M system is the introduction of both low idle (engine speed at 700-900 RPM) and high idle tests (engine speed at more than 2,000 RPM). As recommended above, 4-gas analysers certified for all four gases (CO, CO_2, HC and O_2) must be mandated and lambda measurement adopted for catalyst-equipped cars at least at high idle measurement.

Consultants have had the opportunity to review the new limit values under consideration for petrol vehicles in Delhi. For four-wheelers without catalytic converters the proposed limit values for idle CO and HC are 3.0 per cent and 1,500 ppm respectively. For new passenger cars with catalytic converters the corresponding proposed limit values for CO and HC are 0.5 per cent and 750 ppm respectively. We understand that there is also a proposal for measurement of lambda for vehicles fitted with closed loop three-way catalytic converters. From a strictly technical point of view, the proposed HC values are too lenient.

Studies from round the world for comparable vehicle technology show that the HC level of more than 1,000 ppm at idle is very rare. For all light duty vehicles below 3,500 kg gross vehicle weight ratio (GVWR) without catalytic converters,

Graph 2: Setting appropriate standards is critical



Source: Automotive Research Association of India, Pune

corresponding HC level should be in the range of 600-700 ppm as illustrated in graph 2. Tests by ARAI show that after servicing, vehicles should have no difficulty in meeting these tighter standards. Similarly, from a technical point of view, passenger cars equipped with catalytic converters should not be allowed to emit more than 0.5 per cent of CO and 100 ppm of HC at idle.

Even other light duty petrol vehicles equipped with catalytic converters such as small trucks and 'pick-ups' with a GVWR of maximum 3,500 kg should not be allowed to emit more than 1.0 per cent of CO and 200 ppm of HC. These values can easily be met with a working catalyst and measured according to specifications. The countries in Europe that are implementing limit values for HC are normally using the above values.

It is recommended that the high idle test be adopted and limit values for such a test, together with lambda-value for petrol vehicles with catalytic converters should be introduced. Limit values for CO for passenger cars in Europe is of maximum 0.3 per cent at an engine RPM above 2,000 and the lambda-value is specified at 1.00 $\pm$ 0.03. High idle measurement and calculation of lambda–value is to verify whether the converter is working under a moderate engine load. A lambda-value will also reveal if the exhaust pipe is leaking and whether the measurements have been carried out in an acceptable way.

Experience in Europe shows that for passenger cars CO value of less than 0.15 per cent at idle indicates that the converter is working but values reaching 0.3 per cent indicate something is wrong. If CO levels reach 0.5 per cent the converter is usually not working at all, but because of sophisticated electronic control of the air/fuel ratio the idle value is still relatively low. In order to avoid problems during measurement, a limit value of 0.5 per cent CO at idle should still be implemented.

As is commonly known, the bulk of emissions may be generated during transient engine operation that cannot be captured in idle tests. Moreover, NO_x emissions at idle are negligible. To remedy this, a loaded mode test (measurement during part load of the engine) is recommended.

A number of transient loaded short tests were developed in the US and evaluated for correlation with type approval tests. Different types of loaded mode tests can be used in an I/M programme, such as transient tests (IM 240 — inspection and maintenance, test duration 240 seconds, VMAS — Vehicle Mass Analysis System) or steady state tests (ASM — Acceleration Simulation Mode Test Procedure) in which measurement is carried out at various speeds and vehicle loads. (See discussion on testing options in Appendix A). The advantage of a full transient loaded mode test over an ASM test is that during a transient test, sequence failure of the fast regulation of the lambda sensor during acceleration and retardation which could cause improper air/fuel mixture, can be easily detected.

Discussions are on to decide the future test methods and principles of emission measurements for mandatory vehicle inspection programmes. The focus is to find a cost-effective method and at the same time to have a good correlation with real world driving condition. A recent study in Europe 'The inspection of in-use cars in order to attain minimum emissions of pollutants and optimum energy efficiency', elaborates different methods, related costs and feasibility. One of the conclusions from the project valid for vehicles with catalytic converters is ***"Of all the short tests used, the transient short cycles were found to have the greatest potential in terms of environmental benefits. They can identify practically all gross polluters (i.e. vehicles emitting more than 50 per cent above emission standards) and offer an emission reduction potential of the order of 15 to 20 per cent for all pollutants CO, HC and NO_x on the basis of the random vehicle sample".***

We recommend that privately owned passenger cars be gradually included in privatised and centralised (inspection only) programmes. Give priority to newer vehicles with catalytic converters and subsequently phase in older passenger cars. The test procedure for emission measurement should be a loaded mode test and preferably a transient test. Develop test procedures and new emission standards at the start of the programme. Background material – emissions data etc for the development of new standards (cut points) — might be available at ARAI or at other internationally recognised testing institutions. However, for small groups of vehicles with low annual driving distances a phase-in of limit values could be recommended. Such a measure will meet the objectives of a maximum 20 per cent failure rate. The limit values must then regularly be adjusted to reach the set target within a specified time. Until the new I/M programme is established for passenger cars, they should be subjected to the enhanced PUC system as discussed in the report.

Transient short test cycles can identify almost all gross polluters

F. DIESEL PASSENGER CARS

As mentioned earlier we have not come across any clear official proposal on how to upgrade the test procedure for diesel vehicles. As in Europe, the emission measurement of diesel vehicles is carried out by measuring the opacity by the use of free acceleration method, the shortcomings of which were discussed above.

Oxides of nitrogen (NO_x) and particulates from diesel vehicles are of great concern. The smoke opacity cannot measure these pollutants. It is recommended to develop a new test method where the focus should be on measurement of NO_x and particulates. Since NO_x is mainly produced in the engine during high load and high temperature in the combustion chamber, the most feasible test method is a loaded transient test method.

New test equipment for measuring particulates and NO_x must be incorporated in the system. When the test procedure is decided, new emission standards must be developed and implemented. Background material for the development of new standards (cut-points) could either be obtained via a feasibility study or might be available at ARAI or at other internationally recognised test institutions. Diesel passenger cars could be inspected in the same test centres as petrol vehicles.

G. TWO-WHEELERS

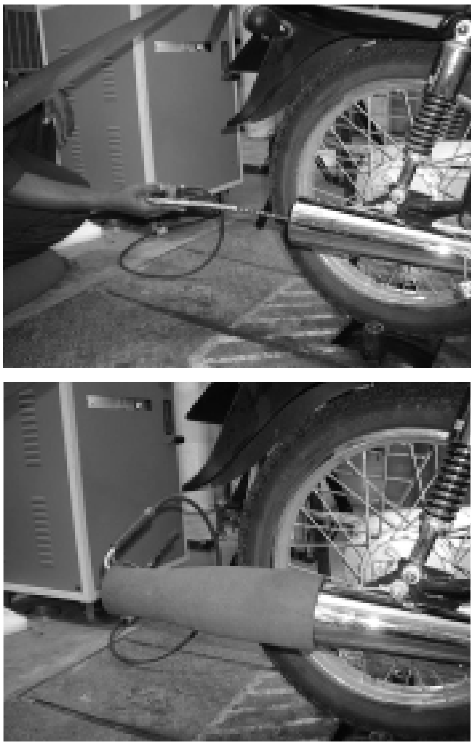
Two-wheelers are powered with two- or four-stroke engines. The target must be to establish limit values related to the engine technology. The large number of two-wheelers in Delhi/India requires greater focus in the development of emission regulations for an I/M programme.

The new limit values are under consideration for idle CO and HC for two-wheelers: 9,000 ppm HC for two-stroke engines, 4,500 ppm HC for four-stroke engines and 3.5 per cent CO for all two-wheelers. The proposed HC norms are too lenient for new two-wheelers and the proposal should be reconsidered to match the engine technology. A small survey conducted by ARAI shows clearly that no new two-wheelers would fail at PUC centres if the proposed set of standards is applied. In view of the fact that limit values should correspond to the engine technology and that 20 per cent failure rate is acceptable, there is a strong need for reconsidering the proposed limit values immediately.

A small survey conducted by ARAI shows clearly that no new two-wheelers would fail if the proposed set of standards is applied

ARAI is developing a simplified test method for two-wheelers. The system consists in general a driver's aid, a computer including software and a simple single roller dynamometer. The driving pattern to follow during the test procedure and displayed on the driver's aid, could, for example, be the Indian driving cycle repeated more than once. During the test sequence, exhaust emissions will be collected from the tailpipe and calculated as grams per kilometre (mass emissions) instead of concentrations expressed as per cent or ppm. This system is very promising but needs further development before a decision can be taken on whether it is possible to use the system in the new I/M programme for two-wheelers.

Proper extension pipes not used which leads to leakage and incorrect readings



Source: Automotive Research Association of India, Pune

Include two-wheelers in the enhanced I/M programme according to the same sequence as established for private passenger cars. The test procedure for emission measurement should preferably be a transient loaded mode test. Develop test procedures and new emission standards in the beginning of the programme. New techniques must be developed for two-stroke engines to measure smoke during controlled conditions. It is essential that the new limit values correspond to the vehicle technology. Background material for development of suitable cut-points (limit values) might be available at recognised test organisations. Until the new I/M programme is established, two-wheelers should be subjected to enhanced PUC control.

14. ACKNOWLEDGEMENTS

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15. APPENDIX A: TESTING OPTIONS

A. NO-LOAD SHORT TESTS

The term denotes all tests during which no external load is exerted and the car operates with the transmission in neutral position.

i. Idle/fast idle test

The test involves carbon monoxide (CO), hydrocarbons (HC) and eventually carbon dioxide (CO_2) concentration measurements in the raw exhaust gas at idle speed and/or a higher engine speed (2000-3000 RPM). The test could last from less than one minute in the case of a one-speed idle test without pre-conditioning to about 10 minutes in the case of a two-speed test with 'second chance' test including pre-conditioning.[5,6] A garage-type non-dispersive infrared (NDIR) analyser capable of measuring CO, HC and CO_2 concentrations is sufficient.

Today, idle/fast idle tests are still widely used in I/M programmes because they are the fastest, cheapest and easiest to perform with the minimum possible testing equipment. For carburetted cars they can effectively identify malfunctioning mixture preparation systems by checking the performance of the carburettor's idle mixture orifice in the idle test and the main fuel-metering orifice in the fast idle test. However, modern cars equipped with electronic fuel injection and ignition systems and three-way catalysts may have a defect (such as defective sensors and degraded catalyst efficiency[7]) that cannot be detected through their pollutant emissions at idle; even worse, the great bulk of emissions may be generated during transient engine operation. An additional and a very significant drawback is the negligible amount of NO_x emissions at idle.

ii. Idle/fast idle tests with lambda test

For catalyst equipped cars, a lambda test may be coupled with an idle/fast idle test in order to check the performance of the mixture preparation system. Three types of tests can be performed:

The air/fuel ratio is indirectly determined through measurement of CO_2, CO, O_2 and HC concentrations at fast idle (2000-3000 RPM) in the raw exhaust.

The air/fuel ratio is artificially modified by adding oxygen, propane or recirculated exhaust gas to the intake air, or by tampering and then checking the response of the lambda control system. Long response times would imply that the oxygen sensor is degraded, while no response would mean that the lambda control system is out of operation.

One or more of the characteristics of electronic lambda control circuit are measured and compared with auto manufacturers' specifications.

Germany has adopted a test that involves both test types 1 and 2 since December 1993; preliminary investigations have shown that the test performs fairly well with excess emitters. A combined idle/fast idle/lambda test (involving lambda test types 1 and 2) is also in force in Austria, where it has demonstrated satisfactory results (Pucher *et al.* 1990). A similar test (but with lambda test type 1 only) is also foreseen for three-way catalyst cars in all EU countries with Directive 92/55/EC, which came into force in 1997.

B. STEADY-STATE LOADED TESTS

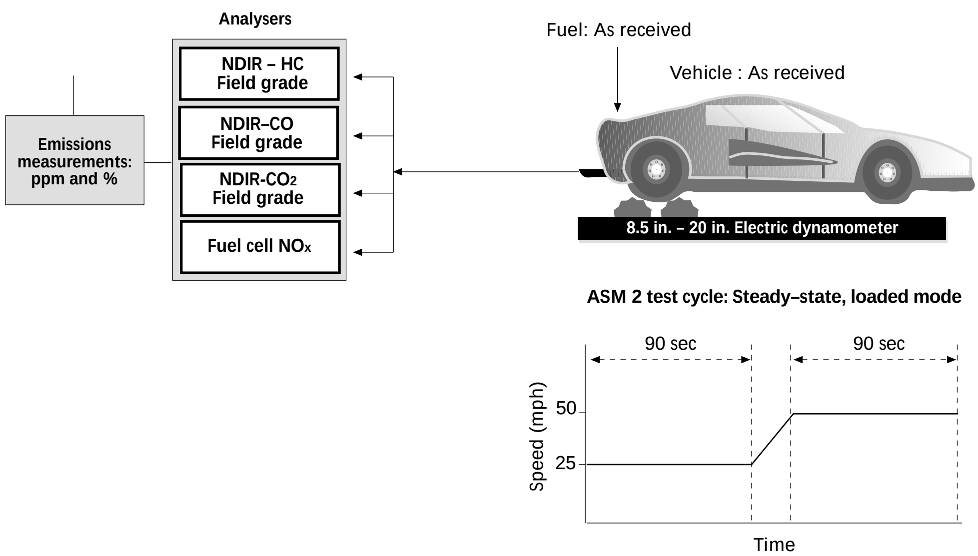
As nitrogen oxide emissions at no-load conditions are negligible, a loaded test is therefore necessary in order to measure NO_x emission levels, a critical issue for urban air pollution and an important pollutant in Delhi. The simplest loaded tests are the steady-state loaded tests. These involve a dynamometer with steady-state power absorption. A simulation of the car's inertia weight is not required because there is no transient phase in the emission test: the car is driven at constant speed and load, and pollutant concentrations (CO, HC, NO_x and CO_2) are measured during the load phase.

In the seventies, several loaded tests were developed in the US; these included the Federal 3-Mode Test, the Clayton Key-Mode Test and the CalVIP. However, their implementation was limited due to the high cost of the dynamometer and the NO_x analyser.

More recently and due to the introduction of three-way catalyst equipped cars, the Acceleration Simulation Mode (ASM) Tests were developed and evaluated. According to the ASM principle the car is driven on a chassis dynamometer at a constant speed and steady-state power absorption that is equal to the actual road load of the car during acceleration. Thus, one can achieve a realistic simulation of the car's load at a specific driving mode without the need of flywheels for inertia simulation. However, at high speed/high acceleration combinations the required power absorption is too high to be achieved without engine overheating problems.[8] Pollutant concentrations (CO, HC, NO_x) are in principle measured in the raw exhaust. Each steady-state test mode would require about 10 minutes for preparation, pre-conditioning, actual testing and documentation.

Austin *et al.* compared several speed/load combinations with idle tests and already developed steady-state loaded tests as well as with transient loaded test. The best results were obtained from the ASM 5015 test, which has a constant speed of 15 mph (24 km/h) and a steady-state load equal to 50 per cent of the

Figure 1: Test type ASM 2



load required to accelerate at 1.47 m/s^2 (the maximum acceleration rate on the FTP) at the speed of 15 mph.

In the late eighties in Europe, the association of the German TÜV also investigated a similar loaded test. The car is driven at 50 km/h and at 7 kW dynamometer power absorption in the third gear (position "D" for cars with automatic transmission) and then idles; pollutant concentrations (CO, HC, NO_x) in the raw exhaust are measured at the end of both the loaded and the idling phases.[9] Vehicle preparation, pre-conditioning, test phase and documentation take on an average, about 10 minutes. The study concluded that the test is much more appropriate for the inspection of catalyst cars than a simple idle/fast idle test. The authors point out that in order to improve the performance of the test, type-specific reference values (and not fixed values) have to be used as cut-points that determine whether a car passes or fails the short test.

C. TRANSIENT LOADED TESTS

In transient tests, cars are driven on the dynamometer according to a specific driving schedule; their main differences from type approval tests are the duration of the driving cycle and the hot start.[10] Since exhaust gas emissions are expressed in mass units, a CVS system and laboratory-quality analysers are required in order to detect low pollutant concentrations in the diluted exhaust sample. A multiple-curve dynamometer with flywheels is also required in order to simulate the instantaneous road load and the necessary power to accelerate the inertia masses of each car.

A number of transient loaded short tests were developed in the '70s in the United States and were examined as to their correlation with the Federal Test Procedure (FTP) 75. However, the costs of implementation of such tests for generalised I/M programmes were prohibitive, and thus the idea was abandoned. The fact that cars equipped with three-way catalysts were just starting to enter the US market in the late '70s and the performance of these tests with such cars had not been examined also played a role in that decision.

More recently, the interest in transient short tests has been renewed. Thus, the CDH 226 test was developed first by the Colorado Department of Health (CDH); this aimed at achieving high correlation with the FTP, especially for three-way catalyst cars. Numerous studies have demonstrated correlation coefficients of 0.79 to 0.96 for all three pollutants.[11,12,13] Excess emission identification rates were about 90 per cent for all three pollutants at 5 per cent errors of commission.[14]

However, the US EPA decided to develop a more transient alternative to the CDH 226 in order to better simulate the FTP and therefore came up with the IM240, illustrated on page 24.[15] Emissions in the diluted exhaust gas are normally derived on a mass basis with a CVS and the test takes about 10 minutes to perform. The IM240 showed correlation coefficients (R^2) with the FTP hot start portion of 0.89 to 0.97 for all three pollutants; another test sample had coefficients of 0.54 to 0.82 with the full FTP including cold starts.[16] The EPA proposed that states or regions which will have to implement the so-called 'Enhanced I/M Schemes', enforce the IM240 at least for cars of newest model years.

Running the IM240 procedure requires a constant volume sampler and laboratory grade analysers for CO, HC, NO_x and CO_2.

Graph 1: The IM240 short driving cycle

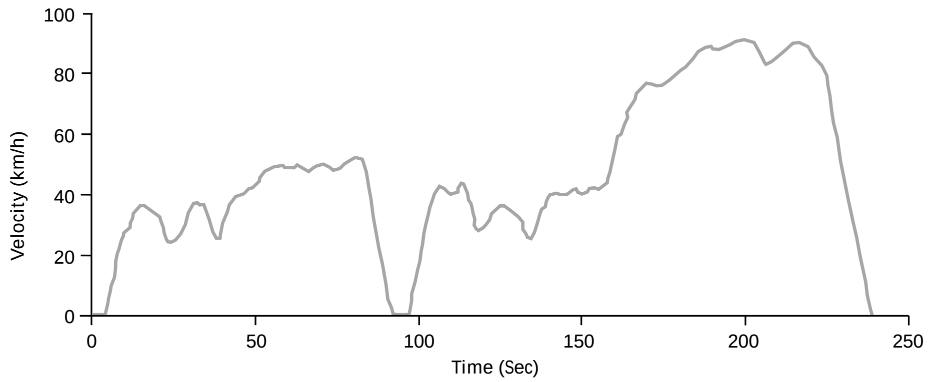


Figure 2: Test type IM240

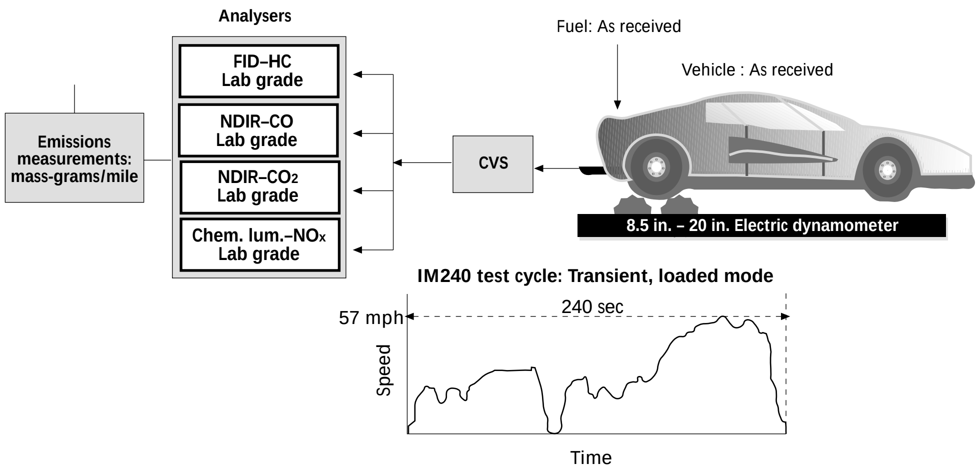


Figure 3: Test type Mass 31 or IM240

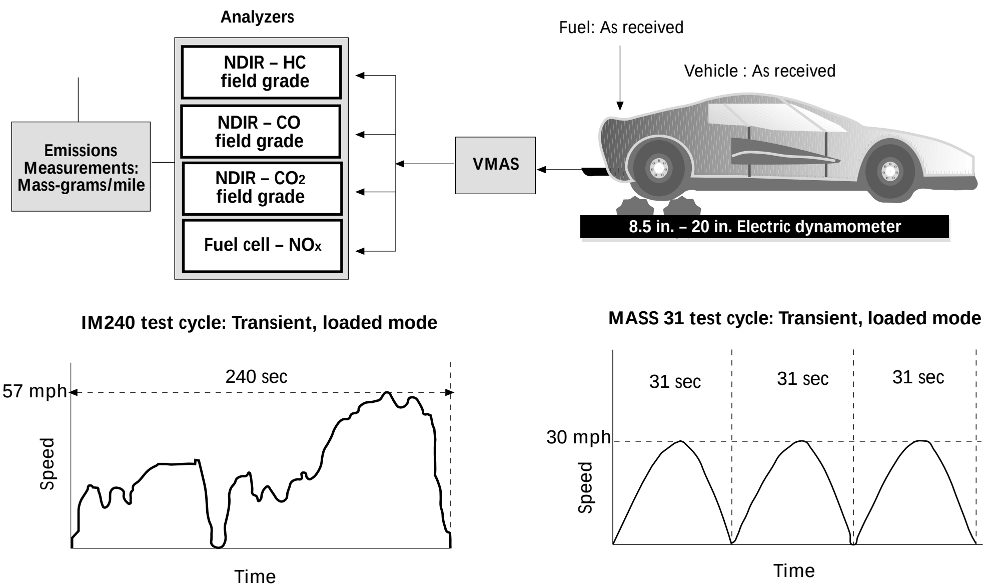
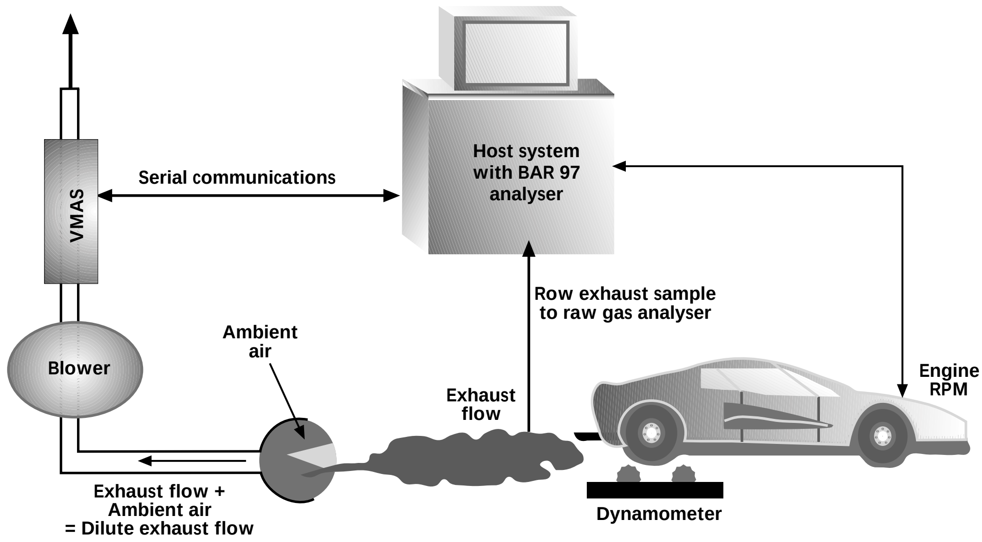
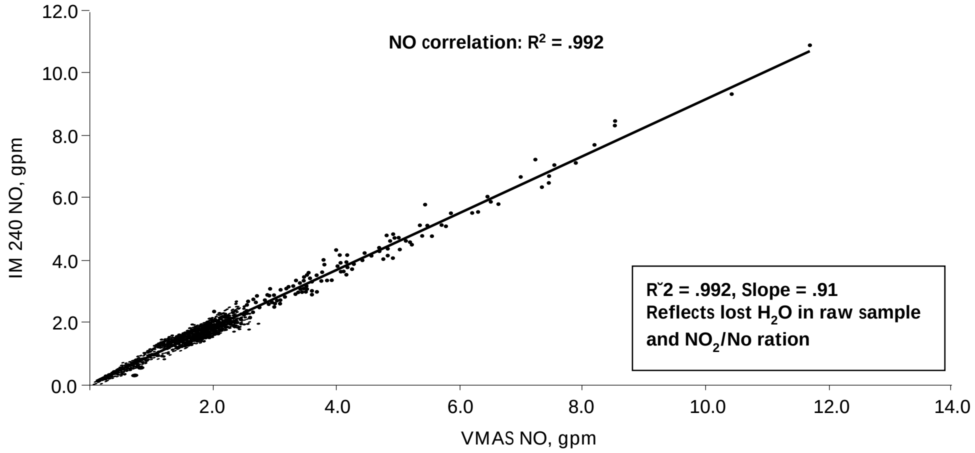


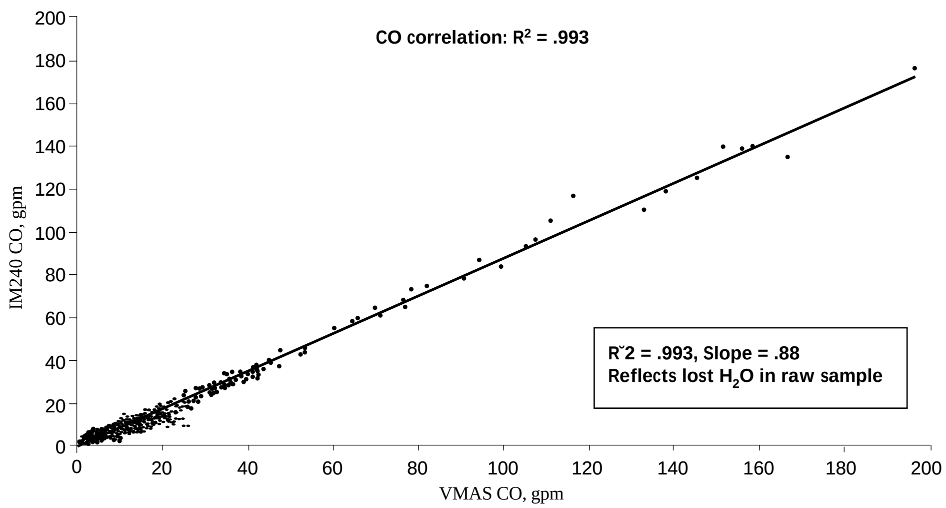
Figure 4: Typical system with VMAS



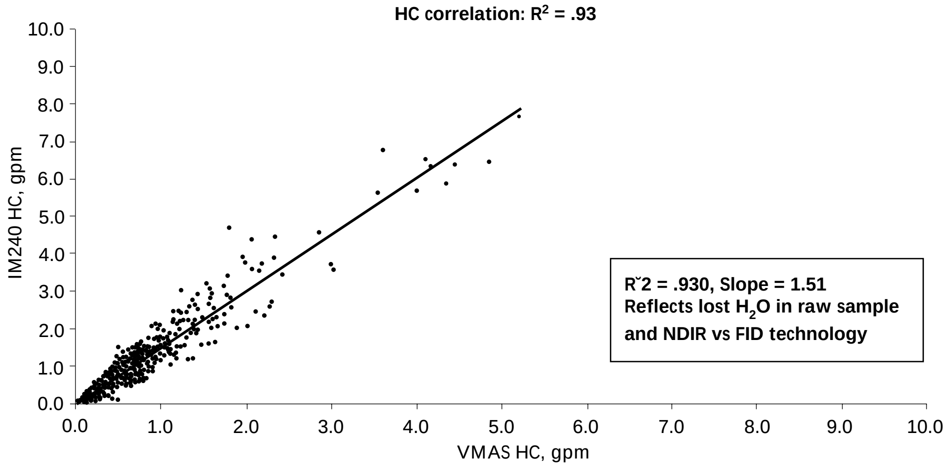
Graph 2: VMAS study results of NO_x



Graph 3: VMAS study results of CO



Graph 4: VMAS study results of HC



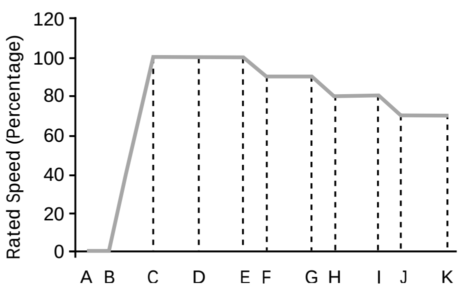
In order to reduce the cost, several states including New York and Massachusetts investigated an alternative test that used less expensive equipment but gave similar results as the IM240 procedure. The test that was developed used field grade analysers and a less expensive dynamometer and was capable of driving several different transient driving cycles as illustrated above.

This procedure evolved into the VMass test procedure, which has demonstrated very close correlation with the IM240 test but at much lower costs.

D. DIESEL TESTS

The lack of robust, commercially available equipment for quickly and accurately measuring diesel PM emissions has meant that regulators have been obliged to focus diesel I/M programmes on smoke opacity. Smoke is a highly undesirable pollutant in its own right, and reducing opacity levels may also tend to reduce particulate emissions. However, available data indicate that smoke opacity, even when measured under a controlled load on a dynamometer, has a poor correlation with particulate emissions measured under the same conditions.[17] High smoke emissions can result from serious engine problems such as worn out injectors or a dirty air cleaner that affect PM emissions **throughout** the driving cycle. They may also result from problems such as tampering with the puff smoke limiter that affects emissions only during transient accelerations and thus has much less impact on PM emissions over an entire driving cycle.[18]

Graph 5: Lug down short test



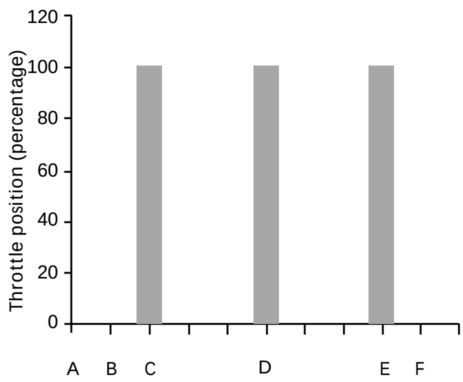
The two most commonly run smoke tests are:

The **Lug Down** test, which is performed at full throttle, with the dynamometer load gradually increased to pull back engine speed so that the engine is labouring, or "lugging". This test is sometimes run at the roadside without a dynamometer by using the vehicle brake.

The **Snap-Idle** (SAE J1667 Free Acceleration) test simply involves fully depressing the accelerator pedal while the transmission is in neutral, and measuring the maximum smoke. The test requires no dynamometer.

Graph-6 is meant to show that the vehicle is sitting at idle for some time — shown as A and B. The throttle is fully depressed three consecutive times — C, D and E — with a short interval between each and then returns to idle — F.

Graph 6: Snap-idle short test



The short test evaluations have shown that dynamometer-based short tests with transient acceleration segments are considerably more effective than unloaded or steady state tests in estimating 'real world' emissions of all regulated pollutants.

Smoke opacity measured during the free acceleration test (SAE J1667), or any of the steady-state tests, does not correlate well with particulate emissions generated during the transient dynamometer test cycle. Smoke opacity is basically a measure of visual amenity only.

E. OVERALL CONCLUSIONS REGARDING TEST PROCEDURES

On the basis of the available test data, the idle test is ineffective for catalyst-equipped cars. It can identify only 15 per cent of the high polluters, while the environmental benefit from it does not exceed 4 per cent reduction in any of the pollutants involved. Especially as regards the lambda test, it was found to add in the direction of NO_x emitter's identification, having the drawback of increasing the errors of commission.

Of all the short tests used, the transient short cycles have the greatest potential in terms of environmental benefit. They can identify practically all gross polluters (i.e. vehicles emitting more than 50 per cent above the emission standards) and offer an emission reduction potential of the order of 15 to 20 per cent for all pollutants (CO, HC and NO_x) on the basis of random vehicle sample.

Cost-effectiveness analysis has shown that 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 the most effective I/M test.

VMass testing correlates very well with the IM240 test but is much less expensive. The ASM test is only slightly less expensive than VMass but its correlation with IM240 is much poorer.

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