Assessment of the Pollution Under Control Program in India and Recommendations for Improvement

By John Rogers, Grupo Trafalgar, Mexico City

Prepared for the South Asia Urban Air Quality Management Program
The World Bank

October 2002

Assessment of the Pollution Under Control Program in India and Recommendations for Improvement

Assessment of the Pollution Under Control Program in India and Recommendations for Improvement

By John Rogers, Grupo Trafalgar, Mexico City

Urban air pollution, primarily in the form of highly elevated ambient concentrations of small particulate matter, poses a serious threat to the health of urban dwellers in many cities in India. The transport sector is one of the contributors to particulate air pollution. Therefore, controlling emissions from vehicles is an important component of urban air quality management.

Studies show that gross polluters, which make up a relatively small fraction of the overall fleet, are responsible for a large percent of total vehicular emissions. For example, the US Auto/Oil program, costing US$40 million and lasting 6 years, found that 20 percent of vehicles were responsible for 80 percent of emissions. These findings suggest that identifying and repairing gross polluters is essential if transport-related air pollution is to be tackled. Experience in developing countries has shown, however, that establishing an effective inspection and maintenance (I&M) program for this purpose is extremely difficult. India is no exception and the current Pollution Under Control (PUC) system, intended to check emissions from in-use vehicles, is widely regarded to be ineffectual.

This assignment was undertaken over a three-week period in August and September 2002 to assess the PUC system in India and make recommendations to make it more effective. The assignment consisted of meeting with a large number of stakeholders—government officials, vehicle manufacturers, research institutions, non-governmental organisations (NGOs)—in Delhi, Mumbai, Bangalore and Pune, and visiting test centres. Whenever possible, fuel and vehicle related issues that affect emissions were also investigated, focusing especially on diesel vehicles to identify causes of high emissions from this category of vehicles. The assignment was carried out by John Rogers, a vehicular emissions specialist who has worked closely with the development and refinement of the vehicle I&M program in Mexico City, working as Consultant to the World Bank. On account of time limitations, the Consultant was not able to verify independently all the observations and claims reported here. However, even if some of the observations are not completely factual, they nevertheless represent the perceptions held by the affected stakeholders. This report summarises the findings and recommendations. The observations and recommendations contained in this report are those of the Consultant and not of the World Bank.

Current Status of the PUC Program

Administrative & Operational Issues

Urban Vehicle Pollution

Effects on Middle/Lower-Income Households

The major cities in India are very crowded. Mumbai in March 2001 registered a population of 11.9 million people living in an area of approximately 480 square kilometres (km^2) which gives them probably one of the highest average population densities in the world. Two-thirds of this population lives in slums, many of which are located in areas abutting major roads and railways as well as on the pavements themselves. Being so close to the traffic movement, the slum dwellers are the first to suffer the consequences of vehicular emissions. Going up the economic ladder towards the middle class, many live in highly crowded parts of the city, where the unpaved roads are only just wide enough for cars, but scooters, motorcycles and auto-rickshaws abound. The high temperatures, humidity and lack of air conditioning force this population to keep windows open, filling their homes with traffic-generated emissions including noise, a strong smell of hydrocarbons and fine-particulate matter. In many households traffic-generated outdoor air pollution complements the indoor air pollution generated by the combustion of solid fuels for cooking.

There is no doubt that people living in highly congested areas suffer more from high pollution levels. These are also the people who are less able to afford the medical treatment needed to reduce its consequences.

2 & 3-Wheelers (2T and 4T) vs. 4-Wheelers and Buses

The most highly congested areas in Indian metropolis are also where the most highly polluting vehicles are to be found. India has one of the lowest ratios of cars per 1,000 people but compensates for this with a very high ratio of two-wheelers and auto-rickshaws, particularly where the public transport system is deficient.

Here, there is radical difference in two-wheeler vehicle population between, for example, Delhi which operates a limited bus fleet, and Mumbai which also has an extensive suburban train system.

Cities where the middle class has lower disposable income tend to have an older two-wheeler fleet. These vehicles, fitted mainly with 2-stroke engines, have higher emissions, especially of fine particulate matter, due to their engine technology, age and condition of maintenance. The traditional mode of transport for a middle class family is a scooter, with a 50 to 130 cubic centimetre (cc) 2-stroke engine that transports father, mother and one or two children all together.

Very few of these vehicles have a PUC certificate, and for those that do, the emissions limits have remained unchanged at very high levels allowing almost all to pass. This affects the poorer population whilst the emissions limits set for cars, of an order of magnitude less, affects higher income areas more where cars abound. Even for **new** 2-stroke and 4-stroke 2-wheelers, the proposed PUC hydrocarbons limits are 9000 parts per million (ppm). Old 2-wheelers of course have still higher emissions levels and the fact that there are almost six 2- and 3-wheelers for every taxi, car and jeep exacerbate air pollution from the transport sector.

Existing PUC Structure

History of Development

The Transport Commissioner, Mr. V.P. Raja, initially introduced the PUC system in Mumbai in 1984. The limit specified was 4.5% carbon monoxide (CO) for all vehicles older than 5 years as well as for 2-3-wheelers and 3% CO for all other vehicles. In 1986, a High Court injunction caused these standards to be published in the Environmental Protection Act (1986) and the limits of 4.5% CO for 2 and 3-wheelers and 3% CO for all other vehicles have not been modified since.

The PUC program is meant to be operating across the whole of India, but in practice the results differ. It is only over the last 5 years or so that public awareness of air pollution has increased. Both NGOs and government are now fully aware that the present PUC system is ineffectual and needs to be replaced.

The Mumbai police cite the main problems as:

- Too many centres to be able to supervise and control (although it is also worth noting that the current number of centres cannot possibly test more than about 25% of the existing vehicle population).
- Anybody can set up a PUC centre with minimal investment and little checking or supervision from a regulatory body.
- A serious lack of training and established operating and test procedures.
- Major calibration problems.
- No independent audits.
- Minimal enforcement.
- Very little accountability. A centre can issue a bogus certificate with impunity.

None of the organisations interviewed expressed the belief that in-use vehicle emissions inspection could be excluded from future air pollution control programs, or that substantial change would be unnecessary. Most of the organisations, however, stated their thoughts on promoting a gradual improvement of the current PUC system rather than going for a step-function change or introducing a new system.

Many people the Consultant talked to within government expressed the view that it would be beneficial to combine the PUC with a fitness and safety check for private vehicles (the current fitness and safety check is only for commercial vehicles) but the stumbling block is the degree of corruption present in the all the Regional Transport Offices (RTO) who operate the fitness and safety program.

The political willpower seems to be in place to improve the PUC system but the dominant thinking focuses on making a small incremental improvement—which can then be left untouched for, maybe, another 15-20 years. The promoters of a new system are the Society of Indian Automobile Manufacturers (SIAM)/Society for Automotive Fitness & Environment (SAFE) and the Automotive Research Association of India (ARAI), but each has its own specific interests and focus. There seems to be little technical expertise outside of these two organisations.

The level of inspection and certification (I&C) knowledge is surprisingly low. There is a distinct lack of attention to detail, when it *is* the attention to detail that makes a good I&C system.

Administration

The responsibility for setting up the PUC program is divided between national and state authorities. The Central Pollution Control Board (CPCB) and the Central Ministry of Road Transport and Highways are responsible for the equipment and test protocol specifications and for publishing the emissions limits, but the program implementation is left up to each state. The local State Pollution Control Board (SPCB) and Ministry of Road Transport and Highways can implement a stricter program if they so desire but are required to cover the minimum requirements specified by the Central Ministries. If the state authorities wished to modify test procedures, they would have to obtain the approval of the central authorities for their proposed modification. Delhi, for example, requires that vehicles be tested 4 times per year whilst the National requirement is 2 times per year.

SIAM is developing a new computerised PUC, described in Box 1 on page 11. With the new computerised PUC program developed by SIAM, it is left up to the individual states to design the database they propose using, since the Central Ministry does not specify the database requirement. This lack of specification leads to a situation whereby different SIAM-PUC databases will be developed in different states with no standardisation across the country.

Emissions Limits

All gasoline/compressed natural gas (CNG)/liquefied petroleum gas (LPG)-powered vehicles are subject to a twice-yearly low idle test measuring only CO. Other gases or the engine speed (revolutions per minute, rpm) are not measured. The technician determines the length of each test, taking the instrument reading at any point during the test (of varying duration).

Diesel vehicles are subjected to a free acceleration smoke check every six months. Neither rpm nor engine temperatures are registered. There is no control or parameters for the rate of engine acceleration.

The limits that are currently in force are shown in the following table (in the third column under Current Standards). New limits have been proposed for those vehicles manufactured after 1 April 2000 (shown in the last column in the table below). Vehicles manufactured before this date will not be affected. The introduction date for these new limits has yet to be decided.

Type of Vehicle	Type of engine	Current Standards (published 1986)		Proposed standards for vehicles manufactured after 1/04/2000 only	
Gasoline/CNG/LPG		CO (%)	HC (ppm)	CO (%)	HC (ppm)
2/3-wheelers	With catalytic converter	4.5	-	3.5	9000
	No catalytic converter	4.5	-	4.5	-
All others (cars, buses, etc.)	With closed-loop three way catalytic converter	3.0	-	0.5	750
	No catalytic converter	3.0	-	3.0	-
Diesel		HSU (Units)	K (m^{-1})		
All vehicles	naturally aspirated or turbo-charged	65 (2.45)			

HC hydrocarbons; HSU Hartridge smoke unit; m^{-1} inverse metre

The possibility of tightening the emission limits for current vehicles has not been seriously investigated, although tighter limits are proposed for new vehicles. The proposal of 0.5% CO for new 4-wheelers is not operable on current equipment (that is, instrument accuracy is not capable of distinguishing those vehicles that pass from those that fail at the limit of 0.5% CO) and, in the opinion of the Consultant, neither is it operable on the new equipment configuration being considered—which is the same as those used at present but with more modern gas benches (4 gas benches calibrated only to measure CO and hydrocarbons (HC). In addition, other issues such as training, calibration, dilution control, measurement of ambient and residual values, zero referencing, quality assurance and audits need to be resolved.

The new proposed limits (such as 9000 ppm HC and 3.5% CO for 2-wheelers with catalytic converters) seem to have been defined without the support of good statistically valid data. Field results are required to define limits that will not only allow clean vehicles to pass and cause dirty vehicles to fail, but also that ensure that the percentage of vehicles that fail is socially acceptable. If a large fraction of vehicles fail, then evasion or corruption could ensue on a wide scale and move public opinion against the I&C system. Under these circumstances, a good approach would be to start off with lenient limits (such as the above) and use the data generated in the real-life tests to define the optimum pass/fail cut points. If the reject rates against these optimal cut points were to be unacceptably high, it would be advisable to progressively tighten the limits over a number of years until the final "ideal" cut points are achieved.

There is no independent body with the responsibility of analysing the results from the PUC centres to determine and / or recommend changes in the emissions limits or to analyse systematic problems with specific vehicle types. SIAM has been collecting data on the tests performed from their auto-clinics held in Delhi, Mumbai, Hyderabad, Bangalore, Kolkata and Chennai and from the new computerised centres in Bangalore, but so far have not found any NGO or government department interested in using this data.

Most of the members of the committees involved in defining the PUC process are from industry and equipment manufacturers and do not have the experience or expertise to develop a PUC program with sustainable improvements over a period of years. Such a continuing improvement would require regular updating of test protocols, emissions limits and operating procedures, likely to be necessary every other year or so.

Centre Characteristics and Requirements

Any company that owns an automotive workshop or a filling station can apply to become a PUC centre. The government does not control or enforce a quota of approved centres. Their application will be approved provided that:

- They own an approved emissions analyser. Twenty makes of gas analyser have been approved for gasoline / LPG / CNG testing and 12 makes of opacity meter have been approved for diesel testing.
- They have at least one designated technician.
- The technician must be a qualified motor mechanic and must be trained by the analyser manufacturer.
- The terms and conditions of the authorization contain the very limited centre operating manuals and procedures.

The PUC testing centre has to pay a Rs 1,000 fee to get its license to operate and a Rs 1,000 yearly renewal fee. The government does not receive anything for each test.

All of the PUC centres are in principle test-only centres. However, in practice they are allowed to conduct minor adjustments to the engines (such as changing the fuel/gas mixture) to get the vehicle through the test.

The centres are mainly established in one of the following modes:

- Mobile units principally stationed at major intersections.
- Fixed units in filling stations.
- Fixed units in automotive workshops.

The test centres that certify CO emissions from gasoline/CNG/LPG engine vehicles are equipped with BAR84[1] style 2-gas analysers whilst those centres that test diesel vehicles have partial flow smoke meters. Some of the centres are equipped with both types of analysers.

There is a requirement for each PUC Centre to contract an annual maintenance program with the equipment manufacturer and for this to include a gas calibration (for gas analysers) or a filter calibration (for smoke analysers) every 6 months. However, the majority of the centres have not done this because of the cost and because of poor enforcement by the government. One of the problems is that there is no legal basis for the government to enforce this requirement. None of the centres visited by the Consultant had calibration gases or filters. No government calibration audit program is in place.

SIAM has developed a computerised data collection system for the PUC. The only city with experience of operating the SIAM designed computerised PUC centres is Bangalore where over 100 have been installed. The public response to this change and the response of the centre owners have been very positive and the program's credibility has increased. The government is widely publicising the argument that if the vehicle is clean its fuel consumption will also improve, based on the data collected at the SIAM "auto camps" although a more rigorous test program by the US EPA has not demonstrated this benefit.

Number of Centres

Fixed and Mobile

Delhi has 430 PUC Centres.

Bangalore has a total of 151 gasoline PUC centres, of which 26 are located in filling stations and the rest in mobile units. This city is intending to promote more PUC centres in filling stations in the hope of reducing the number of mobile units. Having larger companies rather than individual operators running the PUC centres should promote greater responsibility and make it easier to monitor and audit the centres' performance.

New Computerised Centres

Bangalore now has over 100 computerised PUC stations for gasoline vehicles (vs. 2 in Mumbai) and the next in line to adopt them is Hyderabad.

On 13 Sept 2002 the first computerised diesel PUC station was inaugurated in Bangalore.

Installed Capacity

At present only 15% of vehicles are estimated to be actually tested. The rest do not have a certificate or buy their certificate without even presenting the vehicle for test. In Delhi, for example, the PUC Centres visited by the Consultant reported conducting 20-30 tests per day. Even working 7 days a week, the 430 centres cannot be conducting more than 3.9 million tests annually, whilst the requirement for 3.4 million vehicles tested four times a year is 13.6 million tests!

---

[1] "BAR84" (California Air Resources Board's Bureau of Automotive Repair 84) is the name of both the Smog Check program implemented in 1984 in California and the test used in that program.

Cost and Frequency of Checks

Delhi

The test costs Rs 25 with an additional Rs 5 adjustment fee (this covers the cost of the technician tuning the mixture to get through the test) for gasoline/CNG/LPG vehicles. Diesel vehicles cost Rs 50. Tests are required every 3 months in Delhi although the Union requirement is every 6 months. There is discussion within the Delhi government of doubling the fees and reducing the test frequency to half (every 6 months) when the new computerised test is finally adopted.

Mumbai

There is no fixed price for the PUC test, and instead only minimum prices have been defined. Each PUC centre is free to charge whatever the market will bear. For gasoline and CNG/LPG vehicles the cost varies from Rs 30 – 50, whilst for diesel vehicles the minimum cost is Rs 50. Tests are required every 6 months.

Hyderbad

The current test costs Rs 15 for 2-wheelers, Rs 20 for 3- & 4-wheelers and Rs 40 for diesel. With the new computerised test the test fees are proposed to be increased to Rs 30 for 2-wheelers, Rs 40 for 3- & 4-wheelers and Rs 60 for diesel. Tests are required every 6 months.

Bangalore

The old manual test cost Rs 20 for 2-wheelers, Rs 30 for 3-wheelers, Rs 40 for 4-wheelers and Rs 50 for trucks. With the new computerised test, these prices have been increased as follows: Rs 30 for 2-wheelers, Rs 40 for 3-wheelers, Rs 50 for 4-wheelers and Rs 70 for trucks. Tests are required every 6 months.

Proposed Changes

The Mashelkar[2] report is recommending the adoption of the SIAM computerised PUC model and a sliding timescale for the PUC tests based on the vehicles emissions readings.

1. If the registered emissions readings are less than 50% of the corresponding standard for that vehicle, the following PUC test would be after 6 months.
2. If the registered emissions readings are less than 80% of the corresponding standard for that vehicle, the following PUC test would be after 4 months.
3. If the registered emissions readings are less than, but above 80% of, the corresponding standard for that vehicle, the following PUC test would be after 3 months.

Training and documentation

The Batra Car Care Centre, which is one of the best PUC centres in Delhi, was visited. The technician did not have any written procedures or other documentation specifying how the test is to be performed. The diesel free-acceleration test procedure used in India is equivalent to ECE Regulation 24 (BS AU 141a: 1971) smoke test, which specifies that the throttle pedal should be

---

[2] The “Expert Committee on Auto fuel Policy”, chaired by the Director General of the Council of Scientific and Industrial Research, Dr. R.A. Mashelkar, was established in September 2001 to recommend an auto fuel policy for India together with a road map for its implementation.

pushed rapidly but not abruptly to its full-throttle position accelerating the engine, with the transmission in neutral, from low idle to its maximum governed speed. In practice, the technician accelerated the vehicle's engine (a diesel-engine Toyota Land Cruiser) at less than quarter throttle from idle to around 1500 rpm. Five accelerations were performed and the reported average of the last 4 readings was manually transposed from the paper strip printed by the AVL opacity meter to the handwritten certificate. The strip is stapled to the original certificate that is given to the vehicle owner. During testing the probe fell out of the exhaust pipe on two occasions. Smoke density readings are affected proportionally to the percentage of entrained air. Since the smoke mass does not change, more clean air entrained in the exhaust gives a larger volume flow and hence mass density goes down. Smoke density readings are really only concentration readings, and hence affected by dilution. As a result, smoke readings can be easily lowered by entraining clean air into the exhaust. This highlights the importance of following strict procedures for smoke measurements.

When questioned as to why he does not perform the prescribed full-throttle acceleration to maximum engine speed, the operator said that he had not been told how to perform the test but had found that by doing it his way all the vehicles passed.

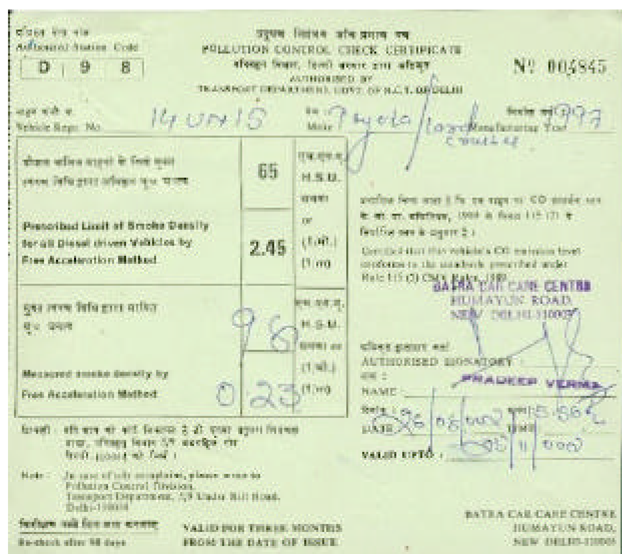
No rpm measurement is made.

Certificates, Stickers and Reporting Requirements

In Delhi, each PUC Centre prints its own certificates and windshield stickers without any government supervision. Neither of these documents contains any elements or security measures to prevent or detect forgery. In other cities the Association of test centre owners coordinates the printing of certificates and stickers for their members.

Certificates are issued only to vehicles that pass the test, except in Bangalore where some centres issue a letter if the vehicle does not pass the test suggesting that the owner checks the following items.

Gasoline	Diesel
Oil change	Oil change
Carburetor air screw	Diesel filter change
Air filter cleaning	Air filter cleaning
Petrol filter cleaning	Nozzles cleaning
Engine tune-up	Bosch pump servicing
	Muffler cleaning


Authorised Station Code D 9 8
POLLUTION CONTROL CHECK CERTIFICATE
AUTHORISED BY TRANSPORT DEPARTMENT, GOVT. OF N.C.T. OF DELHI
No 004845
Vehicle Regn. No 14 UN 15 Make Toyota Land Cruiser
Prescribed Limit of Smoke Density for all Diesel driven Vehicles by Free Acceleration Method 65 H.S.U. or 2.45 (1/M)
Measured smoke density by Free Acceleration Method 96 H.S.U. 0.23 (1/m)
BATRA CAR CARE CENTRE HUMAYUN ROAD NEW DELHI-110003
AUTHORISED SIGNATORY
NAME PRADEEP VERMA
DATE 26/08/2000
VALID UPTO 25/11/2000
VALID FOR THREE MONTHS FROM THE DATE OF ISSUE
BATRA CAR CARE CENTRE HUMAYUN ROAD, NEW DELHI-110003

Under the current system, no document or information is generated by the centres for governmental use.

The centres receive their certificates in a cheque-book-like format and keep the stubs as records. The windshield stickers do not have any legal value; each vehicle is obliged to carry the original certificate at all times. None of the windshield stickers have been designed to facilitate enforcement. Their graphic design does not vary from time to time, making it virtually impossible for a police officer to differentiate between a valid and outdated sticker.

Under the new computerised system, each centre may print a daily or monthly report of tests performed and SIAM is currently collecting the databases once per month. They have yet to find any authority interested in analysing this data.

Box 1 SIAM Computerised Test

SIAM in conjunction with SAFE had been pressing hard to establish prototype computerised test centres in the main metropolis but backed off in the light of political pressure against them. They were accused of making vehicles to a low quality standard that could not get through a strict test, and promoting an I&C test with lenient limits.

The SIAM initiative is focused only on data entry and data collection. SIAM really has not done any work to improve the test itself, measure anything other than CO or tighten limits.


TRANSPORT DEPARTMENT SEAL

COMPUTERISED EMISSION TEST CERTIFICATE

KA 02 EB 1225

TVS XL SUPER

CO

KA 02 EB.1225

GRADE

Bangalore now has over 100 computerised PUC stations (vs. 2 in Mumbai) and the next in line to adopt them is Hyderabad.

SIAM has installed a computerised data entry program in place in Bangalore for non-diesel vehicles and SIAM/SAFE are now proposing the data collection side. SIAM itself has been going around the PUC centres to manually collect data but have yet to find anyone interested in using it. The current software, written in Visual Basic 6 with its database in Access, includes the drivers for obtaining the HC and CO readings from 10 different analysers (four 4-gas analysers and six 2-gas analysers). Some of these data channels are analogue and very few allow synchronous communication with the gas bench.

The software is designed for data input; it does not control the analyser or the length of the test. Its current level of security against tampering is low, being protected by only one Access password. It includes a custom driver for the web camera to include a photo of each vehicle in the database.

The software does not include any functions necessary for quality control and quality assurance, such as calibration control, auto-zero and residual checks. Neither does it include any data transmission functions at this stage.

At a later stage SIAM intends to add a data transmission module for each centre to send the daily results to the main SIAM server via the Internet. From there, they plan to make some of the information available to the local authorities.

Centre Auditing and Supervision

The government does not seem to be aware of the institutional requirements of a good PUC program. Whilst centre investment can be private sector, the government must realise that substantial investment is required on their part to establish the program administration and control.

None of the regional programs visited attach any importance to controlling the certificates that are issued or supervising their use. The current manual system does not generate any useful data to assist the government audit or supervise PUC centre operations. In Bangalore where there are now more than 100 computerised stations, the data collected monthly by SIAM is not being used at all. This is a perfect example of implementing computerised systems to generate data for data's sake. No analysis has been carried out to determine what data is required to cover a series of supervisory and development goals, and there is a serious danger that the data that is collated will be insufficient if and when such goals are finally defined.

Good quality control and quality assurance (QA /QC) is a must for a successful program. This requires a trained, incorruptible staff with information technology systems for data transfer and analysis. ***It also requires a development vector to design and program beneficial modifications to test protocols, operating procedures and emission cut points (standards)***.

In Delhi the government has only four inspectors whose job is to visit each of the 430 centres on a bi-monthly basis to check what they are doing. They hope to increase the frequency of inspection to monthly. The inspectors are meant to ensure that:

- The technicians that work in each centre are authorised.
- The analyser is working.
- The centres are using authorised procedures.

Enforcement

Vehicle Owners "need to comply"

By far the majority of vehicles in India have never had a PUC test or certificate. This has been allowed to happen, despite the program having been in force for 16 years, by almost non-existent enforcement strategies. For example, Delhi has only eight patrols to catch gross emitters on a random basis so the vast majority of the 2-wheeler fleet has never had a test. Those that have been tried are as follows:

Roadside Enforcement

In Delhi-Jaipur-Agra trapezoid, roadside enforcement is working well at controlling visible smoke. Within Delhi, it is surprising how few smoking vehicles can be seen, thanks to a number of measures taken including strong police enforcement. Other cities such as Mumbai and Bangalore have not been as aggressive and still have a large number of visible smokers.

Even the goods carriers with 22-year-old, state licensed, 9-tonne trucks possess current PUC certificates. If the police stops them for visible smoke and they cannot produce a certificate, they are subject to a fine of Rs 5000. In practice, nobody pays this amount and drivers instead pay an "informal" fine of Rs 1000 for an individual truck or up to Rs 2000 for a fleet operator. If stopped repeatedly by the police, this can become quite expensive.

If a private or light commercial vehicle is a gross emitter (visible smoke) it runs the risk of getting stopped by one of the 8 patrols.

- If it does not have a PUC certificate, it is fined Rs 1000.
- If it does have a current certificate but exceeds the limits, the vehicle has 7 days to repair and retest without any fine. If the vehicle does not turn up for a retest within 7 days, it is subject to a Rs 1000 fine.

Traffic police are able to stop gross emitters but the maximum fine they can impose is Rs 100.

It is understood that all these fines are "negotiable" but effective. Delhi is the city, amongst those visited by the Consultant, where there are fewest smoking vehicles. To reinforce these actions, the Delhi government has implemented a reporting process for gross emitters via postcards with no stamp required. The government has also just implemented a hot-line to report offenders.

The truckers also have problems with roadside checks of their fitness and safety certificates. The Transport authorities regularly doubt the validity of the original certificates, particularly from other states, and the truckers have to obtain another one or pay a bribe of Rs 200 – 500. The cost of a black-market fitness and safety certificate is Rs 1500 – 2000.

Link to Annual Tax Payments or Vehicle Insurance

New vehicles in India pay a one-time vehicle tax equivalent to 17 years' of road tax and do not pay an annual road tax. This does not allow the payment of an annual tax to be conditioned on the vehicle having a current PUC certificate.

The State of Karnataka (whose capital is Bangalore) introduced in April 2002 a "Green Tax" on vehicles. This is based on the concept that the older vehicles, particularly those intensively used, pollute more.

- All commercial vehicles (goods and passenger) over 7 years old are required to pay an annual tax of Rs 700 at the time of their Fitness and Safety check.
- Private vehicles over 15 years old are required to pay a green tax every five years and the vehicle has to be re-registered. The tax for 2-wheelers is Rs 250 (Rs 50 per year) and the tax on 4-wheelers is Rs 500 (Rs 100 per year). The funds collected will go to the Transport Department to enable them to take appropriate steps for pollution control and public awareness.

The State Government of Karnataka is considering making the possession of a current PUC certificate a requirement when paying the tax.

The Mashelkar report has recommended improving the PUC program. Some of the points covered are:

- A buy-back scheme to remove old / dirty vehicles from the fleet.
- Adoption of the SIAM computerised PUC model.
- Reducing the frequency of inspection for private vehicles to once a year for vehicles of up to 5 years old and twice per year thereafter. For new commercial vehicles the frequency should be every six months, reducing to every three months, as they get older.
- Making the possession of a current PUC certificate a requirement for obtaining the obligatory annual vehicle insurance.
- Use of the ARAI mass emissions testing scheme for further study to allow the PUC test results to correlate with the new-vehicle transient-driving-cycle certification tests.
- Linking PUC to compulsory vehicle insurance.

All vehicles are required to have insurance cover. Hence limiting the issue of the insurance policy to those vehicles that have a current PUC certificate is seen as being one means of ensuring that the majority of vehicles get tested (at least once per year).

Link to Fuel Supply

Delhi and Mumbai have both tried to force the vehicle owners to get a PUC certificate by limiting the supply of fuel only to those vehicles that have a current certificate. In practice this has not worked. The filling stations do not have the time, inclination or legal backing to check the documents of everybody that goes to the pumps. Their interest lies in dispatching clients and fuel as fast as possible.

Despite this experience, the state of Karnataka is considering introducing this measure this coming year.

Visible Proof of Compliance

Some of the states do expect their PUC centres to give a sticker with the approval certificate to the vehicle owner. However, the vehicle owners are required to have the current PUC certificates with them at all times, since none of the states attach any legal importance to the sticker. In most cases, the stickers are printed by each PUC centre, as are the certificates, and whilst they do follow a basic design there are differences among centres in any given city that would make counterfeit stickers impossible to detect.

None of the states have a sticker design that would make it easy for a traffic police to detect non-current certificates and none of the stickers are designed to be attached to 2-wheelers.

In conclusion, the traffic police are powerless to enforce the PUC program other than by stopping gross polluters and requesting the certificate. In practice, the percentage of the total number of vehicles that they can and do stop is minimal.

Test Protocols and Equipment Used

For Testing Gasoline, CNG and LPG vehicles

Current Test

All the PUC centres that currently test gasoline, CNG or LPG fuelled vehicles are equipped with Bar'84-style 2-gas analysers that have been certified to measure exclusively CO. Each analyser has a sample hose and probe fitted with an in-line filter. Even though it is a government requirement, very few centres have an annual maintenance contract with the equipment supplier. The few that do have an annual maintenance contract receive 2-4 visits per year (when the filters are apparently changed) and a one-gas calibration every six months. The majority of centres do not receive this level of maintenance and none of the centres visited by the Consultant had calibration or working gases. This lack of systematic calibration greatly reduces the level of correlation between the instrument reading and the actual CO concentration.

All the analysers are manually operated. The technician inserts the probe into the vehicle's exhaust pipe and, with the engine operating at low idle, reads the value from the instrument after an undefined period of time and writes the value on the certificate. Manually entering the data increases the chances of incorrect numbers being recorded.

For 2 and 3-wheelers it is virtually impossible to insert the probe sufficiently into the exhaust pipe to avoid air entrainment. This would require the use of an extension tube which none of the PUC centres have.

Since neither carbon dioxide (CO_2) nor oxygen (O_2) are measured, there can be no control for dilution. Thus it is easy to reduce the reading by withdrawing the probe slightly from the exhaust pipe until the entrained air reduces the exhaust CO concentration to the desired level.

Since all the 2 and 3-wheelers, and the vast majority of 4-wheelers, are carburetted, CO levels can also be easily reduced during this low idle test by weakening the mixture, and if required, by retarding the ignition timing in extreme cases. As the test requires the engine to produce only sufficient power to keep itself running there are no checks and balances that could identify these false passes. The technician charges Rs 5 for this service and, as expected, all the vehicles pass after this tuning.

Since the certificates are hand-written, there is absolutely no restriction to the technician generating a certificate without even turning the analyser on. For the small percentage of vehicles that have a current PUC certificate, this is considered to be the principal means of obtaining it.

Proposed Changes

The new computerised PUC system proposed by SIAM addresses only three of these issues:

- The computer prints the certificate obtaining the CO readings from the analyser via a serial connection. This means that the analyser needs to be turned on or a potentiometer connected to the analogue input, although the probe does not have to be in that particular vehicle's tailpipe.
- The inclusion of a photograph of the number plate on the certificate means that the vehicle should at least be present in the PUC centre, unless the certificate is printed using Word of Excel, with an independent digital image.
- The centre would be required to possess extension tubes for the 2- & 3-wheeler exhausts, even though there are no means of checking if they are used correctly or not.

While the proposed system changes are an improvement on the current system and move the PUC in the right direction, they cover only data entry (plus photograph) with the generation of a local database. No changes are proposed to the test procedure, analytical equipment, requirement for calibration or centre supervision and audit.

Only minimal security has been included (a password protected Access database) but due to the current ease of obtaining a false pass, combined with the complete lack of governmental database and certificate control, the probability of electronic tampering is presently negligible (that is, one does not have to go through the trouble of breaking into the database in order to obtain a false pass).

SIAM is developing a proposal covering electronic data transmission from the PUC centres to a SIAM Server, but work has yet to be started on this project.

Box 2 Tata Energy Research Institute (TERI) Proposal

TERI as part of an Indo-UK initiative has recently completed a transport project titled "Regulatory and Management Options for I&M Centres". In this project, TERI in association with ARAI has developed an implementation plan for introducing I&M centres in Mumbai with the first phase concentrating on commercial vehicles and then focusing on private vehicles, while ensuring that old vehicles get inspected early.

They have proposed installing a pilot centre in Mumbai. Their phase I proposal, for immediate implementation, is to follow SIAM's lead by measuring CO and HC on a low idle static test and including the license plate photograph on the certificate. No CO_2, O_2 or rpm measurements have been considered.

Phase II, which they propose introducing in 2003-2004, would include a dynamic test on a dynamometer.

TERI has proposed reducing the CO limit over time to become stricter for both new and old vehicles but this concept has not yet been accepted.

They are fully aware of the inadequacy of the current PUC program and have proposed the following changes:

- The law should be amended to make periodic inspection obligatory.
- The test procedure needs to be changed.
- Technician training must be included.
- Modern Instruments must be used. To this end, ARAI has identified that the Sensors or Andros 4-gas analysers should be used, but measuring only CO and HC.
- The Government should not perform the PUC inspection. The private sector could be invited to participate or it could be managed by NGOs.
- The cost structure must be analysed to determine the fee structures.

The proposed modifications in the emissions limits for vehicles manufactured after 1 April 2000 will cause other changes:

- Whilst all the current PUC centres are equipped with 2-gas analysers, these are certified only for CO measurement. This is causing great consternation with the inclusion of HC in the emissions limits: whilst the analysers are capable of reading this magnitude, they are not certified for measuring HC. The intention was to keep using the current analysers, but for the addition of HC to the pollutants to be measured would require that every instrument be re-certified to measure both CO and HC, which would be a daunting task.
- The proposed new standard for catalytic-converter-equipped vehicles drops the CO limit to 0.5%, which the current analysers are incapable of reading. The proposal is to require more

precise 4-gas analysers for these vehicles, calibrated to read only CO and HC. Again, no consideration has been given to the need for dilution control (which would require checking O_2 and CO_2 readings as well, and certifying the instruments for all the four gases rather than two) or the need for QA/QC checks and balances. No changes have been proposed to the test protocols, operating procedures or the need for systematic calibration.

The intention in India is to continue using the current test protocol in which the exhaust gas concentration is measured with the engine operating at its normal idling speed. The authorities involved have not even evaluated adding a high idle stage to the current static test. The problem is that the low idle test does not represent typical engine operating conditions. The engine has to generate sufficient power only to overcome internal friction, which is very low at this minimum rpm compared with the power level required to accelerate the vehicle or drive it at a sustained road speed. It represents a basically unstable operating condition for most carburetted engines with a highly throttled (restricted) air intake provoking uneven air and fuel flow to the cylinders. Under this minimum flow condition, fuel droplets can easily condense out on cold inlet manifold walls and any problems caused by spark plug fouling or by the timing advance mechanism in mechanical distributors is immediately apparent. Many engines are also very sensitive to any change in their idle speed (idle rpm). Raising the idle speed from, for example, 600 rpm to 900 rpm (a 50% increase) can make a significant difference in its emissions levels.

Because of the above problems, exhaust gas concentration readings measured at low idle (which are normally taken to be between 600 and 1200 rpm), particularly when engine rpm are not measured or controlled, present great variability with a wide statistical dispersion. To account for this dispersion, the emissions cut points have to be set higher to avoid failing vehicles erroneously, thereby leaving greater lee-way for any mechanic to obtain a false pass for a dirty vehicle.

Where a dynamometer (which would allow a loaded mode test) is not available, better consistency can be achieved in the emissions results by increasing the no-load speed of the engine to around 2500 rpm. This has several benefits: the engine is operating at a higher throttle setting (against greater internal friction) with a higher and more consistent air and fuel flow to each cylinder and the engine speed tolerance band is much tighter, as it is easy to control the engine speed within 10% of the 2500 rpm target. As a result, the statistical variability is reduced, improving the definition of adequate cut points.

If exhaust gas measurements <u>must</u> be taken at low idle, preconditioning the engine with 30 seconds operation at 2500 rpm before the test can improve the statistical dispersion in the results—it eliminates the accumulated problems caused by the engine sitting at idle for a prolonged period before the test is started.

SIAM is recommending that no changes be made to the test protocol.

The only stakeholder that is promoting a change is ARAI. ARAI (together with the Vehicle Research and Development Institute, VRDE, and Indian Oil Corporation) are the body that certifies the new vehicles. They are concerned about the lack of correlation between test results from the static low-idle test and from the new vehicle (US Federal Test Procedure, FTP, style) homologation[3] tests. ARAI is proposing developing data expressed in terms of grams of pollutants emitted per kilometre travelled (g/km) from the Indian certification test-cycle run on a free-roll set with raw concentration measurements and has focused principally on CO with just a quick look at HC.

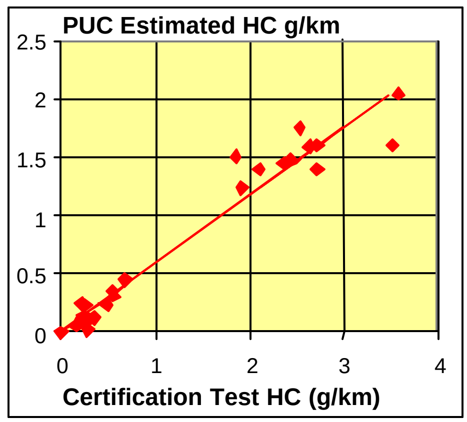
[3] Homologation is the type-approval certification by engineers with expertise in the regulatory requirements and approval processes of the destination country.

The Indian drive cycle used for certifying new 2-wheelers is a transient drive cycle developed in 1985 similar to the US FTP but with a lower maximum speed. It is 648 seconds long (one 108 second cycle, repeated six times) and includes accelerations, decelerations and driving at different steady speeds.

The tail pipe emissions are mixed with varying volumes of diluted air so that the total volume flow is constant (Constant Volume Sampling – CVS – system). Part of the samples are collected in bags during the test and analysed by laboratory grade instruments to give the volumetric composition in percentage or ppm. These in turn are converted to mass emissions and expressed in g/km. The equipment required to operate this test is expensive and complicated to operate, calibrate and to maintain.

ARAI is proposing using the current PUC gas analysers together with a simple roll set with approximately 170 kilogram (kg) inertia and no power absorber or motoring drive. The rear wheel of the 2-wheeler is placed on these rolls and the same transient drive cycle of 108 seconds is repeated 3 times, of which the first is considered a warm-up cycle the results of which are discarded. The undiluted tail pipe HC and CO emissions are measured continuously (in % or ppm) and each reading is multiplied by a distinct factor that depends on the vehicle's speed. The sum of these values is presented as the test's result in g/km. A figure comparing the HC emissions in g/km from the certification test and those calculated in the proposed test is given in the figure below.

In developing this procedure ARAI is looking to achieve acceptable correlation with the new-vehicle certification test at a much lower investment and operating cost; in fact ARAI estimates adding less than US$300 to the SIAM computerised PUC test.



The advantages of having an I&M test that provides good correlation with the new vehicle certification test are:

- The in-use cut points easily relate to the new vehicle certification standards since they are expressed in the same units (g/km).
- The in-use test results can be easily used with vehicle original equipment manufacturers (OEMs) to verify emissions warranty compliance.
- Systematic false-passes and false-failures are automatically limited because of the direct correlation between the in-use cut points and the new vehicle standards.

However, ARAI will have to overcome the following hurdles if good correlation is to be achieved for these advantages to be realised:

- Since the free-roll set has no power absorber or motor, the 2-wheeler only has to generate power during accelerations to overcome the roll inertia (39% of the test). At steady speed and during decelerations (46% of the test), the engines operating condition is very different than in the certification test where road-load and air resistance are taken into account. The remaining 15% is at idle and is the same in both tests. This affects emissions. The results presented by ARAI from their prototype installation indicate that the test is capable of detecting approximately 59% of the HC measured in the certification test (with a straight line r^2 of approximately 0.95).
- Since they do not plan to use a CVS system because of complexity and cost, one basic assumption has to be that ***the exhaust flow rate does not vary from vehicle to vehicle or from time to time***. It would be time consuming but theoretically possible to characterize each and every make, model and model year of 2-wheeler with different engine displacements but any variation in inlet or exhaust restriction on the vehicle, engine misfire, valve-seat condition or operating the vehicle in a different gear will change the flow rates and alter the calculation. This drastically increases the measurement uncertainties associated with this base assumption.

- Different CO and HC analyser systems have differences in the gas transport time which is a function of the sampling pump flow rate (and maintenance) and the sample system volume. This causes the emissions-readings to be delayed with respect to the vehicles speed-readings. Since the proposed system depends on multiplying each instantaneous gas reading by a vehicle velocity dependant factor, these variations also increase the measurement uncertainties associated with this method.
- The proposed instrumentation would allow invalidation of any test with unacceptable speed excursions from the allowable tolerance band, but provides no means of stopping the tester partially removing the probe from the exhaust pipe to generate a pass-certificate. Neither can the test method ensure that the equipment is adequately calibrated or zeroed before each test without going to new, software-controlled, 5-gas (O_2, CO_2, CO, HC and NO) analysers. The current 2-gas analysers have high measurement uncertainties.
- Transient drive cycle tests are typically longer than steady-speed tests and more difficult to drive, requiring better technician training and larger number of installed test lanes.

CPCB is recommending that the benefits of going to a loaded mode test be evaluated, but that no change in the test protocol is to be introduced before 2005.

There seems to be little appreciation of the technical and administrative problems outlined above. Almost all the government officials at national and state level express the belief that adding HC measurements to some of the newer vehicles and adopting the SIAM computerised data entry scheme will eliminate the majority, if not all, of the current woes of the PUC program. However, it is likely that, under the current proposal, measurement inaccuracies and lack of QA/QC will continue.

For Testing Diesel Vehicles

<u>Current Test</u>

All the PUC centres that currently test diesel-fuelled vehicles are equipped with partial flow smoke meters without engine temperature or rpm measurement.

The probe is inserted into the vehicle's tailpipe and a series of five to eight accelerations are performed. Whilst the accelerations should be conducted at full throttle until maximum governed engine rpm is reached, in practice a more lenient test is usually performed, at partial throttle to a much lower rpm. An average of the last 4 readings is reported on a paper tape printout provided that they within a band of 0.25 m^{-1}; otherwise the test must be repeated.

<u>Proposed Changes</u>

ARAI is proposing measuring engine rpm and engine oil temperature during the test. However, ARAI has not been able to reach a consensus with the OEMs on the minimum oil temperature for the test to be considered valid or to decide what to do with the engine rpm reading. Whilst SIAM can help them define the maximum engine rpm specification for each engine type, a computer controlled test would need to be specified with a Master Reference Table lookup to effectively use this information to hinder false passes, and this is not something the parties involved are planning to do.

SIAM is proposing including diesel smoke measurement in their computerised PUC data entry system but so far has only developed the interface connection with one smoke meter.

Dateline for changes

The Mashelkar Committee report proposes the following timeframe for reducing pollution from in-use vehicles.

Action	Dehli (NCT)	Major Metropoli	Entire Country
New PUC system for all vehicles	1 Oct 2003	1Apr 2004	1 Apr 2005
Inspection and Maintenance System for all vehicles	1 Apr 2005	1 Apr 2006	1 Apr 2010
Performance Checking System for catalytic converters and conversion kits	1 Oct 2004	1 Apr 2005	1 Apr 2007

Note: Major Metropoli include Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur & Agra.

Added to the above:

- Having a current PUC certificate should be a necessary condition for annual renewal of the obligatory vehicle insurance.
- Promoting public bus transport must be made a priority issue.
- Schemes combined with incentives should be developed for replacing old vehicles and retrofitting new engines and emissions control components.
- Systems must be put in place to check the emissions warranty on new vehicles and to check the emissions performance of LPG/CNG kits.
- Charging higher motor tax on old vehicles in critical areas should be considered.
- Ensure that an adequate quality level for liquid fuels is available for the new vehicle technologies as they are being introduced.
- Tighten minimum emissions standards for older (pre-1996) vehicles.

Vehicle Fitness and Safety Checks

Tests Conducted

All company owned and commercial vehicles have to pass the fitness and safety check every year. Private vehicles are meant to report for a fitness and safety check when they reach 15 years of age.

Currently all the inspection is visual apart from the emissions test (PUC) where the CO or smoke reading is obtained from a manual analyser and written onto the certificate by the tester. No other equipment is involved.

Vehicles required to test

In each major metropolis there is one appointed centre operated by the Regional Transport Office that can perform the check. This “monopoly” situation is effectively used to charge “extra” for all vehicles that wish to obtain a certificate. Even new vehicles will systematically fail unless the additional fee is paid. Thus, whilst the official fees (in Delhi) are as shown below, the true cost varies from Rs 800 for a 3-wheeler to Rs 1500-2000 for a heavy goods vehicle.

Type	Vehicles/day	Official Fee	Real Cost
Heavy Goods Vehicle >12000 kg	25 – 30	500	2000
Heavy Goods Vehicle 7500 - 12000 kg	45 – 50	400	↓
Heavy Bus	40-45	400	
Light Goods Vehicle	50	300	
Taxi	20 – 30	300	
Auto-rickshaw	100	200	800
Total	300		

Most of the certificates that the Consultant saw in Burari, the Delhi RTO fitness and safety test centre, that had been issued over the previous weeks bore only the vehicles registration details—no inspection had been performed whatsoever and not even the checkboxes had been filled in.

In Mumbai, the government operated fitness and safety check centre was described by the Taxi Union as being a "fish market" with each group of inspectors vying for trade.

New vehicle distributors in Mumbai explained that the quota for them (with new vehicles) depended on the number of vehicles sold by the agency, and as such was higher than that extracted from an individual vehicle owner.

Corruption and Control

It is evident that there are vested interest groups with very strong incentives to prevent a more objective test procedure from being implemented. Objective tests would go against the interest of all those who are benefiting from the current system.

In Mumbai, the true cost for a taxi to legally pass the test would be around Rs 15,000 to Rs 20,000 because of the need to repaint and repair the vehicles, this when the yearly certificate is sold to all at Rs 1,500. For new vehicles the going amount is Rs 300 – Rs 500 depending on the client. As mentioned above, one taxi owner described the RTO facility as a fish market owing to the number of negotiations taking place at any time.

Box 3 Working to improve Public Opinion

The Bangalore Transport Authority, plagued by negative reports in the press, has been working hard to address some of the comments by using modern technology.

Where have they started? With learner drivers test registration.

The only way to register for a test used to be through a "facilitator", a middle-man who charged for his "services" in arranging these governmental tests. The situation got so far out of hand that the newspapers regularly published the going rates.

To counteract this, the Transport Authority has now set up its own web site where any person can register on-line. They have also published a Citizens Charter to improve their interaction with the public. As a result the public opinion of corruption within the Authority has improved.

Their next task? To extend this program to eliminate the middle-men from all other programs. One at a time.

If the current PUC program is ineffectual, the fitness and safety program for commercial vehicles (e.g., Burari in Delhi) is considerably worse. Linking the two in private enterprise could be highly beneficial if, and only if, the present graft structure could be undone.

It is interesting to note that several fleet owners thought that if the fitness and safety check were operated by the private sector, the degree of corruption would increase. (The transport sector is reputed to have a strong mafia involvement and the perception is that this would carry over to the fitness and safety check stations).

There is no doubt that an objective and correctly operated fitness, safety and emissions check would be highly beneficial to society at large. However, it would be no easy task to get it out of the clutches of the present hierarchy that is currently benefiting from the income it produces. Neither would it be easy to establish the checks and balances required to keep the new system corruption-free unless the process of change is unconditionally supported from the highest level and there is sufficient political resolve to make it happen against all odds.

There are several private companies that would be willing to operate such a program in partnership with the government (where the government supplies the land and they, the investment) provided that the program is truly obligatory and that there is a means of enforcement (e.g., with colour-coded stickers on the windscreen and by making it a requirement for vehicle insurance or yearly registration). Such a co-investment scheme would, in concept, be acceptable to the Delhi Government. However, if such a system were installed only in Delhi, it would result in a massive re-registration of trucks into the next province where "visual inspection" would allow them to pass the test easily.

Burari World Bank investment

In the early 1990s, five lanes of computer-controlled vehicle fitness and safety check equipment supplied by Hamilton/ESP were delivered to the Burari Centre through funding from a Japanese grant that was administered by the World Bank.

The equipment consisted of a computer operated and controlled dynamometer emissions test, a heavy duty brake tester, a wheel slip tester, a wheel alignment tester, and a headlight tester. The five lanes were to be operated by 12 technicians with a daily capacity of 750 vehicles (per 10-hour day).

By 1996, the equipment had been installed and underwent approximately 50 tests over the following 6 months. No official fitness and safety checks were ever performed. Today, it is in disuse and totally abandoned and the old practices of "visually inspecting" the vehicles continue unabated.

Why? Admittedly there were some unresolved technical and operational problems, but the principal reason is that Burari is a smoothly operating moneymaking machine and the introduction of "objectivity" into the test regime could hamper this lucrative operation. Five groups, each consisting of 2 inspectors, operate one shift and process an average of 300 vehicles per day.

New Fitness and Safety Checks

The Apex body for the State Transport Authorities who run these programs is the Transport Council which meets every one and a half to two years. This Council is discussing how to set up the test centres and the standing Emissions Norms Committee has defined the test equipment and software specifications that will be used to define the equipment. The different makes of equipment will then be certified against these specifications by ARAI.

Backend computerisation has already started focusing on new vehicle registration to increase revenue. Gains of 14% – 40% have been reported by the states involved.

Private Sector Participation

There is no bar to private sector participation in the I&C centres. The Supreme Court Order to the Delhi government on 28 July 1998 forces the government to strengthen the I&C program and specifically allows private sector participation. However, no regulatory framework has been established that could create suitable conditions to promote private involvement. Whilst the program operation can be decided by the local (state) government, the National Road Transport Ministry is responsible for coordinating any standards related activities.

Vehicle Fleet

Configuration and Age

The most recent official vehicle population figures are for 1998 (Motor Transport Statistics of India, MOST- Ministry of Surface Transport, 1997-1998). These show a total population of 40.9 million vehicles including 5 million cars, jeeps and taxis (12 %) and 28.3 million 2-wheelers (69 %). Commercial vehicles (buses and goods vehicles) account for 6 % of the population. The population of 3-wheelers is not clearly specified.

Provisional figures for March 2000 show a proportional increase in total population to 44.7 million vehicles (excluding agricultural tractors and trailers) with over 75% being 2-wheelers and less than 14% being cars, jeeps and taxis.

Metro Areas	3W	Taxis	Buses	LCV	HCV	Total Commercial
Hyderabad	45,800	3,098	2,539	16,479	20,763	88,679
Delhi	86,985	17,762	37,733	56,548	156,157	355,185
Ahmedabad	39,558	4,307	14,993	9,001	8,700	76,559
Bangalore	68,737	8,638	6,380	17,300	14,890	115,945
Mumbai	97,565	58,696	15,414	33,781	20,199	225,655
Chennai	35,420	9,596	4,409	6,125	26,286	81,836
Kolkata	9,747	32,199	8,586	N/A	59,576	110,108
India Total	1,573,903	553,052	482,682	801,503	1,872,135	5,283,255
% of P+C	3.5%	1.2%	1.1%	1.8%	4.1%	11.8%

Metro Areas	2W	Cars & Jeeps	Others	Total Private	Private + Commercial (P+C)
Hyderabad	757,684	99,314	4,461	861,459	950,138
Delhi	2,184,581	869,820	9,246	3,063,647	3,418,832
Ahmedabad	616,738	104,179	1,337	722,254	798,813
Bangalore	1,164,204	238,374	22,220	1,424,798	1,540,743
Mumbai	407,308	325,473	8,759	741,540	967,195
Chennai	848,118	207,860	10,666	1,066,644	1,148,480
Kolkata	298959	238,560	11,683	549,202	659,310
India Total	33,707,108	5,435,124	291,558	39,433,790	44,717,045
% of P+C	75.4%	12.2%	6.5%	88.2%	100%

However, a vehicle population survey conducted by the Central Road Research Institute in Delhi indicates average vehicle ages much lower that the official numbers.

Average Age of Passenger Vehicles in Years (Surveyed at Filling Stations)

	NTC	OTC	2W	Auto	Bus
Delhi	3.7	6.8	5.2	2.1	2.1

Average Age of Goods Vehicles in Years (Surveyed at Filling Stations)

	LCV	HCV	MAV	Other
Delhi	5.3	4.9	4.7	4.4

There is no annual vehicle registration in India; vehicles are registered when new and are supposed to re-register only after 15 years' service. This makes it very difficult for the government to obtain good population information and to conduct an effective inspection program—the authorities cannot be sure which vehicles are still being operated and hence cannot estimate the percentage of vehicles that evade inspection. Whilst the official figures tend to assume that there is negligible or zero vehicle mortality, this survey highlights the need for a comprehensive vehicle population study since the official figures are likely to be highly overstated, particularly in the major metropolis.

It is important to mention that the estimated number of on-road vehicles in different cities contained in the Report of the Expert Committee on Auto fuel Policy is totally different from the above figures, some being considerably higher and others substantially lower. An extensive survey is required to generate vehicle population figures that can be used as a basis for all emissions inventory work and to define policy decisions on fleet administration.

In a similar vein, the annual mileage (km) for different vehicle categories published by the CPCB are considerably higher than what would be expected from international experience taking into account the Indian operating conditions. The above-mentioned survey should also be used to validate these figures.

Vehicle Type	Average km/year
2W	10,000
3W	40,000
Cars	15,000
Taxis	30,000
Multi-use vehicles	37,000
Light commercial vehicles	40,000
Heavy commercial vehicles	30,000
Buses	60,000

Limiting the age of vehicles—buses less than 8 years in Delhi and to less than 15 years in Mumbai, taxis to less than 10 years and auto-rickshaws to less than 15 years—obviously has a positive effect on emissions but also highlights the amount of time that it will take for the new Euro II technology (to be mandated in India in 2005) to permeate through the vehicle fleet. Many people believe that the vehicle emissions problem will be solved by the High Court's legislating the introduction of such technology in new vehicles.

Cars and Multi-Use Vehicles

There is no maximum age limit for cars and multi-use vehicles (MUVs). The number of cars in India is proportionately lower than in many other countries. This is attributed by the Boston Consulting Group to:

- Lower per capita disposable income
- High car prices due to high taxes
- The market's inability to manage obsolescence resulting in a limited used car market
- The reduced presence and number of OEM dealerships.
- The limited acceptance of credit in non-metro markets.

Comparison of Cars per 1000 people against Per Capita GDP for different Countries

Country	Per Capita GDP	Cars per 1000 people
Thailand	$1,958	103
Brazil	$2,561	77
India	$3,895	25
Mexico	$5,561	143

Note: India's population and Per Capita GDP have been adjusted for the proportion of the population that has a per capita income of at least $1,300 Source: The Economic Times, Mumbai, 12 Sept 2002.

Buses, Trucks

The Supreme Court issued a directive in 2000 limiting the maximum age of these vehicles. No commercial vehicles of over 15 years are allowed into Delhi. Urban buses in Delhi must be no older than 8 years whilst the limit for Mumbai has been set at 15 years. The Brihanmumbai Electric Supply and Transport (B.E.S.T.) bus fleet was excluded from this order because of their good maintenance record, but 179 of their trucks are affected.

Goods carriers (trucks) with All-India license plates are limited to a maximum age of 15 years. Those with state plates, however, do not have a maximum age.

2-Wheelers (2T & 4T)

Whilst the majority of new 2-wheeler sales have 4-stroke engines, almost 80% of the total 2-wheeler fleet is 2-stroke without any emissions control technology, making these vehicles a major source of particulate and HC emissions.

To reduce the emissions from this category of vehicles, the government area in the centre of Delhi (Connaught Place) is planning to experiment with banning parking of 2-wheelers. These will have to park outside this area and take an electric shuttle bus in.

3-Wheelers

In Delhi, the number of auto-rickshaws (3-wheelers) has been fixed at the 1998 level and no additional vehicles are allowed. The maximum allowable age is 15 years, and for each new one sold, an old one must be scrapped or sold into another state.

In Mumbai, all 3-wheelers older than 10 years were planned to be phased out by 31 Aug 2002. and the rest to be converted to CNG/LPG. The government is going slowly on this order due to the fact that the 3-wheelers are mostly in the suburbs and there are not enough filling stations. Attempts are being made to match the conversion rate to the increase in filling stations. Bangalore does not currently have an age limit for 3-wheelers or fuel limitations. All of these vehicles in this city (over 60,000) are 2-stroke and one of the main items on the Transport Commissioners agenda is to introduce LPG.

The owners of 2-stroke engine auto-rickshaws are fighting hard against the movement towards 4-stroke engines. They do not like 4-stroke for the following reasons:

- The initial cost of a 3-wheeler with a 4-stroke engine is higher.
- It is more complicated to maintain and the parts cost is higher.
- The vehicle acceleration is less with a 4-stroke engine.
- 4-stroke engine heat is greater.

The resistance is such that when Bajaj cancelled 2-stroke production they were forced by the market to re-introduce them. The popularity of 2-stroke engine vehicles is also the likely reason that the manufacturers seemingly strongly defend lenient PUC standards, because 2-stroke emissions are virtually universally higher than those of 4-stroke.

Taxis

The Supreme Court issued a directive in 2000 limiting the maximum age of taxis to 10 years in Delhi and 15 years in Mumbai. In Mumbai this age restriction has not yet been made effective.

Natural Gas Conversions

There are two types of vehicles in India that use natural gas:

- Bi-fueled vehicles which can operate on either natural gas or gasoline
- Dedicated vehicles which operate only on natural gas.

Both of these types are available as conversion kits for existing vehicles, and new from the vehicles manufacturer. In both cases, the conversion to natural gas implies an additional investment that must be recouped via lower operating costs.

The primary reason for promoting natural gas as an automotive fuel is to reduce emissions, particularly fine particulate concentrations. In India this conversion adds an additional advantage of eliminating the known fuel adulteration problem. However, fuel distribution and storage costs are much higher, the vehicle cost increases, its driving range is limited and potential operational and performance problems arise.

Bi–fuel conversions cannot be optimised for both fuels. Accordingly when operating on gasoline, their fuel consumption and emissions increase. The experience in Mumbai's taxis shows an increase in fuel consumption from 10 litres to 18 litres per 100 km.

In Delhi and Mumbai all the taxis have been converted from diesel to CNG by substituting the diesel engine with an old used gasoline engine that was then converted for CNG use. In many cases, the retrofitted engine (particularly in Mumbai) was in a worse mechanical state than the diesel engine it replaced.

The 3-cylinder diesel taxis in Mumbai were meant to be phased out by 31 April 2002. However, as of 1 Sept 2002, only 7,000 taxis had been converted to CNG with approximately 11,000 units still to be converted.

The Mumbai taxis were all gasoline until 1991 when fuel costs increased, causing their owners to look at alternative fuels. Some were converted to CNG (with a bi-fuel system) but were later discarded because of the shortage of CNG. The solution was found by fitting scrapped Korean 3-cylinder diesel engines in these vehicles. Unfortunately these engines were not matched to the Fiat taxis and were highly polluting. In 1999, these vehicles were banned in Mumbai and the conversion process to CNG was resumed. This required refitting the vehicles with their old original gasoline engines that had been removed in 1991. The old engine used to be available for Rs 5,000 but because of demand the cost has doubled. For the few that are overhauled, the engine can be bought for Rs 22,000 to Rs 25,000 whilst new engines cost Rs 60,000. When added to the kit cost (Rs 32,000 – Rs 35,000) the use of a new engine was prohibitive. None of these conversions include a catalytic converter.

The majority of the auto-rickshaws that operate in Delhi, fitted with 4-stroke engines, were converted from gasoline to CNG. Bajaj sells new dedicated CNG fuelled auto-rickshaws.

The emissions improvement gained from the forced conversion of light vehicles to CNG has been principally in the elimination of visible smoke. Whilst bi-fuel conversion kits continue to be allowed, the emissions improvement will be less compared with a properly engineered dedicated CNG conversion using fuel injection.

The quality of the conversion kit is critical: a comparison of the type approval mass emissions data from CNG-converted heavy-duty engines shows grams of CO emitted per kilowatt-hour (CO g/kWh) varying by an order of magnitude between the cleanest and dirtiest approved kit and nitrogen dioxide (NO_2) and HC emissions varying by over 300%. High emissions from a sub-standard conversion kit are of a permanent nature.

Poor conversions also pose a safety risk, as recent cases of CNG vehicle fires in Delhi testify. Thus a program to convert vehicles to CNG must be accompanied by a strict safety inspection requirement. All public carriers must obtain a fitness and safety certificate on an annual basis from inspection centres operated by the State Transport Authorities, but these do not cover any of the safety aspects of the CNG installation.

The Association of Road Transport Undertakings (ASRTU) has been given the responsibility of checking CNG Conversion safety both at the kit installers and for the vehicles on a regular basis. This is meant to happen for urban buses but they do not have the power or the means to check if the kit used is authorised or spurious or if it is substandard. It is highly unlikely that any of the other converted vehicles are ever inspected for safety or for kit quality. Thousands of light vehicles have been converted to CNG/LPG with unapproved kits but since the vehicle owner never registers the change in fuel, they are virtually impossible to detect, let alone inspect.

One logistical problem in launching a CNG program is that unless the numbers of refuelling stations and CNG vehicles are balanced, long queues for refuelling become unavoidable. The forced introduction of CNG in Delhi and Mumbai—with deadlines for taxis and 3-wheelers before sufficient filling stations have been installed—has led to a temporary problem of 5-10 hour queues to get enough fuel for an 8 hour shift. In the mean time many auto-rickshaws in Mumbai, faced with the long queues to fill the CNG tank, have opted to revert to gasoline. Whilst the CNG tank capacity for a taxi normally gives a driving range of 160-180 km, the current excess demand on the existing filling stations has resulted in lowered filling pressures and reduced driving range.

The key to the commercial viability of a CNG conversion program is that the higher capital and possibly maintenance costs of CNG vehicle conversion and operation be compensated by fuel cost savings. In India, natural gas for CNG is presently priced below the economic opportunity cost and the fuel cost of running a taxi is reported to be approximately half that of using diesel. In a free market scenario, which is planned after 2002, this price differential will be eroded as the price of CNG moves towards import parity (India will be importing a significant quantity of natural gas as liquefied natural gas, LNG). Fiscal incentives would then be required to promote the use of this fuel.

The urban buses that have been converted from diesel to CNG were all fitted with new, dedicated CNG engines. The lack of large gasoline engines that could be converted with a kit forced the transformation process to be done correctly.

The most detailed comparison between operating with diesel and CNG fuels can be made from the Mumbai bus fleet (B.E.S.T.). B.E.S.T. operates a well-maintained diesel fleet with its own vertically integrated facility. They have 3,866 diesel buses (including 3,380 single deck buses) plus 45 CNG powered single deck buses operating since 1997.

The operating problems they have found with these buses are as follows:

- Filling Station Investment

  The time required to load 70 kg of CNG is approximately 15 minutes vs. less than 2 minutes for an equivalent amount of diesel. Whilst CNG filling stations are considerably more expensive than diesel pumps and tanks, the investment required is multiplied by this difference in filling time. This was not taken into account in the CNG program and hence they lack sufficient filling capacity. A depot with 130 buses would require 3 or 4 CNG compressors, which is an expensive proposition.

- Initial Investment

  A CNG bus costs 52% more than an equivalent diesel unit. One must remember that whilst the diesel components are sourced in India, CNG components are imported.

- Operating cost

  The overall operating cost of a diesel Euro II bus is Rs 34.72 /km whilst the overall operating cost of a CNG bus is Rs 37.86 /km. The principal difference lies in component costs. An imported CNG piston costs around Rs 5000 whilst 6 nationally sourced diesel pistons can be purchased for the same amount. The higher engine temperatures found with CNG also affect durability.

- Fuel Economy.

  The benefits in reduced fuel cost are not as great as expected. They report a fuel consumption of 2.75 km/kg for CNG at a unit cost of Rs 19.71/kg (Rs 7.17/km) whilst for Euro II diesel buses they report 3.0 km/litre at a unit cost of Rs 22.74/litre (Rs 7.58/km).

- Operating Flexibility.

  Whilst all their buses have 12 CNG storage cylinders with a total capacity of 117 kg of fuel, this does not give them the necessary range for their longer routes. They currently deploy these vehicles on routes of up to 200 km whilst their longest routes are 300 km.

25 of their buses are fitted with three-way, closed-loop catalytic converters that have caused a lot of problems because of the high converter temperatures. The failure of exhaust piping between the engine and the converter, red-hot tail pipes and road damage to these very expensive components are some of the most common problems.

B.E.S.T. started a durability project with TERI in April 2002 to evaluate the emissions from four types of bus over 40,000 km with smoke and other contaminants being measures every 5,000 km in Pune on the Bombay Drive Cycle. The vehicles included in the study are given below. The tests should be completed in March-May 2003.

Number	Fuel
2	50 ppm Sulphur diesel
3	350 ppm Sulphur diesel
3	500 ppm Sulphur diesel
2	CNG

LPG Conversions

LPG has recently been authorised as an auto-fuel but currently results in operating costs of approximately 50% greater than CNG. However, some taxis are moving to this fuel to avoid the 5-10 hour lines at CNG filling stations in Delhi and Mumbai. It is expected that this tendency will increase as CNG prices rise.

In Delhi, LPG has been authorised as a vehicle fuel but is not widely used legally due to higher costs (vs. CNG) and lack of fuelling infrastructure, although its use is on the increase because of the serious shortage of CNG refuelling capacity. Approximately 60,000 vehicles are currently operating illegally on this fuel in the Delhi area using LPG destined for home use. These vehicles have been converted to bi-fuel (gasoline/LPG) and are not equipped with catalytic converters. If they are adequately tuned for one of these fuels, the fuel consumption and emissions when using the other fuel increase substantially.

Eighteen conversion kits have been authorised for 3 & 4-wheelers. In both Delhi and Mumbai, a small number of taxis are converting from CNG to LPG despite the increase in operating costs. This conversion costs approximately Rs 8,000 but since these units do not have to queue for 5-10 hours to get enough fuel for an 8-hour shift, they are currently seeing more money in their pockets as a result.

New Vehicle Sales

Vehicle Sales:	2000	Calendar Year 2001		
	Units sold	Units sold	Total	% of Total
Utility Vehicles (MUV)	127,455	128,573		
Cars	603,069	601,132		
Total Cars + MUVs			729,705	14.1 %
LCVs	63,232	56,138		
Buses	28,650	22,066		
Trucks	63,896	66,684		
Total Commercial			144,888	2.8 %
Scooters	1,013,737	897,223		
Motorcycles	2,122,489	2,675,086		
Mopeds	731,548	527,516		
Total 2-wheeler			4,099,825	79.2 %
3-wheelers	217,356	200,066	200,066	3.9 %
Total	**4,971,432**		**5,174,484**	**100 %**

SIAM: Statistical Profile 2000 – 2001

It is interesting to note that over 83% of all new vehicle sales are 2- and 3-wheelers with cars and MUVs accounting for only about 14% of sales. Approximately one-third of current 2- and 3-wheeler sales are 2-stroke (using gasoline-oil mix) whilst the remaining units are 4-stroke. All 2-stroke current sales have catalytic converters (phased in 2000) and port injection.

There is a tendency for the younger set to buy motorcycles (around 100 cc) rather than scooters which have traditionally been the family transport of choice for the middle-aged middle class who are now moving to small cars, and hence motorcycle sales are substituting scooters. This tendency is enhanced by the motorcycles being more fuel-efficient (up to 80 km/litre).

Moped sales are also going down.

New vehicle financing at around 14% per year (inflation rate of approx 3-4%) is now available in the major metropolises. The lowest cost new car is the Maruti Suzuki 800 cc at approximately US$4,000.

Maruti is operating a buy-back scheme on old Maruti cars. These are then factory reconditioned and sold with 1-year warranty and available financing at a price of US$2,500 – 3000. This has provoked a change in the market with middle class families moving up from scooters to these vehicles.

Emissions Warranty

The vehicle manufacturers (SIAM) have voluntarily offered an emissions warranty on new vehicles of 18 months or 18,000 km. The warranty covers vehicles that fail the PUC test with its current limits, provided that the vehicle owner can prove that all the required regular maintenance has been correctly carried out at the vehicle dealer. Not surprisingly, no vehicles have yet obtained a payment via this warranty (according to SIAM); very few vehicles are serviced at the vehicle dealership and it is virtually impossible to fail the current PUC test.

Automotive Fuels

Fuel Prices

Product		Mumbai	Delhi	Chennai	Calcutta
Diesel (2.5% & 0.05% SULPHUR)	Rs/litre	23.97	18.91	20.81	20.3
Gasoline (std)	Rs/litre	34.42	29.91	32.42	31.35
Gasoline (BP-Speed)	Rs/litre	35.5	31	33.5	32.1
KEROSINE (DOMESTIC)	Rs/litre	9.01	8.91	8.42	9.27

On 1/10/02 See: http://www.bharatpetroleum.com/general/gen_petroprices.asp

Commercial kerosene is about Rs. 22 per litre.

Fuel Specifications

Between 1994 and 2000 lead was completely phased out from gasoline in India. In addition the sulphur content of gasoline was reduced from a maximum of 0.2% to 0.1% from 2000 in the entire country. The four major metropolitan areas are currently being supplied with gasoline with a maximum of 0.05% sulphur.

Between 1996 and 2000, diesel sulphur content in the entire country was reduced from 1% to 0.25%. Currently, 500 ppm (0.05%) sulphur diesel (Bharat Stage II, equivalent to Euro II compliant diesel) is available in Delhi, Mumbai, Kolkata and Chennai.

The High Court has ruled that 500 ppm sulphur must be introduced in Bangalore, Hyderabad and Ahmedabad by 1 April 2003, and in the rest of the entire country by 2005. The oil industry has argued that this step will require an investment of Rs 350,000 million (about US$7 billion). The High Court has also ruled that 350 ppm sulphur diesel fuel (Bharat Stage III, equivalent to Euro III compliant diesel) must be in place in the above mentioned 7 metropolitan areas by 1 April 2005. However, meeting this or tighter goals (Bharat Stage IV fuel with 50 ppm sulphur diesel in these cities by 2010) will be severely complicated by the need for supply infrastructure investment.

All cross-country pipelines, ocean tankers and road and rail tankers are currently multi-product leading to cross-contamination of fuels. These difficulties can only be overcome by installing fractionating columns at each pipeline tap-off point—which are like mini-refineries and are capital intensive—to ensure that the higher sulphur content of one product, for example, does not increase the sulphur content of the product that follows it through the pipeline. Likewise the tanks in ocean tankers and the surface transport fleet would have to be used for only one product each. This would require duplicating the surface transport fleet and holding tanks and force ocean tankers to return with empty tanks to their point of origin after having delivered a specific product.

The Government's decision to dismantle administered price controls in the oil sector and to approve the proposal to give market rights for gasoline, diesel and aviation fuel to companies willing to put up a refinery in the country with a minimum investment of Rs 20 billion may accelerate this change, however.

Essar and Reliance Petroleum, which are capable of producing products meeting Euro II specifications and stringent Californian standards, are expected to be among the first companies to benefit from the opening up of petroleum product marketing to the private sector. As a result, a large number of petrol pumps selling different brands of gasoline and diesel are expected to mushroom all over the country.

All these companies have yet to establish their supply infrastructure and as such are free of the limitations of the public sector petroleum industry. Their entry into the market is likely to accelerate the availability of ultra low sulphur fuel and to improve the quality of gasoline at the pumps which will put much pressure on the other local refiners to upgrade their refineries and improve their distribution systems.

The government is also planning to make each refinery responsible for the fuel quality right through the distribution chain to the filling station pumps. This will most likely meet significant resistance from those that currently benefit from the systematic adulteration process.

Fuel Availability

Diesel (Low Sulphur vs. High Sulphur)

Diesel demand in India is currently higher by approximately 5.5 times than gasoline, primarily because of the low number of private cars.

The Supreme Court has determined in its 15 July2002 directive that only Euro II trucks and buses (Baharat Stage II technology) be allowed to enter Delhi (apart from limited pickup-and-delivery rights). The first Euro II specification diesel engines were introduced in the market in 2001. According to fleets, these are still suffering teething problems.

CNG

CNG is considered to be a short-term alternative fuel for those cities suffering from high vehicular emissions that produces an immediate benefit in terms of reduced visible smoke and particulate emissions, although the emissions of CO and oxides of nitrogen (NO_x) may increase when compared to Bharat Stage II diesel engines. It is also free from adulteration, which continues to be a major problem for liquid fuels.

CNG can be used only in those cities that have access to the natural gas pipeline (Delhi, Mumbai and Baroda on a limited scale). The west coast of the country may have access to this fuel (as LNG) after 2003 via imports, although LNG is considerably more expensive than the current supply of natural gas that is domestically sourced.

In Delhi, the entire city bus fleet is being converted to CNG, making it one of the largest CNG bus fleets in the world. The approximate number of CNG vehicles in Delhi is as follows:

Vehicle type	Number
Buses	6,000
Cars	10,000
3-wheelers	42,000
Taxis	1,000
RTV	2,000
Total	61,000

Source: CSE

In Mumbai, there are currently 32 CNG stations and the government plans to increase this number to 45 by March 2003 to cover this increase in demand.

In the Mashelkar Report, the conversion to CNG is considered to be "emergency room" treatment to clean the air in these cities, although it is recognised that a multi-fuel policy is required. The government has decided that the priority sectors for natural gas are:

1. Fertilizer
2. Energy
3. Transport
4. Industry

This has provoked concern in the municipal transport fleets in Delhi and Mumbai. They have had to convert to CNG by High Court Orders, but the long-term availability of this fuel for automotive use is now questionable.

<u>Gasoline</u>

For 4-stroke engines

India has two automotive gasoline fuels, unleaded regular and unleaded premium with octane ratings of 88 and 93, respectively. Both fuels have 0.05 % (or 500 ppm) maximum sulphur as per the Supreme Court order.

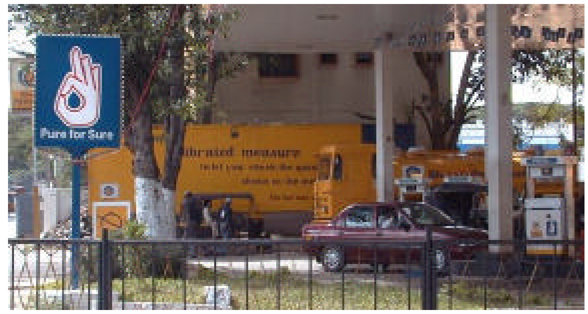
Recently, Bharat Petroleum launched a "new generation" high performance gasoline called "Speed". Speed contains additives that remove deposits from fuel metering systems and components and is said to result in "enhanced overall engine performance—easy starting / smooth idling, maximum power and acceleration, reduced emissions, and no engine knocking— improving mileage and reduced maintenance costs". It has been priced at a nominal difference of Rs 1.25 per litre over normal gasoline and has been very well accepted by the public. Bharat Petroleum is marketing "Speed" only from its "Pure for Sure" certified retail outlets, several of which reported the sales volume of this fuel has increased far faster than expected.

For 2-stroke engines

In Delhi and Kolkata, premixed gasoline and two-stroke oil is sold. This has helped considerably in reducing 2-stroke smoke.

Low smoke two-stroke oil is now available throughout India. Tests have shown, however, that whilst JASO-FC grade "low smoke" lubricants do reduce visible smoke, there is no evidence that they lower particulate emissions. The quality of the lubricant does not seem to have statistically significant impact on HC, CO or NO_x emissions, but increasing the quantity of lubricant resulted in increased particulate emissions and reduced HC and CO emissions.

Fuel Adulteration



Fuel adulteration is an important issue, but one that is extremely difficult to quantify since adulteration by definition is a covert operation and as a result little hard data is available. It is enough of a perceived problem to promote the "Pure for Sure" marketing campaign by Bharat Petroleum and the "company owned-and-operated" signs at Hindustan Petroleum filling stations.

In India, whilst gasoline has a higher tax burden than diesel, kerosene is subsidised as a cooking and lighting fuel for the poor and many industrial solvents and recycled lubricants bear no tax at all. This opens the door to adulteration as a means of making money by diverting tax revenues.

There are several types of adulteration for automotive fuels:

- Blending large amounts of hydrocarbon-based industrial solvents into gasoline
- Blending small amounts of distillate fuels such as diesel and kerosene into gasoline.
- Blending large amounts of kerosene into diesel
- Blending small amounts of heavier fuel oils into diesel
- Blending small amounts of waste products such as lubricants into diesel as means of disposal.

Not all these are directly hazardous to vehicular emissions. The addition of kerosene to diesel does not increase vehicle emissions but other adulterants do increase the emissions of HC, CO, NO_x and

Box 4 PURE FOR SURE

Bharat Petroleum has recognised that one of the basic needs of the customers is standard-compliant quality and correct quantity of fuels. As one of the major initiatives in this direction, Bharat Petroleum has launched a nation-wide voluntarily effort to dispense standard-compliant quality and correct quantity of fuel.

This program is being launched in phases. The first phase consists of certifying retail outlets covering the 4 Metros, Bangalore & Hyderabad, at 108 sites. Another 600-700 sites are to follow, in 2 more phases in various cities. The retail outlets covered under this program display the **'Pure for Sure'** sign. At such retail outlets, Bharat Petroleum guarantees that the correct quality and quantity are dispensed. In order to be able to do so, strict quality control and tracking measures have been put in place at every point from the supply point (depot) to the customer's fuel tank.

Before certification, the retail outlets are subjected to stringent tests by TUV SUDDEUTSCHLAND - INDIA to ensure that all parameters of the program are complied with.

The main pillars of this program are:

a) Tamper proof locks: Supplying product to retail outlets in modified tank lorries fitted with tamper proof locks.

b) Comprehensive sealing: Dispensing units are sealed in a comprehensive manner, which makes meter tampering impossible.

c) Periodic and surprise checks by staff: Stringent periodic and surprise checks are carried out to check for correct delivery and the sealing of the pumps.
d) Testing of product samples: Regular comprehensive testing of samples for clinical and octane rating is done with an element of surprise.
e) Certification of retail outlets: Periodic audits and re-certification of retail outlets by a reputed certification agency, TUV SUDDEUTSCHLAND, India.
f) Dedicated manpower: Dedicated field staff has been placed to monitor and sustain the program. Mystery audits anc extensive inspections are carried out at these retail outlets to ensure that they continue to comply with the requirements of the Enhanced Fuel Proposition program.

These measures have been embraced by the Mashelkar Committee report which has recommended that they be made obligatory for all petroleum companies.

particulate matter.

It is important to keep fuel adulteration in proper perspective. The age and state of vehicle maintenance, the duty cycle, and engine and exhaust after-treatment technology levels all have a first order effect on the vehicular exhaust emissions.

Gasoline

When gasoline is adulterated with kerosene or diesel, higher emissions of HC, CO and particulates result, because these fuels are more difficult to burn. The higher sulphur levels in kerosene can also deactivate the vehicles catalytic converter. If too much kerosene is added, engine "knock" can result which also increases NO_x emissions, which is a precursor for secondary particulate and ozone formation.

If gasoline is adulterated with low-tax gasoline-boiling-range solvents such as toluene or xylenes, or other light materials such as pentanes and hexanes, it can be very difficult to detect and the vehicle's drivability may not deteriorate. Large amounts, however, can increase HC, CO and NO_x emissions from the vehicles exhaust.

Adulterants that contain halogens, phosphorous or metallic elements completely outside the range of normal gasoline can provoke costly internal damage to the engine components such as valves and valve seats, fuel injectors, spark plugs, catalytic converters and oxygen sensors.

Naphtha which is a feedstock for chemicals production is finding its way into fuel as an adulterant for gasoline, as is kerosene and "other solvents". Even white spirit was mentioned in the context of 2-stroke, three-wheelers.

Both diesel and kerosene added to gasoline will increase engine deposit formation including in fuel injectors, potentially leading to increased emissions. In the short term, however, kerosene added to gasoline will reduce CO emissions (in the low idle PUC test) but causes white smoke.

For gasoline, any additive that changes its volatility can affect drivability and emissions. High volatility in hot weather such as in South Asia can cause vapour lock and stalling

Spark ignition gasoline engines exhibit a high correlation between air/fuel ratio (lambda) and the emission of fine particulate matter (total number of particles per fuel mass increases when lambda goes down from 1) so particulate emissions should also increase considerably when the engine is run at a high fuel-to-air ratio ("rich"), which is often done in South Asia.

Adding too much oil to the fuel of 2-stroke engines and using reclaimed or other unsuitable oil is a major problem wherever premixed 2T fuel is not available.

Diesel

The adulteration of diesel with kerosene does not increase engine emissions but for low sulphur diesel, it could cause the sulphur level to exceed the specification, increasing sulphate-based particulate emissions. If, in addition, oxidation catalysts are installed, higher sulphur decreases the catalyst's conversion efficiency. The addition of heavier fuels to diesel can increase particulate emissions and foul injectors, valves and piston/ring sets.

Any added substance that substantially reduces diesel fuel lubricity would accelerate wear (naphtha, for example, would do this). Anything that increases resin-like deposits or sulphur or waxing could cause the problems seen on the Tata Sumo.

Adding heavier components to direct injection systems as found in diesel and gasoline engines, or indirect injection systems as found in diesels, can also increase the penetration of the fuel spray within the combustion chamber, leading to serious erosion of the chamber wall. (In direct injection diesel engines the chamber is normally in the piston crown). Normal port injection in gasoline engines has much higher injector temperatures than throttle body injection and thus will suffer more from deposit build-up.

Adulteration is said to take place on 3 levels:

(1) Systematic adulteration between the refinery and the filling station

> Most believe that the fuel leaves the refinery in good condition. However, five independent sources suggested that there is systematic Mafia-controlled adulteration taking place between the refinery and the filling station with kerosene and industrial solvents being added to diesel and gasoline. Adulteration levels of as much as 30-70% was mentioned to the Consultant. This is reported to affect fuel consumption and drastically increase engine wear and specifically cause clogging problems in fuel injection pumps and nozzles.

(2) At the filling station

> Adulteration is believed to be more prevalent at non-company owned-and-operated stations outside the urban areas where the station owner mixes and matches to earn a few extra rupees. Many of the filling stations outside the main urban areas dispatch automotive fuels and kerosene, making it particularly easy for them to mix in a lower taxed fuel and increase their earnings by, some sources suggest, over Rs 25,000 per day.

(3) By the vehicle driver

> As a nationwide average, approximately 40% of the auto-rickshaws are estimated to be hired out by their owners to an independent driver. The driver pays the owner a fixed fee for the use of the vehicle and has to return it every night with a full tank. There is an obvious incentive for him to reduce his expenses by adulterating the fuel. This is also a problem for liquid-fuelled taxis and commercial goods carriers. It is known that some filling station owners pay drivers to fill up at the adulterated pump.

The move to CNG for 3-wheelers and taxis in the major cities is very apparent and solves the fuel adulteration problem although the Consultant was told of filling stations diluting with air to increase profits.

Box 5 Smoke in SUMO Proportions

Bilal Rahill of the Environmental Unit of the World Bank has a 2000 model year Tata Sumo fitted with a 2 litre turbo diesel. This vehicle has received the best service available on a rigorous 5,000 km interval.

Recently, with 50,000 km on the clock the fuel consumption suddenly went from 11.3 km/litre to 6.8 km/litre with all the rest of the fuel literally coming out of the engine in the form of very black smoke. The cause: fuel injection pump and nozzle clogging which was put down mainly to fuel adulteration, this despite Bilal and his driver having made every attempt to fill the tank only in Delhi where the fuel is considered cleaner. The injector nozzles were cleaned and the fuel injection pump plungers and 'O' ring seals were changed, bringing the vehicle back to its original specs. When the fuel tank was cleaned a log of dust particles were found.

This is consistent with problems caused by supply-chain dirt contamination and fuel adulteration. Also one must recall that when the US and EU first went to 500 ppm there were cases of pump failures because sulphur was reduced from 0.25 to 0.05% and the fuel lost some of its previous lubricity. Since Delhi is the first city to go down to 0.05% in India, it is possible that this is also a contributing factor.

The Indian vehicle manufacturers are only just addressing this, and related problems. A fleet that the Consultant visited with some of the first Euro II diesel-engine trucks reported many continuing teething problems.

Diesel Emissions

Diesel engine emissions in India can be classified into two broad categories: emissions with an important social impact, and those with an important health impact.

Respiratory suspended particle matter (RSPM) with a particle diameter of less than 10 microns (PM_{10}) have, without doubt, a high health impact, particularly since they exceed air quality standards in several of the major cities, unlike sulphur dioxide (SO_2) and NO_2 which are typically within these national air quality standards. The few studies that have been performed in India on source apportionment suggest that about 15-20% of RSPM may come from vehicular emissions with a significant fraction from diesel vehicles, despite the small percentage of the overall vehicle fleet that use diesel. When smaller particle sizes are analysed, the percentage coming from vehicular exhaust increases, as does the health costs involved since there particles penetrate deeper into the respiratory tract. A qualitative description of ambient air quality in large cities in India is tabulated below.

	Annual Mean Concentration Range (µg/m^3)					
Zone	Industrial Zones			Residential Areas		
CITY	SO_2	NO_2	RSPM	SO_2	NO_2	RSPM
Hyderabad	L	M	M	L	M	H
Delhi	L	L	C	L	M	C
Ahmedabad	L	M	C	L	M	C
Bangalore	L	L	H	L	L	C
Mumbai	L	L	M	L	L	H
Chennai	L	L	M	L	L	H
Kolkata	L	H	H	L	H	C

Key:

	Industrial Zones		Residential Areas
	SO_2 &NO_2	RSPM	All
L =Low	0-40	0-60	0-30
M =Moderate	40-80	60-120	30-60
H = High	80-120	120-180	60-90
C = Critical	>120	>180	>90

Source: *"Air Quality in Seven Major Cities During 2001"* National Ambient Air Quality Monitoring Programme (NAAQM), Available at <http://164.100.32.5/mcity/2002/m2001.htm>

Contributing Factors

The main causes of diesel engine smoke are lack of preventive maintenance (together with overloading) followed by bad quality engine parts and then fuel quality and other related problems. Low lubricating oil quality is also seen as being a contributing factor to greater engine wear and higher emissions.

Fuel

Fuel quality and adulteration is of major concern to the truck operators. Whilst they recognise the existence of systematic adulteration between the refinery and the filling stations, most fleets try and fill the tanks at company owned and operated filling stations. Their worst experiences due to adulteration have been at independently owned stations, where the station owner can make over Rs 25,000 per day by adulterating the fuel as described above. Many filling stations are said to offer the truck driver money to fill up at the adulterated pump. Fuel adulteration could cause not only higher emissions, but it also has a direct effect on fuel economy and since fuel and tire costs are the highest operating costs for a truck, the vehicle owners take notice.

Aside from adulteration, fuel quality in general is perceived to be an issue. Many fleets commented that they get less smoke when they use fuel from the Delhi area (which is one of the Metropolitan areas that has fuel to a tighter specification than the rest of the country).

Fleets reported more fuel injection pump and injector problems in the North-Eastern part of the country, believed to be due to fuel quality. The Mumbai – Orissa route is also renowned for fuel quality problems.

Overloading

The principal long distance goods carrier is a two axle, 9-tonne truck. Three-axle, 12-tonne trucks occupy a minority position in the heavy goods vehicle (HGV) population and very few tractor-trailer units are found.

The 9-tonne trucks usually carry around 9 tonnes for half the total trip (e.g., from Delhi) and over 14 tonnes on the other half of the trip (e.g., to Delhi). In season this load increases to 22 tonnes. The independent truckers charge less per tonne of freight if the load is over 12-14 tonnes, which is the guaranteed load they look for on a 9-tonne truck.

The Tata 9-tonne truck usually gives a fuel consumption of 3.5 – 4 km/litre but due to overloading this drops to an average of 2.5 – 3 km/litre.

The three axle units would normally carry 20-22 tonnes and, depending on the cargo up to 35 or more tonnes.

Volvo is starting to introduce the FH314 tractor-trailer which is used with one trailer and overloaded to a combined weight of around 60 tonnes. The regular practice of over-loading affects emissions. The law does not allow overloading, but truckers can freely operate without interference if they pay the fine and can produce a current fine receipt.

When a truck is routinely overloaded three effects are typically seen:

1) The engine has to work harder since it is pulling a heavier vehicle up the hill (or accelerating from a stop to cruising speed.) As a result, the engine tends to operate at a higher brake mean effective pressure[4] (in the cylinders) to produce more power and, particularily on older engines, more smoke.

2) Since the engine is working harder it tends to wear out more quickly, but the engine does not necessarily get serviced for maintenance more frequently. Hence it is normally operating in a worse state of repair than a vehicle that operates within specifications. This affects engine, tires, brakes etc.

   The time to first major overhaul for a Tata 9 tonne truck was quoted by the best fleets to be around 150,000 km when a “normal” minimum time for the same type of engine should be at least over 200,000 km. Other fleets, with less rigorous preventive maintenance, quoted 80,000 to 90,000 km to first major overhaul. The best urban bus fleets are getting, by comparison, around 300,000 km. In addition to more rapid wear resulting from overloading, the time between first major overhaul and

[4] Brake mean effective pressure is essentially the engine torque normalized by the engine displacement.

second major overhaul is less (around, or less than 75% - 80% of initial period) also because the spares used are not fully to OEM specifications and not all the components are replaced.

3) As the engine is working harder (and the vehicle is slower) due to the excess weight, there is a tendency to over-fuel to compensate. Over-fuelling in turn is a significant cause of higher black smoke emissions.

Truckers worldwide have traditionally looked to overload to increase revenue and get more profit. However, truckers in industrial countries have found that they are better off financially in the long run using new trucks and operating within the vehicles specifications. That way their maintenance costs come down significantly, they do not have vehicles breaking down on the highway with perishable cargo and they can get contracts with the bigger more professional operations (such as Walmart in the United States). This has yet to happen in India.

These older trucks, even when new, smoked more than the new ones, thereby exacerbating the difference between old and new trucks.

Maintenance

Apart from some very notable examples (such as Orix, which operates at US automotive dealer standards), the quality of the automotive repair garages that the Consultant visited was found to be very low. They were under-equipped and in need of mechanic training. Many basic workshop fixtures and hand tools were not evident in either car or truck workshops. This obviously affects the quality of repair.

Another exception is the urban bus fleet in Mumbai (B.E.S.T). As previously mentioned, they are getting 300,000 km to first major overhaul on their buses whilst most other fleets are around 150,000 km.

Their time between first and second major overhaul, however, falls significantly to 150,000 km, which is mainly an indication of poor spare parts quality. They consider that the optimum engine life in their type of operation, taking into account purchase and maintenance costs, is 6 years.

The Bombay Municipal Corporation maintains 600 vehicles that are owned by the Municipality. Amongst them are 240 garbage trucks, 150 jeeps and 200 other heavy-duty vehicles with an average age of over 10 years. To comply with High Court Orders, all their light vehicles over 15 years old have been converted to CNG or LPG. The conversion kits used are bi-fuel and do not include a catalytic converter. Heavy trucks, with diesel engines as original equipment (OE) can only be transformed to CNG or LPG via an engine substitution. Although they employ 576 staff (excluding drivers and cleaners) to maintain their fleet of 600 vehicles, they complain of a lack of diesel engine tools and equipment and a lack of mechanic training.

Corporations such as this and B.E.S.T. do not have a fuel quality problem since they are supplied directly by Indian Oil Corporation, but do have a problem with spares quality and engine oil due to corruption in the purchase departments. Where possible, they try to ensure better quality parts for those critical assemblies such as engines and transmissions and use lower quality components for the rest of the vehicle.

Parts and Quality of Repair

The truck spare parts market in India is divided basically into four segments: genuine original equipment parts, grade 2 parts, grade 3 parts and spurious parts with quality and price differences between each category.

For engine and transmission parts, the price structure is as follows:

Category	Price Scale	Quality
Genuine (OE)	100	Original Equipment
Grade 2	70	Parts from the OE suppliers and parallel market through their own distribution channels. Includes parts surplus to OE requirements and parts with minor quality problems
Grade 3	50	Parts mainly from the OE suppliers that were rejected by the OE for unacceptable quality and lower quality parallel parts
Spurious	<40	Will-fit parts from non-OE approved suppliers. Usually of dubious quality

Most vehicle owners try, within their economic means, to use “closer to genuine” parts for critical assemblies such as engines and transmissions and lower cost components for “non-critical” areas such a brakes and electrics.

For engine and transmission components, the main volume sales are grade 2 parts. However, for other components the breakdown is different.

In electrical components, the price differential is far greater because their standardised design makes this market more attractive to the spurious supplier.

An alternator regulator, for example, has an OE price of Rs 3,500 whilst a similar “will-fit” component can be obtained from spurious suppliers at Rs 150.

Air brakes have only been introduced recently on the newer trucks and not yet marketed by the spurious suppliers. Because of this, the main competition to genuine OE for a component such as a brake valve assembly is the component manufacturer’s own distribution network at approximately 20% discount.

Since most of the trucks still use hydraulic brakes, parts used come mainly from the spurious suppliers.

The engine components that most affect emissions are probably fuel injection pumps (FIP), fuel injectors and turbochargers. Because of the high cost of these components, only 20-25% of the spares requirements for FIPs are genuine parts supplied by Mico (Bosch India). Approximately 70% of this market is supplied from alternative sources, many of which probably buy their parts from Mico. The remaining 5–10% are rebuilt and reconditioned. For fuel injectors, the market is divided between genuine and rebuilt assemblies.

Turbochargers are another high cost assembly costing approximately Rs 25,000 new. As a result, around 50% are rebuilt at a cost of Rs 5,000. In Europe and the United States this would entail changing a core assembly that includes the bearing housing and bearings together with the complete turbine, shaft and compressor wheel assembly because of the critical balance of these components. The practice in India is to change only the bearing and the compressor wheel.

The component suppliers have always been Indian companies operating in a closed economy, with a reputation for quality of somewhat less than international standards. This, however, is slowly changing since OEMs are now are able to source components from foreign suppliers. This has yet to impact the spares market where low cost suppliers from Taiwan have yet to penetrate.

It goes without saying that the poorer truck owners (and fleets) tend to own the older vehicles and also tend to use the cheaper spare parts. Thus, as the trucks get older, its emissions increase even more by the use of lower cost (and quality) components.

The richer fleets with the newer vehicles that use original parts in their repairs have to send a manager or the owner himself to stand over the mechanic whilst he is rebuilding the engine or transmission assembly to ensure that he does not switch the components for lower quality ones.

Enforcement and Control

The lack of diesel smoke in Delhi is striking, and to a lesser extent in the other cities visited. . Although the diesel PUC test is very much in need of improvement, the on-the street visual inspection by police can be effective as shown in Delhi. In this area (Delhi,-Jaipur-Agra trapezoid) black smoke will cause the truck to pay an on-the-spot "fine" of Rs 1,500 – 2,000 which is a major incentive to keep the vehicle clean.

The lack of repeatability of the free acceleration smoke test due to equipment and test protocol variations, described in detail below, causes alarming measurement errors that create problems, particularly for the larger fleets. The Bombay Municipal Corporation, for example, complains bitterly of driver harassment because the government smoke tests give different readings to the free acceleration tests that they perform in house.

Reducing Emissions from in-use Vehicles

The main tools for reducing emissions per unit of fuel consumed by in-use vehicles are:

- Improving the maintenance condition of the vehicles
- Improving engine technology and exhaust gas after-treatment
- Improving fuel quality
- Using alternative "cleaner" fuels

These measures go hand-in-hand with other policy decisions that affect the amount of fuel consumed, such as reducing the need for transportation, promoting mass transportation and downsizing vehicles, to name just a few.

Reducing Emissions from Vehicles with Diesel Engines

For vehicles with compression ignition engines, possible options include the following.

- Making sure the existing fleet is well maintained

Progressively tighten in-use emissions standards for existing vehicles.

Enforce an improved I&C test procedure with strict QA/QC.

Educate vehicle owners about the long term financial benefits of maintaining vehicles properly.

Promote enhanced mechanic training and the availability of workshop diagnostic equipment.

Empowering traffic police to fine vehicles that emit visible smoke may be useful, as the experience in Delhi suggests. This can effectively control exhaust smoke and, most likely, improve the maintenance standards. However, the lack of correlation between visible smoke levels and fine particle emissions is a concern and should be borne in mind. In the worst case scenario, visible smoke may be eliminated with little impact on public health if visible smoke reduction does not result in a marked reduction of particulate emissions. The development of an enhanced I&C test that correlate much better with particulate emissions is needed.

- Making sure the existing fleet is properly operated

  Take measures to identify and stop over-loading.

  Educate fleet operators about the long-term financial benefits of proper vehicle operations, such as not over-fuelling (which decreases fuel economy) and using proper quality lubricants (the benefit of which is to slow down engine and parts wear).

- Improving fuel quality at the pump

  Adulterated fuel can harm emissions and increase the vehicle's need for corrective repairs.

  Make the refineries accountable for fuel quality up to the pump.

- Accelerating vehicle renewal

  Specify maximum ages for vehicles that enter highly congested urban environments. This tends, however, to move these vehicles to other cities and uses.

- Accelerating the introduction of clean fuel and engine technology

  Supply diesel with tighter fuel standards—particularly for lower end point, density, polynuclear aromatics and sulphur content—to reduce particulate emissions. Lower sulphur also enables the adoption of oxidation catalysts, and eventually particulate traps.

  Require electronic fuel injection on all new vehicles.

  Retrofit new engines together with their emissions systems into existing vehicles operating in highly congested urban environments. The incorporation of alternative cleaner fuels such as CNG often requires the whole engine and emissions system to be replaced.

  In special circumstances, make judicious use of fiscal incentives.

Reducing Smoke and Particulate Emissions

The present in-use diesel engine smoke test specified in India roughly follows the SAE (Society of Automotive Engineers) J1667 Free Acceleration test procedure but without the checks and balances that the SAE standard includes. ARAI, amongst others, have proven that the measurement uncertainties associated with the current test procedure are considerably greater than the magnitude that is being measured: in other words, the current test is essentially ineffectual.

A free acceleration smoke test performed on a regular basis by one operator using one opacity meter and where no penalty is associated to failing the test can produce repeatable measurements. For this purpose, the free acceleration test can be a useful tool.

The problem comes, however, in an I&M environment where a large number of operators, using a large number of opacity meters from different manufacturers, can make money by passing dirty vehicles. In Mexico City, it has been found that under these conditions repeatable results are not obtained and the validity of such a test procedure for I&M purposes is high questionable. In July 2002 in Mexico, a programme was mounted in which simultaneous free acceleration tests were conducted using the ECE R24 (BS AU 141a:1971) procedure (as specified in India) on 4 makes of opacity meter with different operators. All were taking simultaneous samples from a Mercedes Benz L1217. On any particular run, the difference between the lowest and highest reading was as much as 700%. Even the two closest readings differed by 30%. With this level of discrepancy, the results obtained in an I&M test can even be said to be effectively arbitrary. Why did the tests produce such large differences?

- The test procedure attempts to get instantaneous readings from an instrument that was not basically designed for transient measurements. The exhaust flow velocity through the smoke chamber (of the partial flow opacity meter) is not a controlled variable and yet directly affects the time spent by each exhaust gas particle in the ray of light. The effective chamber length has a similar effect and both vary from instrument to instrument.

- Each instrument can generate between 100 and 1,000 readings per second. Each reading is an average of the gases in the chamber at that time. Each "instantaneous " reading has considerable variability depending on how many blobs of exhaust soot are blocking the ray of light in that instant. Different opacity meters have optical paths of different effective diameters. Larger diameter smoke paths usually display less variability in this respect. Each opacity meter applies its own algorithm to smooth these peak readings before recording its "instantaneous " reading.
- The ECE R24 procedure registers the highest opacity reading during the test, which is directly affected by these variability considerations. The SAE J1667[5] procedure calls for each manufacturer to design a Bessel low-pass second-order digital filter algorithm as required for each opacity meter to generate an overall response time of 0.500 seconds and registers the highest reading that this generates. Since the gas flow velocity through the smoke chamber is unmeasured and uncontrolled, and the design of the filter varies from manufacturer to manufacturer, this calculation is also is directly affected by these variability considerations.
- The ECE R24 procedure does not require correction of each instantaneous reading for gas temperature, pressure, humidity and altitude, all of which have been shown by the SAE to directly affect the reported results. The J1667 procedure requires such corrections before the Bessel filter is applied, with its obvious data processing overhead. This is not performed in all stand-alone opacity meters.
- The ECE R24 procedure calls for consecutive free acceleration tests to be performed until the readings do not form a decreasing sequence. A decreasing sequence would indicate that the engine has not reached its normal operating conditions. The J1667 procedure averages the results from three runs within a certain band but does not check for a decreasing sequence.
- Both procedures call for the operator to move the engine throttle to the fully open position as fast as possible; however neither test contains elements that would allow this to be validated. If the operator opens the throttle slowly, the engine accelerates slowly and generates less power and less smoke.
- Both procedures call for the operator to accelerate the engine from low idle to the engines maximum governed rpm; however neither test contains elements that would allow this to be validated. On a turbocharged engine, smoke readings will be lower if the operator starts the test at an elevated idle rpm, since this allows the turbocharger to spin up. If the test is cut short at a lower-than-maximum rpm, smoke readings can also be decreased.
- Both procedures require the technicians to take precautions when they inset the probe into the exhaust tail pipe. Any air that is entrained will dilute the sample and generate lower readings. Any sharp bend in the tail pipe can provoke the gas flow on the inside of the bend to have a lower opacity through centripetal force. The probe should be inserted in a straight section of tail pipe the length of which is at least six times the pipe diameter and the probe should not be within 5 millimetre (mm) of the internal exhaust pipe wall; however neither test contains elements that would allow validating the correct placement of the sample probe.
- Modern engines with electronic fuel injection or even with boost control circuits (on turbocharged engines) will react totally differently when subjected to a slowly changing speed and load under real-life driving conditions than how they react to a free acceleration.

---

[5] The SAE J1667 procedure covers a free-acceleration exhaust opacity test for diesel-engine vehicles in which a sophisticated mathematical Bessel function filter is used to eliminate instantaneous non-systematic peak readings from temperature-, pressure- and humidity-corrected maximum opacity levels collated over a 0.5 second time-frame.

- The typical test run is very short. The J1667 procedure does not specify the acceleration time for the engine to reach maximum governed rpm, whilst the ECE spec calls for no more than 3 seconds. The engine is then held at this speed for 1 to 4 seconds, allowed to decelerate back to idle in an unspecified time where it remains for a minimum of 5 seconds. Rpm measurement is not obligatory.
- The J1667 procedure allows the use of full-flow opacity meters that should be clamped on the end of the vehicle's exhaust pipe. It is particularly easy to generate false passes with full-flow opacity meters. Blowing cigarette smoke or passing a sunglasses lens through the light beam is all that is required.

The sum of all these elements can cause major variations in the final reported reading.

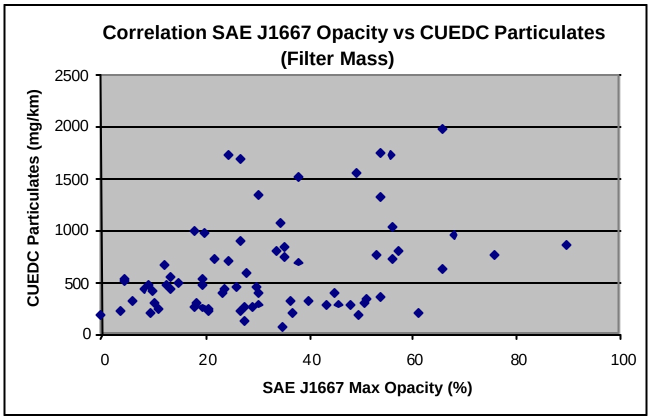
There are several modifications that can be included in the free-acceleration (or snap-idle) test procedure to improve accuracy provided that the opacity meter is computer controlled. The inclusion of an engine database specifying the make and model of engine, the engine's idle and maximum governed speeds, and the maximum and minimum acceptable acceleration times between these speeds improves repeatability. The prohibition of full-flow opacity meters, the inclusion of temperature, pressure and humidity corrections, and a tighter control on exhaust flow rate through the partial-flow opacity meter together with a strict transient-response homologation of the instrumentation can also help substantially but will not completely solve the problem since the test continues to be an atypical operating condition, especially for modern diesel engines.

Applying the full SAE J1667 specification with strict certification and homologation requirements for the measurement equipment and test centres can considerably improve this situation, allowing somewhat repeatable measurements to be made. However, this test procedure cannot be used for controlling anything other than visible smoke, which in turn has been demonstrated to be poorly correlated with particulate emissions, the pollutant of concern. The intrinsic limitations of this test procedure and type of equipment will never permit acceptable measurement uncertainties to be achieved.

Studies performed by Peter Anyon (Parsons) for the National Environment Protection Council of Australia have produced strong evidence that smoke opacity measured under a controlled load on a dynamometer has a poor correlation with particulate emissions, and that smoke opacity measured under the SAE J1667 Free Acceleration test has essentially no correlation at all with particulate emissions. The latter has also been shown to have very low correlation for HC and for NO_x measurements and is considered to be the test that is most unlikely to predict the emissions performance of modern computer-controlled engines. Hence the SAE J1667 Free Acceleration test procedure is not adequate for controlling particulate emissions or NO_x.

There is an Engineering adage that states, "You cannot improve something you are not measuring".

The control and reduction of particulate emissions from in-use diesel vehicles requires a short transient dynamometer test procedure to be defined and implemented in which both visible smoke and particulates are measured. The benefits of including HC and NO measurements together with control elements such as CO, CO_2 and O_2 should also be considered.



The figure above, taken from a study by Peter Anyon and others, indicates a very poor correlation between visible smoke and "real-world" mass particulate emissions, and also illustrates that a number of high particulate emitters have quite low scores on the SAE J1667 test, while some of the high "smokers" have relatively low particulate emissions compared to the true gross polluters. Therefore, aside from the problem of poor reproducibility, the SAE J1667 test runs the danger of misclassifying gross polluters as relatively clean and low polluters as high emitters.

Reducing Emissions from Vehicles with Gasoline/CNG/LPG Engines

For vehicles with spark-ignition engines, possible options include the following:

- Making sure the existing fleet is well maintained

  Progressively tighten in-use emissions standards for existing vehicles.

  Enforce an improved I&C test procedure with strict QA/QC.

  Bearing in mind the limitation of smoke to predict particulate emissions and the near absence of correlation between visible smoke and particulate emissions, empowering traffic police to fine any vehicle that emits visible smoke may still play a useful role, if such checks force vehicle owners to pay more attention to regular vehicle maintenance.

  Promote enhanced mechanic training and the availability of workshop diagnostic equipment.

  Require an effective, extended emissions warranty on all new vehicles.

- Improving oil quality and fuel quality at the pump

  Enforce lubricant standards for 2-stroke engine oils

  Authorise only pre-mix fuel for 2-strokes in areas with high population exposure to air pollution.

  Adulterated fuel can harm emissions and increase the vehicle's need for corrective repairs. Monitor and enforce fuel quality standards more rigorously.

  Make the refineries accountable for fuel quality up to the pump.

- Accelerating vehicle renewal

  Use differential vehicle taxation and much tighter emissions standards for old vehicles to increase their cost of ownership.

  Specify maximum ages for commercial vehicles that operate in highly congested urban environments.

- Accelerating the introduction of clean engine technology

  Ban new 2-stroke engines unless proven to meet the new tight emissions limits as for 4-stroke.

Only permit fuel conversions that include a closed-loop three-way catalytic converter.

Prohibit bi-fuel systems.

The Impact of Reducing HC and CO on NO_x

Vehicles that have spark-ignition engines and consume gasoline, CNG or LPG are subjected to a static, no-load, low-idle emissions test in which only CO is measured. There are plans to include HC measurements from vehicles manufactured after 2000 but no other measurements have been considered. The lack of control elements such as CO_2 and O_2 measurements (to check dilution of the exhaust gas) allows any vehicle to pass the test by just partially withdrawing the sample probe from the exhaust pipe to allow sample dilution to reduce the gas concentrations. The current CO limits are very high, confirming the insignificance of this test. It can fairly be said that this test procedure is not likely to produce any improvements in emissions performance.

Measurement uncertainties are also very high in this current test procedure due to the lack of systematic equipment calibration and instrument zeroing between tests, but this is not currently an important factor due to the ease of fudging the results. However if the test procedure and equipment specifications are significantly improved to apply a stricter control to HC and CO emissions, and more stringent limits are specified, measurement uncertainties will become a serious problem greatly compromising the effectiveness of emissions inspection.

It is easy to reduce the CO and HC emissions from a vehicle during a no-load test by leaning out the mixture and delaying the ignition. This "late-and-lean" approach reduces CO and HC but also reduces engine power and increases NO. On a no-load test, neither engine power nor NO can be measured, so the vehicle happily passes: that is, the test method cannot detect if the engine has been tuned "late-and-lean" solely for the purpose of passing the inspection test. If the engine is retuned immediately after the test, then the emissions tests have no impact on air quality. If the engine is not retuned after testing to its previous polluting state, it will present increased NO emissions. This can cause a move away from a hydrocarbon-rich atmosphere towards one propitious for secondary particulate and ozone formation due to the increase in this important precursor.

Conclusions and Recommendations

Vehicle Fleet Size Information

In India, as in many developing nations, detailed information on the size and composition of the vehicle population does not readily exist. Many different figures are available from official sources for the vehicle population in India and probably most are overstated. The government has not had the mechanisms in place to evaluate the live population on an annual basis or to eliminate from the database those vehicles that have been scrapped or are no longer operating. It is difficult to develop an effective vehicle emissions control strategy if the number of vehicles in the fleet is not known, especially if the lack of information is centred primarily on old vehicles.

Having data that accurately reflects the vehicle population allows adjusting the emissions control strategy to match the characteristics of the fleet. It goes without saying that a well designed vehicle control strategy for Western Europe, for example, with its high proportion of new vehicles will not be suitable for Indian cities where the fleet composition is very different. ***Therefore, updating the vehicle population database is one of the critical steps in making the PUC program more effective.***

Enhanced I&C for Dirtiest Vehicles in Major Metropolitan Areas

The current PUC program covers the whole country and is universally regarded to be ineffectual. Making the program effective would require a number of changes. Given that available human, institutional and financial resources are limited, it is recommended that the limited resources be concentrated on those metropolitan areas that have critical air quality problems in the form of high ambient concentrations of fine particulate matter, the pollutant of most concern in India. ***An enhanced Inspection and Certification (I&C) program should be introduced in highly populated and polluted areas to replace the current PUC system for those vehicles that are likely to contribute the most to urban air pollution from mobile sources¾high annual mileage gross polluters***. Special attention should be paid to high emitters of particulate matter, namely two-stroke engine gasoline vehicles (2- and 3-wheelers) and diesel vehicles. Thus, initially an enhanced I&C system might be applicable only to commercially operated vehicles (3-wheelers, taxis, goods and public carriers—since they are typically driven many more kilometres than privately owned vehicles) above a certain age. The inclusion of private 2-wheelers would also be recommended. Greater benefits can be gained by investing in better emissions control for the dirtiest vehicles rather than in new inspection equipment to be able to measure against a 0.5% CO limit for the newer, cleaner vehicles. The current PUC system, with improved controls and supervision, could be maintained for other private 4-wheelers and commercial vehicles of, say, less than 5 years old.

Such a new I&C program could be installed first in one of the critical metropolitan areas as a pilot to test the system and learn from the experience. Once initial problems are ironed out, after, say six months to a year of operation, the program could be extended to the other critical areas, building upon this experience Within a given area, the program could later be expanded to cover the other vehicle categories, starting with the oldest private vehicles.

Enhancing Credibility

A vehicle emissions program depends on public opinion and acceptance. It directly involves a large and diverse sector of the population who both contributes to air pollution and benefits from its reduction. Thus the public can be very critical of its operation and effectiveness. For the program to work, it must be seen to be effective, totally objective, and transparent. Public opinion of the program should be that it is doing a good job and its benefits outweigh its social cost. ***The government must be willing and able to invest the resources, staff and effort in auditing and supervising the program to guarantee its objectivity and transparency***, and ultimately to win the acceptance of the public.

Enforcement – the Need to Comply

All vehicle owners must have a need to comply, or else there will be large-scale evasion. This means that ***there should be a readily identifiable indication of compliance***. A legally enforceable PUC sticker—that is controlled by the government, difficult to falsify and that has a highly visual design that enables any police officer at 5 metres distance to identify immediately if the vehicle has a current certificate—culd serve this purpose. This of course would also require the traffic police to be empowered to stop vehicles without such a current sticker.

Effective penalties for filling stations that supply fuel to vehicles without such stickers would additionally help, as would linking to insurance payments as recommended by the Mashelkar committee, provided that *all* vehicles (including 2-wheelers) have insurance coverage.

Fraud and Corruption

At present it is relatively easy to evade inspection and the risk of being fined for not possessing a PUC sticker is small. Once enforcement is sufficiently strengthened to the point where the vast majority of the vehicle owners feel compelled to have a current certificate, the next problem that is certain to arise is that of owners resorting to whatever means necessary to obtain a pass certificate. If they are able to buy a black market certificate or cheat on the test for less money than it would cost to repair the vehicle, many are likely to follow this route unless the risk of getting caught and the penalties involved are sufficiently high. It is important to remember that the majority of vehicle emissions probably originate from a relatively small number of very dirty vehicles. Thus for the program to be effective, ***the controls must be strict enough to change the emissions behaviour of these vehicles***. If the government's supervision and control of the program is effective and energetic, it can be cheaper for most vehicle owners to repair their vehicle rather than obtaining a certificate fraudulently. When this occurs, the program is likely to be effective.

Minimising False Passes

The program must be designed from the outset to minimise false passes. ***This implies choosing a test protocol that is difficult to cheat on or to bypass and implementing strong and rigorous audit and supervision schemes from the very beginning***. Test centres and technicians, whether they are employed by the government or the private sector, will always be presented with financial incentives to generate a pass-certificate for a dirty vehicle. An effective program requires a good test procedure that is well enforced, supervised and audited.

Increasing Accountability

The PUC test centres must be held accountable, with the application of strict penalties, for any cheating or fraudulent activities. This requires that the government dedicate the resources, staff and effort to enforce a rigorous supervision and audit program.

Mobile PUC Centres

Mobile test centres and roadside checks are particularly difficult to supervise and control, and the decision to pass or fail a vehicle often depends on the discretion of the test technicians involved. ***It is recommended that mobile and roadside testing be phased out of the current PUC program and not be permitted in the enhanced I&C system***.

Test & Repair Garages

Automotive garages or workshops are not ideal PUC centre owners. No garage will tell its client that it does not have the technical ability to repair the vehicle and pass the test. To save face, it will often choose to force its own PUC centre to cheat on the test and generate a false pass. International experience has shown that as many as over half of the vehicles can obtain their certificates fraudulently from this type of centre. ***It is recommended that test and repair centres be phased out of the current PUC program and not be permitted in the enhanced I&C system***.

Test-only Centres

An inspection system that is capable of inspecting the complete vehicle population will need at least twice as many centres as currently exist in the cities the Consultant visited unless each centre is made more efficient. This problem will be magnified if a longer test procedure (such as the one proposed by ARAI) is adopted. Strict supervision and control of such a large number of centres would be extremely difficult and costly for each state government.

A smaller number of multi-lane, test-only centres are far easier for the government to supervise and allow better technical and administrative control to be enforced. Having a small number of high volume, test-only centres gives rise to easier adoption of new technology and results that are more consistent among centres. ***It is recommended that the enhanced I&C program be based on multi-lane test-only centres***.

Test Capacity and Profitability

The enhanced program should be designed to generate sufficient profitability for test-only centres to ensure enough interest from the centre owners to "police" themselves. This requires the local authority to control and limit the number of authorised centres to arrive at the optimal ratio of vehicles tested to test lanes. For example, the government may consider allowing one lane per 10,000 vehicles of population for two, five-minute tests per year per vehicle, working a 12-hour shift six days a week at 45 percent utilization.

Making test centres profitable is important because if these centres can view their businesses as profitable ventures, they will be more willing and able to invest in the quality assurance elements that are required to control their operation. Conversely, if there are too many test centres and profitability is low, the temptation to cheat to attract more customers by issuing false passes becomes strong.

By defining the proportion of the investment that the government is willing to bear in a joint venture relationship, an acceptable test cost to the end user can be balanced against this profitability requirement.

Corporate Centre Owners

In addition to limiting the number of lanes to match the number of vehicles, if there is a large number of individual centre owners, this could still generate competition that in turn could lead to a loosening of standards as each "helps" the vehicles to obtain a pass certificate. ***It is preferable for the government to open a public bid process for only a handful of companies (for example, two or three in large cities, one in a medium size city) to operate all the centres in a given area for a limited time period***. This enables healthy competition to ensure that the city obtains the best quality of service and price from the selected operators.

Legal Framework and Penalties

The public bid process for selecting the centre operators should enforce a legal framework for contracting the services of each centre that facilitates applying penalties when fraudulent practices are detected. Rigid recording and reporting rules must be enforced for the general operation of each centre and for all incidents in the centre. ISO 17020 certification[6] helps this requirement. Unless there is a strong legal basis, it can be virtually impossible for the local authority to sanction the centre. This does not favour self-policing.

Definition of Operating Standards for the Local Authorities

There have been cases, in several countries, of fraudulent practices involving local authorities. Obviously this reduces the effectiveness of the program. ***Thus the enhanced I&C program should include some measure of supervision and compliance for the enforcing authority***. The Central Ministry should be empowered to ensure that any local authority that decides to launch an I&C program does so correctly. They also need the feedback from the different programs as an input to their ongoing standards development.

The twin objective of supervising the local authority and feeding the data back to the Central Ministry can be promoted if the local authorities were required by law to publish on the Internet all the I&C test results and accompanying databases within a well-defined timeframe. This would give the central authorities, NGOs and academia open access to the information and generate a degree of transparency in the operation of the distinct programs.

Increasing Governmental Supervision and Control

The local authorities must dedicate more resources, personnel and effort in supervising and controlling both the PUC and I&C programs.

---

[6] ISO/IEC 17020 "Inspection body accreditation" is the procedure by which an authoritative body, the National Accreditation Board for Testing & Calibration Laboratories (NABL), gives a formal recognition that an inspection body is competent and impartial to carry out the inspection service according to ISO/IEC 17020. The objective of the accreditation is to assure the clients of the quality of the inspection service given by the inspection body

Certificate Management

In an environment where the requirement to possess current certificates is enforced, the black market value of the certificate increases. If the certificates continue to be uncontrolled as at present, any quantity can easily be printed and sold, defeating the entire system.

For both the PUC and I&C programs, it is recommended that the pass-certificates and stickers be printed and administered under governmental control. Certificates and stickers should be issued to the inspection centres on a controlled basis and their use supervised. Both certificates and stickers should incorporate anti-forgery design elements, similar to those used in banknote production. Security paper, holograms, micro-printing and plastics can all be considered. ***The stickers must incorporate a highly visual design, easily visible at a distance of 5 metres, indicating if it is current or not***. Designs similar to the UK's road tax disc could be adapted. Both the certificate and sticker should be conferred the legal status of an official governmental document enabling any forgery to be duly sanctioned.

If the government sells the certificates to the authorised testing stations, the revenue from the sale could generate the necessary funds to supervise and control the program and for on-going development and QA/QC. At the same time this can ensure that the centres take adequate safety precautions in handling these documents.

Remote Audits

It is very difficult for a salaried on-site government inspector to adequately control an authorised testing station that is making a lot of money fraudulently. ***Both the PUC and I&C programs should make use of remote auditing to distance their staff from the temptation of turning a blind eye to fraudulent practices in exchange for monetary payments***.

The local authority needs to invest in remote, computer-based auditing of all centres. The Central Ministry could develop such computer programs cost-effectively, since the same requirement will exist in every state that adopts the new system.

It would be counter-productive to try and constantly police all the centres. ***The local authority must go for systematic in-depth audits of those centres that show suspicious activity in the remote auditing ¾ and take strong and immediate action***.

Real-time Data

The use of a computerised data entry system as proposed by SIAM, coupled with the adoption of centralised databases, makes it possible to collect the data required for the supervision process and for statistical analysis. Electronic data transmission is essential for the authority to have fresh data to work with, and unless fresh data from all tests performed are readily available, it will be very difficult to supervise and audit test operations effectively. ***The Central Ministry should define the database structure and auxiliary tables such that consistent information is produced by every state that adopts the new system***.

It is recommended that the I&C centres be required to install real-time data transmission with the local authority offices. PUC centres should transmit their test archives at least 2 to 4 times a day over the internet. Old information does not permit good surveillance.

Electronic security measures must be added via specific access codes for each operational function and checksum algorithms or encryption to protect all the registers. These measures should be designed to restrict tampering of the test results by the personnel in the test centre. Without these measures, the test centres can easily fill in the certificates and generate the electronic information without even doing an emissions test.

Ideally the software involved should be developed centrally. This would drastically reduce its initial and on-going costs for each state and centre and at the same time take the control of the source code out of private hands.

Vehicle Surveillance

It is recommended that video monitoring of each test lane be considered for the I&C centres. This provides an additional input that can be analysed in conjunction with the distinct test databases to check for tampering, clean-piping (inserting the probe into another "clean" car's exhaust pipe during the emissions test to generate a pass result for a dirty vehicle), etc.

Administrative Controls

Since each centre has to be duly authorised by the government and should maintain its own QA/QC system as per ISO 17020 or similar standard, an administrative control system needs to be established and managed by the local authority.

Technical Assistance from the Central Ministry

Whilst all the local authorities must retain the qualified personal that are required to supervise and control their programs, many will not have the technical expertise to specify and coordinate on-going changes in equipment and software specifications. Neither will they have the personnel to homologate[7] these changes.

The Central Ministry, duly supported by technical institutions such as ARAI, should be actively involved in the supervision of local inspection programs. Their being an active stakeholder in the process can help ensure that the same lessons do not have to be learnt over and over again by each local authority, and thus would ensure greater uniformity among the distinct programs in different jurisdictions.

Improving Test Repeatability and Accuracy

It is difficult to sustain an emissions verification program when substantial measurement differences are evident among testing stations. ***The elimination of measurement differences must be assigned a high priority***. This requires changes in the equipment and test protocols used in the programs together with calibration audits and other activities.

Objective Results

To be effective, the test protocol must minimise the impact the test technician can have on the test's outcome. It is recommended that visual inspection of vehicular emissions not be included at test centres. It is too easy for the test technician to turn a blind eye to any defects identified.

Further, ***it is recommended that the test results not be made available to the test technician in the test lane until the computer has entered the results in the database***. Otherwise it is common practice for testers to prevent rejects from occurring by tampering with the lane computer, the test procedure or with the vehicle. In the current PUC system, the availability of real-time emissions measurements even helps the tester to generate a false-pass for vehicles that would otherwise have failed the test.

The computer should take the gas reading after a pre-established time. As long as this decision is left to the tester, there can be tampering until a pass result is generated. This would not be so bad if a permanent emissions reduction were obtained from the vehicle, but usually tampering provides no such permanent improvement.

In-use Emission Standards

Emissions data representative of the active vehicle population are required to define limits that will allow clean vehicles to pass and cause dirty vehicles to fail. A good approach would be to start off with

---

[7] Homologation is the type-approval certification by engineers with expertise in the regulatory requirements and approval processes of the destination country.

lenient limits (such as the current limits) and use the data generated in the real-life tests to define the optimum pass/fail cut points. ***It is advisable to set emission standards for in-use vehicles that are achievable, with some effort, by a majority of vehicles, even if that means setting quite lenient standards. Standards can then be tightened progressively over time***, rather than introduce tough standards in the name of strong commitment to environmental protection, only to result in large scale non-compliance and moving public opinion against the I&C system.

For the PUC program, the data collected by SIAM as part of the computerised system from gasoline/CNG/LPG vehicles should be sufficient to define the first stage for tightening these cut points. ***Accurate emissions data need to be collected from diesel vehicles to select the optimal cut points***. The second stage cut points, to be applied in a couple of years that would further tighten the emissions limits, should be defined from field data collected from the operating test centres, with the improvements in measurement and calibration techniques in place.

It is recommended that the proposed new standard of 0.5% CO for catalyst-equipped vehicles not be applied in the current PUC centres since the existing analysers are incapable of effectively evaluating against such a tight limit. This limit can be applied when more precise four-gas analysers with dilution control are deployed. Before implementing these tighter emission limits, the test procedures and protocols must be modified to generate reliable and consistent emissions measurements.

The selected cut points should lead to a higher failure rate in old vehicles than in new. Accelerated vehicle renewal in the form of getting new technology vehicles into the vehicle population and removing old polluting vehicles in critical metropolitan areas provides an immediate and sustainable improvement in emissions, and both the PUC and I&C systems should support this.

Gas Measuring Instrumentation

Many of the two-gas analysers in use in the PUC centres have been operating for over 10 years and need to be replaced. As such, they should not even be considered as an option for the new I&C centres. ***It is essential that modern gas measuring benches ¾ calibrated and certified to measure HC, CO, CO_2 and O_2 ¾ be used with their inherently better accuracy***.

CO_2 and O_2 need to be measured to control dilution. The calculation and application of a dilution correction factor eliminates the problem of the tester withdrawing the probe slightly from the exhaust pipe until the entrained air reduces the exhaust CO and HC concentrations to the desired levels. ***The establishment of dilution threshold values, outside of which the test is automatically aborted, is also required***.

For benches used in dynamic testing (on a dynamometer) it is advisable to include NO measurement. It is easy to reduce the CO and HC emissions from a vehicle by delaying the ignition timing and leaning out the air/fuel mixture. This “late-and-lean” approach reduces CO and HC but also reduces engine power and increases NO. Without measuring NO, it is not possible to detect if the engine has been tuned “late-and-lean” just to pass the test. Vehicles that have been tuned in this way to pass the test are usually re-tuned immediately afterwards to regain this lost power. Hence the measurement of NO on a dynamometer test is a useful control to minimise this practice.

Lambda (ratio of the air-to-fuel mixture compared to the theoretical stoichiometric ratio) should also be evaluated. If it is greater than 1.08, the vehicle should be rejected as being unfit for test.

Not only the data entry, but all the gas measuring equipment used in the I&C test must be controllable from the computer. This is the only way to ensure that automatic gas calibrations and leak checks are correctly performed every three days at a minimum, and that ambient and residual gas values are within limits before allowing the instruments to be zero-referenced between tests. This computer control also would allow the instrument to be locked out if any functional problems are detected or if the systematic calibration audits are not performed.

All the gas measurement instrumentation used in the I&C centres are recommended to include the above-mentioned points. Whilst the recommendation is to concentrate investment in emissions verification on those vehicles that most contribute to urban air pollution (i.e., in the I&C centres), ***it must be recognised that the greatest technical weaknesses of the current PUC system is lack of measurement of CO_2/O_2 (to monitor dilution of exhaust gas) and the lack of systematic calibration***. At the first opportunity these need to be addressed, requiring a move towards a computer-controlled gas analyser.

Gasoline/CNG/LPG (Spark Ignition) Test Protocols

The I&C program should be developed based on the use of dynamic testing (i.e., using a dynamometer). ***International experience with spark ignition vehicles has shown that dynamometers are essential to minimise false passes***. Nitric oxide (NO) should be measured to stop vehicle owners from tuning "late-and-lean" as a means of getting a false pass. The power level applied to the vehicle during the test must be high enough to ensure good vehicle drivability on the road. Thus, if the vehicle passes, it is drivable and any inclination to re-tune after the test is reduced. These two measures help reduce the "Clean for a Day" brigade. At a minimum, two types of dynamometer are required, one for 2- and 3-wheelers and one for 4-wheelers. In Delhi and Mumbai, a third heavier dynamometer should ideally be specified to allow dynamic testing on CNG and diesel powered buses.

Whilst different test protocols could be specified for each type of vehicle, a fundamental similarity should exist between them, such as measuring the emissions in terms of exhaust concentration (% or ppm) or measuring them in terms of g/km.

If further development of the ARAI proposed test should demonstrate acceptable correlation for CO and HC to the vehicles' certification test results for this spectrum of vehicles, its adoption could be recommended for the I&C program. However, they are faced with greater difficulties for the 4-wheelers where NO_x must also demonstrate correlation and the vehicles inertia weight varies over a wider range.

The other proven alternative would be to specify a short constant-speed acceleration simulation mode (ASM) test for all vehicles. Whilst a drive-cycle test is often more representative, its implementation is usually more expensive and difficult to operate and maintain. The additional investment for drive-cycle tests is probably better applied to QA/QC. ***An ASM test with a dynamometer power adsorption equivalent to 75% of the maximum acceleration load at a median road-speed as specified for each vehicle during its certification test would be recommended***. Such steady-speed ASM dynamic tests on a dynamometer have proven to be easy for an untrained technician to operate and accessible in both investment and cost because of the high throughput that can be achieved from each test lane. This ASM test cycle is adequate for identifying gross emitters.

Since the power required to accelerate a 2-wheeler at 75% of the maximum acceleration load specified in the Indian drive cycle does not vary much among makes and models of 2-wheelers, ***a simple air-brake dynamometer would suffice for 2-wheelers***. This eliminates most of the cost and all of the control complexity normally associated with dynamometers. A single-speed test of, say, 90 seconds duration at 20 – 25 km/hour would be adequate. For 2-wheelers, the investment per unit test per year would also be considerably less than the ARAI alternative.

For the remaining PUC centres, it is recommended that the addition of 30 seconds pre-conditioning at 2500 revolutions per minute (rpm) before the low idle emissions test be evaluated. This would help improve test repeatability.

Exhaust Opacity Measuring Instrumentation

An objective test is required to back up the commonly used subjective appraisal by means of visual checking for smoke in diesel vehicles for two reasons: subjective judgment makes it more difficult to apply uniform standards, and equally or perhaps even more important, visual smoke has been shown in a number of studies not to correlate with particulate emissions, the pollutant of concern in India.

It is recommended that a modified SAE J1667 procedure be evaluated using those existing opacity meters that are capable of performing the temperature, pressure and humidity corrections and Bessel calculations internally or via a computer interface. It is further recommended that the reported, corrected reading be an average of four consecutive readings that do not form a decreasing sequence (as specified in the BS AU 141a:1971 regulation but not in SAE J1667). The central authorities must homologate the transient response of each opacity meter with particular emphasis on the integration of the Bessel function filter to ensure similar results from the different makes of opacity meter.

The development of a Master Reference Table for diesel vehicles should be evaluated in which the free-acceleration time from low idle to maximum governed speed is specified together with both low-idle and maximum governed rpm for each engine type. This would require adding rpm measurement to the test equipment.

Diesel Test Protocols

As mentioned above, smoke opacity has been demonstrated to have poor or negligible correlation with particulate emissions. In the worst-case scenario, visible smoke may be eliminated with little impact on public health if this visible smoke reduction does not result in a marked reduction of particulate emissions. Thus the development of an enhanced I&C test that correlates much more closely with particulate emissions is needed.

It is recommended that a short transient dynamometer test procedure for in-use diesel vehicles be defined and implemented in the I&C program in which both visible smoke and particulate matter are measured. The benefits of including HC and NO measurements together with control elements such as CO, CO_2 and O_2 should also be considered.

Software Development and Maintenance

Both the diesel and gasoline/CNG/LPG vehicle tests need to be controlled using specialised software by the same lane computer that SIAM is proposing for data entry. Development of this program could be left up to the different equipment manufacturers. However, the complexity and cost of certifying, homologating and maintaining 20 or more software programs (one for each authorised analyser) is daunting. If this gamut of product offerings is multiplied by slightly different requirements from each state authority, it will become increasingly difficult to maintain all at the same level of development.

It is recommended that a central agency be made responsible for developing and maintaining one software package for all the states and for all makes of equipment. This would require each manufacturer to develop an interface between its analyser and the common centralised program.

Calibration Audits

Calibration audits play a very important role in ensuring that the test equipment is correctly maintained and eliminating the perennial problem of the same vehicle producing different test results in different centres. ***It is recommended for PUC centres that gas and opacity-filter calibration audits be performed by independent accredited materials standard laboratories on each test lane every three months. For the I&C centres, gas, opacity-filter and dynamometer calibration audits should be performed by independent accredited materials standard laboratories on a monthly basis***.

The gases used should be traceable to international standards and certified in accordance with the US Environmental Protection Agency protocol G1 or G2, or other internationally recognised protocols. ***It is recommended that four cylinders be used, each containing a mixture of CO, CO_2, HC and NO together with a cylinder of vehicle emissions zero-air to ensure the linearity of the measurement system***. ***Similarly, a set of four internationally traceable neutral filters should be used to evaluate the linearity of the opacity meters***.

Attention to Details

The changes this report recommends are focused on correcting the problems of the current PUC system. The intention is to establish the ground rules that would ensure that, if a local authority decides to implement a vehicle emissions verification program, they do it right. If they are not willing to do it properly, it would be better for them not to do it at all.

The intention is to make sure that the program is strictly enforced, even if the limits are relatively lenient. To maximise the social benefits from the program, the main investment in emissions control must be focused on the dirtiest vehicles.

Keeping One Step Ahead

As the proposed changes take effect, it will become more difficult to obtain a certificate for a dirty vehicle, and the value of a black market certificate will increase. When this happens, people will be more willing to dedicate time and recourses to thwart the system. ***Thus, the system must be prepared for vehicle owners' response to increasingly stricter enforcement and willing to dynamically change security features to keep one step ahead.***

Design for Future Changes

"The only constant feature of the system is continual change". If the investment items and published standards are designed from the very start to accommodate future changes, these can be applied without long lead times

Abbreviations, Acronyms and Glossary

2 Wheelers	Motorcycles, scooters and mopeds
2T	Two-stroke engine
2W	Two-wheelers (m otorcycles, scooters and mopeds)
3 Wheelers	Auto-rickshaws
3W	Three-wheelers (auto-rickshaws)
4 wheelers	Cars, taxis and MUVs
4T	Four-stroke engine
ARAI	Automative Research Association of India, Pune
ASRTU	Association of Road Transport Undertakings
Auto-rickshaws	three-wheeled vehicles fitted with internal combustion engines
AVL	
BAR84	California's Bureau of Automotive Repair 1984 standard
BEST	Brihan Mumbai Electric Supply and Transport, Mumbai
cc	cubic centimetres
CNG	Compressed natural gas
CO	Carbon monoxide
CO2	Carbon dioxide
CPCB	Central Pollution Control Board
CSE	Centre for Science and Environment, Delhi
CVS	Constant volume sampling
EPA	Environmental Protection Agency
FIP	Fuel injection pump (diesel)
FTP	(US) Federal Test Procedures
g/km	Grams per kilometre
g/kWh	Grams per kilowatt-hour
GVW	Gross vehicle weight
HC	Hydrocarbons
HCV	Heavy commercial vehicle (>3500 kg GVW)
HGV	Heavy goods vehicle (>3500 kg GVW)
HSU	Hartridge smoke unit
I&C	(Vehicle) inspection and emissions certification program (does not include a controlled maintenance vector)
I&M	vehicle inspection and maintenance program
IT	Information technology
kg	Kilograms
km^2	Square kilometres
km/hour	Kilometres per hour
LCV	Light commercial vehicle (<3500 kg GVW)
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
m^{-1}	Inverse metre
MUV	Multiple use vehicle
NGO	Non-governmental organisation
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
O_2	Oxygen

OE	Original Equipment
OEM	Original Equipment Manufacturer
Orix	Orix Auto Finance (India) Limited – Mumbai
PM_{10}	Particles smaller than 10 microns in aerodynamic diameter
ppm	Parts per million
PUC	Pollution Under Control
QA/QC	Quality control and quality assurance
Rs	Rupees
Rpm	Revolutions per minute
RSPM	Respiratory suspended particle matter
RTO	Regional Transport office
SAE	Society of Automotive Engineers
SAFE	Society for Automotive Fitness & Environment, Bangalore
SAUAQM	South Asia Urban Air Quality Management
SIAM	Society of Indian Automobile Manufacturers
SO_2	Sulphur dioxide
SPCB	State Pollution Control Board
TERI	Tata Energy Research Institute
VRDE	Vehicle Research & Development Establishment
$\mu g/m^3$	Micrograms per cubic metre

Documents Used

"Report of the Expert Committee on Auto fuel Policy" (Mashelkar Committee report) published by the Government of India 25.09.2002

"More CNG Outlets planned": The Times Of India, page 2, Sept 12, 2002

"Motor Transport Statistics of India" (MOST- Ministry of Surface Transport) (1997-1998)

"Urban Road Traffic and Air Pollution Study (URTRAP)", Central Road Research Institute 3/4/2002

"India loses the race in car ownership": The Economic Times, Mumbai page 15, Sept 12, 2002

"Air Quality in Seven Major Cities During 2001" NATIONAL AMBIENT AIR QUALITY MONITORING PROGRAMME (NAAQM) , http://164.100.32.5/mcity/2002/m2001.htm

"Clean Air News / Opinion" CSE India http://www.cseindia.org/html/cmp/air/apc_news.htm

"CSE Press Release 16 July 2002" http://www.cseindia.org/html/cmp/air/press_20020716.htm

CPCB Delhi http://envfor.nic.in/cpcb

"8th Conference of Parties to UNFCC Agenda 21 - An Assessment, Chapter 5", GOVERNMENT OF INDIA, MINISTRY OF ENVIRONMENT & FORESTS http://envfor.delhi.nic.in/divisions/ic/wssd/doc2/ch5.pdf

"State of Inspection and Maintenance Policy for vehicles in India and Citizen Involvement", Kisan Mehta and Priya Salvi, GITE Regional Workshop on Inspection and Maintenance Policy in Asia, Bancock 10-12 Dec 2001 http://www.giteweb.org/iandm/mehtapaper.pdf.

"Environment Protection: Government's proactive role"- Dr. Ranjit Singh May 2002, http://www.indianpurchase.com/magonline/chemicals/200205/article1.htm

"New Goal and New Initiatives", PETROLEUM AND NATURAL GAS, Press Information Bureau, Govt of India http://pib.nic.in/archieve/ppinti/ppioct2001/petroleum_natural.html

"TERI in the news" http://teriin.org/press/press.htm

"Centre to tighten emission norms", Times of India, Oct 16, 2002

"Petroprices and Refinery Specifications", Baharat Petroleum Corporation http://www.bharatpetroleum.com

"Controlled petro products -- RPL unhappy with offtake model", The Hindu Business Line, June 8, 2001

"India to export one million tonne of petrol", Financial Express, July 26, 1999

"India's petroleum product exports overtake imports", Alexander's Gas and Oil Connections, May 29, 2002

"Reliance Petroleum loses Rs. 515 cr. on exports of petrol, diesel", The Hindu, July 09, 2001

"Improvement in quality of fuel with particular reference to reduction in sulphur content of diesel and benzene content of petrol to acceptable limits", Govt of Maharashtra, Vehicles Department, "http://www.mahatransport.org/vm_lal/chap/chap3.htm

"GREY REVOLUTION REQUIRED IN INDIA" : R A MASHELKAR, Confederation of Indian Industry April 2002

The Gazette of India, July 26, 2002

"Statistical Profile 2000-2001", The Indian Automobile Industry, SIAM

"Vehicular Air Pollution: Setting Priorities, SAUAQM Briefing Note No 1", Oct 2001, The World Bank

"International Experience with CNG Vehicles, SAUAQM Briefing Note No 2", Oct 2001, The World Bank

"Catching diesel and Gasoline Adulteration, SAUAQM Briefing Note No 7", Jul 2002, The World Bank

"Measurement of Mass Emissions from in-use Two-Stroke engine Three-wheelers in South Asia", Masami Kojima, Robert W Bacon and Jitendra Shah World Bank, Medha S. Mainkar, M.K. Chaudhari and B. Bhanot ARAI, Allan Smith and Will D. Atkinson AEA Technology, SAE Technical Paper 2002-01-1681

"*Proposed Diesel National Environment Protection Measure, Project 2, Phase 2 - Vehicle Testing, Emissions Performance Testing of 80 In-Service Diesel Vehicles, Evaluation & Correlation of Short Test Protocols"*, Final Report prepared for Environment Australia, Parsons Australia Pty Ltd, 12 Karnu Drive Ninderry, Queensland, Australia, Anyon P, Brown S., *et al., May 2000.*

"Inventory of Vehicle Emissions in Delhi" Dr S.A. Dutta, CPCB; Presentation at the Air Quality Management workshop, 12-13 Sept 2001

List of People Met

Abbreviations

Alck - Ace Lpg Car Kits Pvt – Mumbai
ARAI - Automative Research Association of India – Pune
Bajaj - Bajaj Auto Limited - Pune
BEAG - Bombay Environmental Action Group – Mumbai
BEST - Brihanmumbai Electric Supply and Transport – Mumbai
BRPL - Bal Roadlines – Mumbai
Btpl - Bhatti Transport – Mumbai
Btu - Bombay Taximen's Union – Mumbai
CPCB - Central Pollution Control Board - Delhi
CSE - Centre for Science & Environment – Delhi
CSIR - Council of Scientific & Industrial Research - Delhi
Darc - Delhi – Assam Roadway Corp - Delhi
Kpcb - Karnataka Pollution Control Board - Bangalore
Mcmw - Solid Waste Management & Transport, Municipal Corporation of Greater Mumbai – Mumbai
Mpnc - Ministry of Petroleum & Natural Gas - Delhi
Mrth - Ministry of Road Transport and Highways - Delhi
NEERI - National Environmental Engineering Researh Institute – Mumbai
Niviqure - Niviqure. - Bangalore
Orix - Orix Auto Finance (India) Limited – Mumbai
Rotax - Rotax Marine Pvt. Ltd. - Delhi
Rsas - R. S. Ajit Singh & Co - Delhi
SAFE - Society for Automotive Fitness & Environment – Bangalore
Sgcs - Shrimankar Gas Car Services – Mumbai
SIAM - Society of Indian Automobile Manufacturers - Delhi
TATA - Tata Engineering and Locomotion Company – Pune
Tdgk - Transport Department, Government of Karnataka - Bangalore
Tdgm - Transport Department , Government of Maharashtra – Mumbai
Tdmcgm Transport Department, Municipal Corporation of Greater Mumbai – Mumbai
Tdnd - Transport Department, Government of NCT of Delhi – Delhi
TERI - Tata Energy Research Institute - Delhi
Tpm - Traffic Police Headquarters – Mumbai

DELHI

Centre for Science & Environment (CSE)
Core 6A, 4th Floor, India Habitat Centre, Lodhi Road, New Delhi 110 003
- Ms. Anumita Roychowdhry

Central Pollution Control Board (CPCB)
Ministry of Environment & Forests, East Arjun Nagar, Parivesh Bhawan, Shahdara, Delhi 110 032
- Mr. Dilip Biswas, Chairman
- Dr. B. Sengupta, Member Secretary
- Dr. S. A. Dutta , Sr. Scientist
- Mr. Rajesh Debroy, Asst. Environmental Engineer

Council of Scientific & Industrial Research (CSIR)
Anusandhan Bhawan, 2 Rafi Marg, New Delhi 110 001
- Mr. R.A. Mashelkar
  Director General, CSIR & Secretary, Dept. of Scientific & Industrial Research

M/s Delhi Assam Roadways Corp. Ltd
M-2, Himland House, Karampura Commercial Complex, New Delhi-110 015
- Mr Roshan Lal Agarwal, Director
- Mr. Khair, Director

Ministry of Petroleum & Natural Gas (Mpnc)
Shastri Bhawan, A-Wing, Room No. 238, Dr. Rajendra Prasad Road, New Delhi 110 001
- Mr. A.P. Ram, Advisor (Refineries)

Ministry of Road Transport and Highways (MRTH)
1, Parliament Street, Parivahan Bhawan, New Delhi – 110001
- Mr. Alok Rawat, Joint Secretary
- Mr. S K Misra, Director

Rotax Marine Pvt. Ltd. (Rotax)
D-221 Defence Colony, New Delhi 110 024
- Mr. Sree Verma, Director
- Mr. Ashok Johri, General Manager
- Mr. Mohit Chandra, Manager Marketing
- Mr. Kumar Pratyush, Sales & Dervice Engineer

R. S. Ajit Singh & Co (Rsas) (Eicher Authorised Workshop)
C-10/91, Wazirpur Industrial Area, Ring road, Delhi
- Mr. Tomar, Workshop Manager

Society of Indian Automobile Manufacturers (SIAM)
Core 4-B, 5th Floor, India Habitat Centre, Lodi Road, New Delhi 110 003

- Mr. Rajat Nandi, Director General
- Mr. Atanu Ganguli, Assistant Director
- Mr. K.K. Gandhi, Senior Advisor

Tata Energy Research Institute (TERI)
Darbari Seth Block, India Habitat Centre, Lodhi Road, New Delhi 110 003

- Mr. Ranjan Bose, Senior Fellow Policy Analysis Division
- Mr. S. Sundar, Distinguished Fellow
- Mr. Kaushik Deb, Research Associate
- Mr. Ankush Malhotra, Research Associate

Transport Department (Tdnd)
Government of NCT of Delhi, 5/9 Underhill Road, Delhi 110 054.

- Mr. T.M. Balakrishnan, Additional Director (Transport)

BANGALORE

Government of Karnataka (Tdgk)
4th Floor, M.S. Building, Dr. Ambedkar Veedhi, Bangalore 560 001

- Mr. T. Thimmegowda, Transport Commissioner
- Mr. Mohammed Suleman, Joint Transport Commissioner
- Mr. Aiyappa, Joint Transport Commissioner

Karnataka Pollution Control Board (Kpcb)
Bangalore

- Mr. Upendra Tripathy, Chairman

Niviqure. (Software programmers) (Niviqure)
311/2 10th E Main, 1st Block, Jayanagar, Bangalore 560011

- Mr. Vittal S Candade, Director

Society for Automotive Fitness & Environment (SAFE)
P.B. No. 4, Harita, Hosur, Dharmapuri Dist., Tamil Nadu 635 109

- Mr. M.N. Murali Krishna, President

MUMBAI

Ace Lpg Car Kits Pvt (Alck)
202 Anjani Complex, Pareira Hill Road, Andheri, Mumbai 400099

- Mr. Manoj Vithalani, Director - Marketing

Bal Roadlines (BRPL)
301 Krishna Bhavan, B.S.D. Marg, Govandi, Mumbai 400088

- Inderjit Singh Bal, Director

Bhatti Transport (Btpl)
Plot 341 Borla Govandi Road, Chembur, Mumbai 400088

- Mr. Kartar Singh Bhatti, Director
- Mr. Gurmeet Singh Bhatti, Director

Bombay Taximen's Union (Btu)
1/108 Navjivan Society Dr., D. Bhadkamkar Marg., Mumbai 400008

- Mr. A. L. Quadros, General Secretary

Bombay Environmental Action Group (BEAG)
Kalbadevi Municipal School, 2nd Floor Rm 54, Mumbai 400 002

- Mr. Debi Goenka, Member - Activist

Bombay Electric Surface Transport (BEST)
Transport Engineering Dept., Tilak Road, Dadar East, Mumbai 400 014

- Mr. Vasant K. Katadare, Chief Engineer (Transport)
- Mr. S.M. Desai, Executive Engineer (Transport)

Government of Maharashtra (Tdgm)
New Administrative Building, 4th Floor, Near Dr. Ambedkar Garden, Government Colony, Bandra (E), Mumbai 400 051

- Mr. B.I. Nagarale, Transport Commissioner
- Mr. S.B. Sahasrabudhe, Deputy Transport Commissioner

Municipal Corporation of Greater Mumbai (Tdmcgm)
New Transport Garage Building, Dr. E. Moses Road, Worli, Mumbai 400 018

- Mr. U.D. Holla, Deputy City Engineer (Civil) Environment

Municipal Corporation of Greater Mumbai (Mcmw)
(Solid Waste Management & Transport), New Transport Garage Building, Dr. E. Moses Road, Worli, Mumbai 400 018

- Mr. Rathore, Chief Engineer

National Environmental Engineering Research Institute (NEERI)
NEERI Building, 89-B, Dr. Annie Besant Road, Worli, Mumbai 400018

- Dr. R. N. Singh, Director
- Dr. Rakesh Kumar, Sr Assistant Director

Orix Auto Finance (India) Limited (Orix)

(ILFS Venture), Gala No. 1&2, Mohata Bhawan, Off Dr. E. Moses Road, Worli, Mumbai 400 018

- Mr. S. Rengarajan, Chief Operating Officer
- Mr. Ashutosh Atray, Asst. Vice President

Traffic Police Headquarters (Tpm)

87, Sir Bochkhanwala Road, Worli, Mumbai 400 025

- Mr. Sunil Vaidya, Joint Commissionner (Traffic)
- Mr. Himanshu Roy, DCP (Traffic)

Shrimankar Gas Car Services (Sgcs)

Old Jakaria Bunder Rd, Sewri (W), Mumbai 400015

- Mr. B. Shrimankar, Director

PUNE

Automative Research Association of India (ARAI)

Survey No. 102, Vetal Hill, Off Puad Road, Kothrud, PUNE 411 018

- Dr. Balraj Bhanot, Director
- Mr. M.K. Chaudhari, Sr. Deputy Director
- Mrs. Madhuri Marathe, Deputy Director
- Mr. Arun B. Komawar, Deputy Director
- Mr. A. Sekar, Assistant Director

Bajaj Auto Limited (Bajaj)

Akurdi 5, PUNE 411 035

- Mr. T. M. Balaraman, Dy. General Manager (Product Engg.)
- Mr. N.V. Iyer, General Manager (Engg. Support)

Tata Engineering and Locomotion Company (TATA)

Pimpri, Pune 411018, PUNE 411 018

- Mr. R.R. Akarte, General Manager (Engineering Research Centre)
- Mr. R. Sampath, Assistant General Manager - Engines
- Mr. Abhijit A Athawale, Assistant Manager – Engine Development
- Mr. K. Veeramani, Project Manager Emissions Systems
- Mr. R. M. Petkar, Project Manager Emissions Systems